

# **Control of Cycad aulacaspis scale, *Aulacaspis yasumatsui* (Homoptera:Diaspididae)**

## **Environmental Assessment**

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## Introduction

The Cycad aulacaspis scale (CS), *Aulacaspis yasumatsui*, appears to have originated in S.E. Asia, and more specifically in Thailand, from where it was described in 1977 (Takagi, 1977), or China, which appears to be part of its natural range. As a result of a growing interest in Cycads and an expansion in international trade, this pest was probably transported to Florida sometime prior to 1996 (Hamon, 2000). Owing to its relatively inconspicuous nature and perhaps the ability to infest the roots of its host, it was probably subsequently transported to the Cayman Islands and to St John. It was also found subsequently in Hawaii and Hong Kong. There are unconfirmed reports that it has been found in additional localities (Howard & Weissling, 1999).

### I. Description of the Proposed Action

The Animal and Plant Health Inspection Service (APHIS) of the U.S. Department of Agriculture (USDA) proposes to suppress Cycad aulacaspis scale (CS), *Aulacaspis yasumatsui* Takagi in the Continental United States and its Caribbean and Pacific territories.

The proposed alternatives for control of CS are:

- a. No Action
- b. Biological Control
- c. Pesticides
- d. Cultural Control
- e. Crop Modification

The preferred alternative, biological control, is proposed because it is the best alternative to resolve the problems poised by CS on various cycad hosts. Wasps in the Genus *Coccobius*, *C. fulvus* (Hymenoptera: Encyrtidae) have been reared from CS, (Baranowski & Glen, Unpub. Note). There is evidence of a solitary endoparasitoid in the genus *Encarsia* (Hymenoptera, Aphelinidae) as highly parasitizing CS (Polaszek, p.c., 2002). And finally, a predator, a predaceous beetle, *Cybocephalus binotatus* is effective against CS (Baranowski & Glen, Unpub. Note).

*Coccobius* species are of interest because they have been observed to almost completely free the cycad host of the scale in Florida, along with the predator, a nitidulid, both collected in Thailand in 1997 (Baranowski & Glen Unpub. Note). These species have been observed to be very active in attacking CS and thus have a significant impact. The genus *Encarsia* has a solitary endoparasitoid that is commonly found attacking CS, even to the point of pupal exuviae being in type material of CS (Polaszek, p.c., 2002) and would appear to be an effective biological control agent.

APHIS will rear local Florida strains of natural enemies as well as import these biocontrol agents from different geographical locations around the world and rear them in USDA-certified insect quarantine facilities where species identifications will be confirmed by USDA and State taxonomists, and undesirable organisms such as hyperparasites will be screened out and properly eliminated. Laboratory colonies will be established by USDA, APHIS, PPQ and State cooperators. The wasps and predator will then be released by USDA, APHIS, PPQ and State cooperators in areas invaded by the CS.

Such areas include Florida, which is now infested. Anticipated releases of these biocontrol agents in Puerto Rico, and the U.S. Virgin Islands will be made where existing infections occur and follow up releases made in new areas as CS spreads to new geographical areas on cycads, either cultivated or native and other favorable habitats.

The limit of CS geographical distribution in the United States has been calculated to include South Carolina, California, Texas, Alabama, Mississippi, Louisiana, Georgia, New Mexico, Arizona, and Hawaii.

Due to the sale and shipment of infested plants from Miami-Dade County nurseries, infected plants have been sent to many area of the United States by chain stores. Infected plants have been reported in Alabama, California, Georgia, Hawaii, Louisiana, South Carolina and Texas (Broome, 2002a). There are parts of Hawaii that have infestations just as bad as in Miami (Broome, 2002a). Only Georgia, Florida, Hawaii, the Virgin Islands and the U.S. Virgin Islands have endemic and introduced forms of Cycads growing naturally. Ornamental cultivation occurs in the other areas listed. It is expected that these biocontrol agents will become established in areas where the host occurs and reproduce naturally without further human intervention. Specimens of the biocontrol agents given above will be identified to species by recognized taxonomists when possible, and voucher specimens will be deposited in collections of recognized museums and universities. Since field collections very often result in the collection of previously unknown and hence undescribed species of parasites, these voucher specimens will assist in describing the species involved as a new species when a taxonomic study is eventually undertaken by qualified personnel.

This environmental assessment (EA) was prepared in compliance with the National Environmental Policy Act (NEPA) (42 USC 4321 *et seq.*) as described in implementing regulations adopted by the Council on Environmental Quality (40 CFR 1500-1509), by the USDA (7 CFR 1b), and by APHIS (7 CFR 372).

## **II. Purpose of and Need for the Proposed Action**

The purpose of the proposed action, i.e., the suppression of CS infestations throughout the eventual U.S. distribution of the pest through the release of exotic parasitic wasps/predators is to control and limit anticipated damage to ornamental cycads and to endemic and introduced cycads.

Cycads are an ancient group of plants that date back 250 million years. They are cone bearing, and thus more closely related to pine trees than palms. During the age of the dinosaurs, the cycads were the most prevalent plants on Earth. They can live as long as 2,500 years. (Broome, 2002b)

The flora of Cycads in North America were extremely depauperated during the last ice age. This pushed them down to their current permanent home in Mexico (Walters, pers. com., 2001). Out of many cycad taxa that once existed in the United States, only one endemic Cycad remains in Georgia, Florida and the Caribbean. The species, *Zamia integrifolia* had been thought to represent a number of distinct species, but has been recently determined to be only one species, with 19 synonyms (Stevenson, 1997). This species is also known as The Coontie of Florida, and a thriving industry grew up around it, producing starch until 1925, when the vast stands in South Florida were exhausted, with only remnants remaining (Broome, 1998). Several exotic Cycads also grow there (see Table 1).

<b>Table 1. Endemic &amp; Exotic Cycads growing wild in the United States and Territories</b>		
<i>Cycas revoluta</i> <sup>(2)</sup>	Introduced	Florida, Georgia, Puerto Rico
<i>Cycas circinalis</i> <sup>(2)</sup>	Introduced	Puerto Rico
<i>Zamia integrifolia</i> <sup>(1)</sup>	Native	Florida, Georgia, Puerto Rico
Literature Cited		
1. Hill, 1998		
2. Mohlenbrock, 1997		

CS already occurs in Florida causing significant economic losses to the Cycad industry (Howard, et al., 1999). From Florida, CS could rapidly spread through the Gulf states on ornamentals and eventually to Texas and California. The limits of its spread northward cannot be accurately predicted, but certain greenhouse cycads would be at risk, even in cold regions. It must be noted that both cycad and scale can be cold hardy.

Some cycads can grow in harsh conditions such as sand or rock with little rain and withstand hard freezes every year, as well as snow. Many species are salt tolerant. *Dioon edule*, probably the most cold hardy of all cycads, survived a 1989 freeze in Florida of 17<sup>0</sup> F with only tip burn to show for the trial (Broome, 2002b).

The scale has survived in the fuzz around the apex of *Cycas revoluta* plants that were subjected to a freeze of 23<sup>0</sup>C and nine hours below 32<sup>0</sup>C. This scale has been known to crawl down to the roots of plants during the winter time. This suggests that they may survive much lower temperatures than the example above and that most of the Southern States are not safe from this scale (Broome, 2002b).

Any local survey needs to take into account not only the list given here but also those local cycad species grown as ornamentals, either in the open or in greenhouses, which may prove to be

hosts. Since CS may demonstrate apparent changes in host preferences by locality, perhaps as a reflection of changes in habitat, environment, and interactions with the local flora, fauna, predator, parasite complex, a local host list should be designed, based on actual local finds, with this list of value only as a guide in the search for preferred and other local hosts.

CS attacks only cycads. Many of these listings are only to genus. The primary genus affected is *Cycas*. The known hosts to the date of that document are given in Table 2:

<b>Table 2. Host Plants of <i>Aulacaspis yasumatsui</i> (Asian Cycad aulacaspis scale)</b>	
Common Name	Scientific Name
Family Cycadaceae	
King Sago	<sup>1</sup> <i>Cycas revoluta</i> <sup>1</sup>
Queen Sago	<sup>1</sup> <i>Cycas rumphii</i> <sup>1</sup>
Emperor Sage	<sup>1</sup> <i>Cycas taitungensis</i> <sup>1</sup>
	<sup>1</sup> <i>Cycas</i> spp. <sup>1</sup>
Family Stangeriaceae	
	<i>Stangeria</i> spp. <sup>1</sup>
Family Zamiaceae	
	<i>Ceratozamia</i> spp. <sup>1</sup>
	<i>Dioon</i> spp. <sup>1</sup>
	<i>Encephalartos</i> spp.
	<i>Zamia</i> spp. <sup>1</sup>
NOTES	
1. Hosts follow the Cycad Encyclopedia (Hayes,1998), which in turn follows the classification proposed by Dennis Stevenson in 1990 and formalised by that author in a publication that is still in press.	
2. Those hosts recorded with damaging populations of CS are denoted with a number before the scientific name. They may or may not be horticulturally important hosts. The superscript number corresponds to the reference in which the host was stated to bear large numbers of the scale and this reference is given below.	
3. Some hosts may be attacked at their roots.	
4. Symptoms may vary depending on host.	
Hosts known Only by Common Name or Vague Designation	
Palm (Family-Palmae)	
Literature Cited	
1. Broome, 2002a	

As CS hosts are horticulturally important and endangered species (CITES Appendix II), the impact of CS in new areas exists (NPAG, 1997). Species included in Appendix II are those which, although not necessarily threatened with extinction, may become so unless trade in specimens of such species is subject to strict regulation in order to avoid utilization incompatible with their survival (CITES, Appendix II).

It is reasonable to further anticipate that CS will find and utilize additional new hosts as it spreads throughout the biological limits of its distribution in a new habitat.

CS has been known to reach damaging population levels on the marked hosts listed above. These hosts have been highly impacted in the Caribbean and in Florida (Howard et al. 1999) since the arrival of CS. While the economic risk to United States agriculture due to an invasion of the cycad aulacaspis scale is minimal, the effect on the horticultural trade in cycads is serious, resulting in a complete disruption of the industry. This is in addition to the damage to Cycad ecosystems in Florida and Georgia, Puerto Rico and the Virgin Islands and the threat of possible extinction of endangered species of endemic and exotic cycads in these areas outside of protected areas.

### **III. Alternatives to the Proposed Action**

#### **A. No Action Alternative**

The no-action alternative to releasing parasitic wasps or predators is to forgo implementation of biological control. In this case, the no-action alternative would be that APHIS would do nothing at all to control or suppress CS in the Continental United States and its Territories. Nevertheless, it would be expected that private individuals would continue to use insecticides against this pest indefinitely in an attempt to control its population density, although there are no pesticides specifically registered for the control of CS.

#### **B. Biological Control Alternatives**

##### Parasitic Wasps

Parasitic wasps have traditionally been considered one of the best ways to control armored scales, owing to shortcomings in other means of control for various reasons. The success achieved with parasitic wasps against some extremely serious scales such as the Olive Scale, *Parlatoria oleae* (Huffaker, 1986, Huffaker, et al, 1986) in California are of such a scale as to render the pest virtually ineffective on its hosts and of no consequence in economic terms.

Directly related to this EA is the successful release of the parasite, *Coccobius fulvus* in Florida in 1998 for the control of CS, along with an effective predator (Baranowski & Rosen, 2001). Affected cycad hosts became almost free of scales (Howard & Weissling, 1999).

## Bacteria

To date, there are no known bacterial controls for armored scales and for CS in particular.

## Fungi

To date, there is only one known fungal control for *Aulacaspis*. This is an unknown fungus described as growing as a grey-brown mat that later becomes hard and brown which grows over massed *Aulacaspis tegalensis*, particularly during wet weather. Scale insect aggregations appear to be a requisite for its growth (Williams, 1970). This fungus is not mentioned in Armored Scale Insects, Chapter 2.1. Entomopathogenic Fungi by Evans & Prior, 1990. To date, it is not known how this fungus would function against CS on cycads.

## Viruses

There are no viruses available for armored scales and for CS in particular. However research is ongoing for recombinant insect viruses and/or genes to attack insects. To date there is no evidence that armored scales are a target of any of this research, and in particular of CS (Cornell Univ., 1997; Retnakaran, 1999).

## Predators

Predators have sometimes provided spectacular control of armored scales. For example, the Coccinellid, *Cryptognatha nodiceps*, acted very successfully against *Aspidiotus destructor*, the Coconut scale on the island of Principe in 1955 (Simmonds, 1960).

Directly related to this EA is the successful release of an effective predator, *Cybocephalus binotatus*, in Florida in 1998 for the control of CS, along with an effective parasite (Baranowski & Rosen, 2001). Affected cycad hosts became almost free of scales (Howard & Weissling, 1999). This predator has been successful in controlling a related scale, *Aulacaspis tubercularis*, the mango scale along with a parasitoid, in South Africa (Finnemore, 2000; Anon., 2001).

The lady beetle, *Cryptolaemus montrouzieri* might be used as a biopesticide in place of parasitic wasps and the nitidid *Cybocephalus binotatus*, but this species would not be self sustaining in subtropical and temperate climates. Two other possible Coccinellids are *Cryptognatha nodiceps*, which attacks *Hemiberlesia palmae* on *Cycas revoluta* on the island of Principe (Sao Tome & Principe) off the West Coast of Africa (Simmonds, 1960) and *Lindorus lophanthae*, which attacks *Aulacaspis tegalensis*, the sugar cane scale in Mauritius (Williams, 1970). However, it is not known how any of these predators would function against CS or if indeed they would attack CS.

Another choice would be a mite such as *Hemiarcoptes* prob. *coccophagus*. This mite foiled initial attempts to breed *Aulacaspis tegalensis* in the laboratory in Mauritius (Williams, 1970). While such a predator may contribute heavily towards the control of scales in a general sense, it is not known how well it would perform against CS in particular, due to a lack of research in addressing this choice.

## C. Pesticide Alternatives

The following pesticides are currently registered for control of scales in the United States. There are no pesticides registered for control of PHM. The use of sticker/spreader is very important when using insecticides because of the need to penetrate the wax which covers the body. Typically, twice the normal dose of spreader/stickers is used when treating for scales.

**Cygon** - (For Woody Ornamentals and Herbaceous Perennials) Use oil as a dormant treatment in the spring. Treat with dimethoate (Cygon) when overwintering nymphs become active in mid-May and about June 1 and again in late July. Drench plants thoroughly.

**Imidacloprid** - As a soil drench at high rates (up to 1/5 ounce/ 5 gallon container); unlabeled rates, which would require a section 18 exemption. This rate is not economical. Label rates on container grown or field grown cycads does not provide effective control. (Howard & Weissling, 1999)

**Oils** - Fish oil applications consistently reduce scale populations, but are not adequate to control heavy populations. Ultrafine horticultural oil is also effective in controlling CS. However, it is difficult to obtain thorough coverage of cycads with oils, since scale development is mostly on the underside of the fronds. Weekly sprayings for a few months or more eventually result in almost complete control of the scale on fronds and stems.

Water + Oil Treatments: Application of a garden hose with water in a hard spray and washing off what scales can be removed is followed by an application of oil.

In general, chemical control of scales has always been difficult. For CS, the following biological characteristics apply that make chemical control difficult:

- Wax covering of eggs through adult stages. Only the crawlers are relatively free of wax. This wax protects the pest from many kinds of chemical applications.
- CS may be found in cracks and crevices or under fibers of hosts where chemical applications may not be able to reach them.
- CS individuals may be in bunched clusters, which may protect them or at least only the covering scales are exposed to the chemical application.
- Eggs are adventitious and egg laying accumulates under the scale. This limits the effectiveness of chemical applications, because such applications are restricted to the host plant to avoid contaminating the environment.

It is not known how successful any of these treatments will be against CS. The above biological characteristics would suggest that:

- control of CS would only be partly effective
- would require repeat applications for the foreseeable future
- resistance could develop at any time since sizable elements of the population would almost certainly survive
- the loss of natural control by killing off parasites and predators

It is notable that most control recommendations for scales stress the use of parasites and predators and minimize chemical applications, owing to the difficulties as outlined above. In addition, labels, laws and regulations are constantly changing and no liability can be assumed for the suggested use of the chemicals contained herein. Pesticides must be applied according to the label directions on the pesticide container. That means that any chemical control program for CS must take all such changes into account on a continuous basis.

## **D. Cultural Control Alternatives**

The following are possible cultural control measures.

- Quarantine new plants and treat before placing them with established plants. Spot treat with insecticidal soap if needed, taking care to cover all crack crevices and other possible hiding places.
- Water + Oil Treatments: Application of a garden hose with water in a hard spray and washing off what scales can be removed is followed by an application of oil.
- Wash plants with soapy water (2 teaspoons mild detergent per gal of Water) and a soft cloth.
- When plants are lightly infested, kill scales by rubbing them off with your fingers, if possible.
- Where there are few plants and a light scale infestation, prune out the infestation.
- Dislodge scales by hosing down plants frequently, unless biological control agents are present
- Use an insecticidal soap.
- Apply a 2% solution of horticultural oil.
- Use a botanical insecticide of pyrethrins and rotenone.
- Use a high pressure stream of water to dislodge scales. Wetting them also encourages fungal pathogens.

- In the packing house, cycads are scrubbed and carefully examined before shipment.
- Infested material should be removed from field and destroyed.

These cultural control measures are only suitable for very small scale applications, such as back yards and gardens.

## **E. Crop Modification**

Another alternative is crop modification, where the crop itself, like papaya, could be genetically altered for selection for resistance to the CS. This would have to be done for all horticulturally important plants that are known as hosts to CS. Such an approach could take many years to develop the genetically altered plant varieties and many more years to determine if such varieties would be effective. To completely put off the current need to control the CS would do nothing to address the problem and avoid damaging losses in the present.

## **F. Integrated Pest Management**

An integrated pest management alternative could be applied that would consist of a combination of pesticides, cultural practices and the use of biological control agents. Besides the serious inadequacies already mentioned with pesticides and cultural controls, this approach would not be considered self-sustaining and would require continual input to maintain control.

# **IV. Environmental Consequences of the Different Alternatives**

## **A. Impacts of the Preferred Alternative - Biological Control through Parasitic Wasps.**

### Intended impact of the releases

The intended objective of the preferred alternative is to reduce the severity of CS infestations. The total impact of this alternative on CS is such that hosts are almost free of scale in South Florida (Baranowski & Glenn, Unpub. Note). It is anticipated that similar results will occur in other areas where the scale occurs.

Implementation of a biological control program for the Cycad aulacaspis scale in the mainland United States has already been commenced. The estimated economic risk to United States agriculture due to an invasion of Cycad aulacaspis scale is minor, except to the ornamental industry which depends on rearing cycads for homeowners and other businesses. The estimated

cost of implementing a biological control program for this pest is not known, but it would be very small in comparison to the cost of the near total eclipse of this industry (Gempler's, 2001).

#### Area affected by releases

Biological control agents such as parasitic wasps generally spread throughout the geographical range of its host insect even without the assistance of man.

In principle, therefore, release of a parasitic wasp or specific predator at even one site in the continental United States must be considered equivalent to release over the entire host range of the United States in which CS will occur and in which the climate is suitable. Eventually the wasps/predator should establish self-sustaining populations throughout the pest's entire area of distribution.

Although that area cannot now be predicted with confidence, the U.S. Virgin Islands, Puerto Rico, Florida, Georgia, South Carolina, California, Texas, Alabama, Mississippi, Louisiana, Georgia, New Mexico, Arizona, Hawaii and Guam in the Pacific are considered to be the minimal limits. The potential maximum limits could include all greenhouse areas further North.

#### Environmental impact and safety of releases of the parasitic wasps

The proposed introductions of parasitic wasps/predators raise the question of environmental safety, since the wasps/predator conceivably might attack nontarget insects. Whiteflies and armored scale insects are the primary known hosts of *Encarsia*. *Coccobius* seems to attack only armored scale insects as far as it is known. The nitidulid, *Cybocephalus binotatus*, is only known to attack *Aulacaspis yasumatsui* and *Aulacaspis tubercularis*, so far as is known.

Since only whiteflies and armored scale insects are attacked, the question arises as to the environmental impact of the reduction or loss of nontarget whiteflies and armored scales:

- Whiteflies and armored scales are not considered beneficial to agriculture.
- There is no evidence that indigenous whiteflies and armored scales play a critical role in noncrop systems since native whiteflies and armored scales usually occur at very low population levels. This is supported by observations in nearly a century of parasitic releases against such pests.
- There is also no evidence that any targeted or non targeted whitefly or armored scale species have ever been eradicated due to the release of parasitic enemies in the same time frame, partly due to the natural waxing and waning of parasite and host populations, to the biological fact that the released parasites will be selected for those which attack CS, and to the fact that a declining host population will be harder and harder to find by searching female wasps to the point where they are no longer successful.
- No whiteflies or armored scales are found on the Threatened and Endangered Species List of Fish and Wildlife Service.

The following information in Table 3 and 4 indicates the range of whiteflies and armored scales attacked by various species of *Encarsia* and *Coccobius*. While information on the genus is far from complete, the data indicate that these parasites only attack a single or narrow range of specific whitefly or armored scale hosts in the field.

<b>Table 3. Encarsia spp. (Insecta: Hymenoptera: Aphelinidae) that Attack Whiteflies and Armored Scales (Insecta: Homoptera: Aleyrodidae/Diaspidae)</b>		
<b>Encarsia spp.</b>	<b>Distribution</b>	<b>Hosts</b>
<i>Encarsia agilior</i> <sup>(3)</sup>	Hawaii <sup>(3)</sup>	<i>Aspidotus destructor</i> <sup>(3)</sup>
<i>Encarsia aleyrodidis</i> <sup>(3)</sup>	Italy <sup>(3)</sup>	<i>Siphoninus phillyreae</i> <sup>(3)</sup>
<i>Encarsia angelica</i> <sup>(2)</sup>	California <sup>(2)</sup>	<i>Aleuroplatus coronatus</i> <sup>(2)</sup>
<i>Encarsia aurantii</i> <sup>(3)</sup>	Texas, California <sup>(3)</sup>	<i>Melanaspis obscura</i> , <i>Aonidiella citrina</i> <sup>(3)</sup>
<i>Encarsia basicincta</i> <sup>(2)</sup>	Florida <sup>(2)</sup>	<i>Aleurothrixus floccosus</i> <sup>(2)</sup>
<i>Encarsia berleseii</i> <sup>(1)</sup>	Oriental origins <sup>(1)</sup> , Europe <sup>(1)</sup>	<i>Pseudaulacaspis pentagona</i> <sup>(1)</sup>
<i>Encarsia citrina</i> <sup>(1)</sup>		<i>Aonidia</i> , <i>Aonidiella</i> , <i>Aulacaspis</i> , <i>Chionaspis</i> , <i>Dynaspidiotus</i> , <i>Lepidosaphes</i> , <i>Parlatoria</i> , <i>Quadraspidiotus</i> , <i>Unaspis</i> <sup>(1)</sup>
<i>Encarsia coquilletti</i> <sup>(2)</sup>	Idaho, Washington, Arizona, California <sup>(2)</sup>	<i>Aleuroplatus coronatus</i> , <i>Aleyrodes</i> sp. <sup>(2)</sup>
<i>Encarsia dichroa</i> <sup>(3)</sup>	Italy <sup>(3)</sup>	<i>Siphoninus phillyreae</i> <sup>(3)</sup>
<i>Encarsia elongata</i> <sup>(1)</sup>	China (origin) <sup>(1)</sup> , California <sup>(1)</sup>	<i>Insulaspis gloverii</i>
<i>Encarsia formosa</i> <sup>(2)</sup>	Cosmopolitan <sup>(2)</sup>	<i>Trialeurodes vaporariorum</i> <sup>(2)</sup>
<i>Encarsia gautieri</i> <sup>(3)</sup>	Italy <sup>(3)</sup>	<i>Siphoninus phillyreae</i> <sup>(3)</sup>
<i>Encarsia inaron</i> <sup>(3)</sup>	Greece, Italy, Greece, Egypt, Israel <sup>(3)</sup>	<i>Siphoninus phillyreae</i> <sup>(3)</sup>
<i>Encarsia inquirenda</i> <sup>(1)</sup>	Israel <sup>(1)</sup>	<i>Parlatoria pergandii</i> <sup>(1)</sup>
<i>Encarsia lounsburyi</i> <sup>(1)</sup>		<i>Aonidia</i> , <i>Aonidiella</i> , <i>Aulacaspis</i> , <i>Chionaspis</i> , <i>Dynaspidiotus</i> , <i>Lepidosaphes</i> , <i>Parlatoria</i> , <i>Quadraspidiotus</i> , <i>Unaspis</i> <sup>(1)</sup>
<i>Encarsia luteola</i> <sup>(2)</sup>	Mass., Conn., D.C., Calif. <sup>(2)</sup>	<i>Trialeurodes fernaldi</i> , <i>Trialeurodes packardii</i>
<i>Encarsia meritoria</i> <sup>(2)</sup>	Florida to California <sup>(2)</sup>	<i>Trialeurodes floridensis</i> <sup>(2)</sup>

<i>Encarsia pergandiella</i> <sup>(2)</sup>	New York to D.C. to Illinois, Washington, California <sup>(2)</sup>	<i>Aleuroplatus coronatus</i> <sup>(2)</sup>
<i>Encarsia perniciosi</i> <sup>(1)</sup>	Far East, North Atlantic States, Canada, Russia <sup>(1)</sup>	<i>Quadraspidotus perniciosus</i> <sup>(1)</sup>
<i>Encarsia quaintancei</i> <sup>(2)</sup>	D.C. To Illinois <sup>(2)</sup>	<i>Aleyrodes</i> sp. <sup>(2)</sup>
<i>Encarsia siphonini</i> <sup>(3)</sup>	Italy <sup>(3)</sup>	<i>Siphoninus phillyreae</i> <sup>(3)</sup>
<i>Encarsia variegata</i> <sup>(2)</sup>	Florida <sup>(2)</sup>	<i>Paraleyrodes perseae</i> <sup>(2)</sup>
References Listed.		
1. Viggiani, 1990 2. Hayat, 1984	3. Nechols et al., 1995	

**Table 4. *Coccobius* spp. (Insecta: Hymenoptera: Aphelinidae) that attack armored scales (Insecta: Homoptera: Diaspidae)**

<b>Coccobius spp.</b>	<b>Distribution</b>	<b>Hosts</b>
<i>Coccobius aligarhensis</i> <sup>(2)</sup>	India <sup>(2)</sup>	<i>Aonidiella orientalis</i> <sup>(2)</sup>
<i>Coccobius annulicornis</i> <sup>(2)</sup>	Germany <sup>(2)</sup>	<i>Coccus</i> sp. <sup>(2)</sup>
<i>Coccobius atrithorax</i> <sup>(2)</sup>	Australia <sup>(2)</sup>	<i>Ceroplastes rubens</i> <sup>(2)</sup>
<i>Coccobius azumai</i> <sup>(4)</sup>	Okinawa <sup>(4)</sup>	<i>Hemiberlesia pitysophila</i> <sup>(4)</sup>
<i>Coccobius borovkovi</i> <sup>(2)</sup>	Russia <sup>(2)</sup>	<i>Diaspidiotus transcaspensis</i> <sup>(2)</sup>
<i>Coccobius ceroplastidis</i> <sup>(2)</sup>	India <sup>(2)</sup>	<i>Ceroplastes</i> sp. <sup>(2)</sup>
<i>Coccobius danzigae</i> <sup>(2)</sup>	Russia <sup>(2)</sup>	Prob. <i>Asterodiaspis japonica</i> <sup>(2)</sup>
<i>Coccobius diaspidis</i> <sup>(2)</sup>	South Africa <sup>(2)</sup>	<i>Diaspidis</i> sp. <sup>(2)</sup>
<i>Coccobius donatellae</i> <sup>(3)</sup>	USA <sup>(3)</sup>	<i>Comstockiella sabalis</i> <sup>(3)</sup>
<i>Coccobius ephedrassidis</i> <sup>(2)</sup>	Russia <sup>(2)</sup>	<i>Ephedrasspis ephedrarium</i> <sup>(2)</sup>
<i>Coccobius fijiensis</i> <sup>(2)</sup>	Fiji <sup>(2)</sup>	<i>Aspidiotus</i> sp. <sup>(2)</sup>
<i>Coccobius flavicornis</i> <sup>(2)</sup>	China <sup>(2)</sup>	<i>Pseudaonidia duplex</i> <sup>(2)</sup>
<i>Coccobius flavidus</i> <sup>(2)</sup>	Indonesia <sup>(2)</sup>	<i>Sclopetaspis madiuniensis</i> <sup>(2)</sup>
<i>Coccobius flaviventris</i> <sup>(2,4,6)</sup>	Philippines, USA <sup>(2)</sup> , Texas <sup>(4,6)</sup>	<i>Aonidiella arantii</i> <sup>(2,6)</sup> <i>Antonina graminis</i> <sup>(4)</sup>
<i>Coccobius flavoflagellatus</i> <sup>(2)</sup>	Argentina <sup>(2)</sup>	<i>Melanaspis paulistus</i> <sup>(20)</sup>
<i>Coccobius fulvus</i> <sup>(2)</sup>	China, India, Japan, USA <sup>(2)</sup> , California <sup>(4)</sup>	<i>Lepidosaphes beckii</i> <sup>(2)</sup> (in Lab), <i>Pinnaspis strachani</i> <sup>(2)</sup> , <i>Unaspis yanonensis</i> <sup>(2)</sup> , (?) <i>Planococcus citri</i> <sup>(2)</sup>
<i>Coccobius gracilis</i> <sup>(2)</sup>	Australia <sup>(2)</sup>	<i>Lepidosaphes</i> sp. <sup>(2)</sup>
<i>Coccobius granati</i> <sup>(5)</sup>	Aberbaidjan <sup>(5)</sup>	<i>Lepidosaphes granati</i> <sup>(5)</sup>
<i>Coccobius howardi</i> <sup>(2,4,6)</sup>	USA <sup>(2,4,6)</sup>	<i>Nuculaspis californica</i> <sup>(2,4,6)</sup>
<i>Coccobius indefinitus</i> <sup>(2)</sup>	Russia <sup>(2)</sup>	<i>Teacaspis asiatica</i> <sup>(2)</sup>
<i>Coccobius intermedius</i> <sup>(2)</sup>	Indonesia, Fiji <sup>(2)</sup>	<i>Aonidiella aurantii</i> <sup>(2)</sup> , <i>Aspidiotus destructor</i> <sup>(2)</sup> ,

		<i>Chrysomphalus ficus</i> <sup>(2)</sup>
<i>Coccobius juliae</i> <sup>(6)</sup>	Mexico <sup>(6)</sup>	Diaspine scale <sup>(6)</sup>
<i>Coccobius luteolus</i> <sup>(2)</sup>	Russia <sup>(2)</sup>	<i>Quadraspidotus slavonicus</i> <sup>(2)</sup>
<i>Coccobius mesasiaticus</i> <sup>(2)</sup>	Afghanistan, Iran <sup>(2)</sup>	<i>Tecaspis asiatica</i> <sup>(2)</sup>
<i>Coccobius miyatakei</i> <sup>(2)</sup>	Japan <sup>(2)</sup>	<i>Lepidosaphes machili</i> <sup>(2)</sup>
<i>Coccobius nigriclavus</i> <sup>(2)</sup>	Australia <sup>(2)</sup>	<i>Sclopetaspis maduiniensis</i> <sup>(2)</sup>
<i>Coccobius noaeae</i> <sup>(2)</sup>	Russia <sup>(2)</sup>	<i>Duplachionaspis noaeae</i> <sup>(2)</sup>
<i>Coccobius odonaspidis</i> <sup>(2)</sup>	Japan <sup>(2)</sup>	Odonaspis secreta <sup>(2)</sup>
<i>Coccobius paoli</i> <sup>(2)</sup>	Somalia <sup>(2)</sup>	<i>Selenaspidium articulatus</i> <sup>(2)</sup>
<i>Coccobius pistacicolus</i> <sup>(2)</sup>	Russia <sup>(2)</sup>	<i>Lepidosaphes pistacicola</i> <sup>(2)</sup>
<i>Coccobius reticulatus</i> <sup>(2)</sup>	India <sup>(2)</sup> , Pakistan <sup>(2)</sup> , Oman <sup>(2)</sup>	<i>Aonidiella orientalis</i> <sup>(2)</sup> , (?) <i>Cerococcus hibisci</i> <sup>(2)</sup> , <i>Coccus herperidum</i> <sup>(2)</sup>
<i>Coccobius seminotus</i> <sup>(1,2)</sup>	East Africa <sup>(1)</sup> , Mauritius <sup>(1)</sup> , Ethiopia <sup>(2)</sup> , Thailand <sup>(2)</sup>	<i>Aulacaspis tegalensis</i> <sup>(1)</sup> , prob. <i>Duplachionaspis</i> sp. <sup>(2)</sup>
<i>Coccobius stanfordi</i> <sup>(2,4)</sup>	USA <sup>(2)</sup> , California <sup>(4,6)</sup>	<i>Stramenaspis kelloggi</i> <sup>(2,4,6)</sup>
<i>Coccobius subflavus</i> <sup>(1,2)</sup>	India <sup>(2)</sup> , Kenya <sup>(2)</sup> , Mauritius <sup>(2)</sup> , Tanzania <sup>(2)</sup> , Thailand <sup>(2)</sup>	<i>Aulacaspis tegalensis</i> <sup>(1)</sup> , <i>Melanaspis glomerata</i> <sup>(2)</sup>
<i>Coccobius subterraneus</i> <sup>(2)</sup>	Russia <sup>(2)</sup>	<i>Chortinaspis subterraneus</i> <sup>(2)</sup>
<i>Coccobius testaceus</i> <sup>(2,4)</sup>	Palaearctic <sup>(2)</sup> , USA <sup>(2)</sup> , California <sup>(4)</sup>	<i>Contigaspis kochiae</i> <sup>(2)</sup> , <i>Diaspidiotus prunorum</i> <sup>(2)</sup> , <i>D. transcapiensis</i> <sup>(2)</sup> , <i>Furchadiaspis zamiae</i> <sup>(2)</sup> , <i>Lepidosaphes</i> <i>conchiformis</i> <sup>(6)</sup> , <i>L. ficus</i> <sup>(2)</sup> , <i>L. malicola</i> <sup>(2)</sup> , <i>L. ulmi</i> <sup>(2,4)</sup> , <i>L. spp.</i> <sup>(2)</sup> , <i>Lineaspis</i> <i>junipericola</i> <sup>(2)</sup> , <i>Quadraspidotus gigas</i> <sup>(2)</sup> , <i>Q. jaapi</i> <sup>(2)</sup> , <i>Q. perniciosus</i> <sup>(2)</sup> , <i>Tecaspis asiatica</i> <sup>(2)</sup> , <i>Comperiella bifasciata</i> <sup>(2)</sup>
<i>Coccobius uvae</i> <sup>(2)</sup>	Haiti <sup>(2)</sup>	<i>Diaspidiotus uvae</i> <sup>(2)</sup>
<i>Coccobius varicornis</i> <sup>(2,4,6)</sup>	USA <sup>(2,6)</sup> , Canada <sup>(2)</sup> , Quebec to Florida to Wisconsin to Nebraska to California <sup>(4)</sup> , (?) Mocambique <sup>(2)</sup>	<i>Aspidiotus destructor</i> <sup>(2)</sup> , <i>Aspidiotus</i> sp. <sup>(2,6)</sup> , <i>Aspidiotus</i> spp. <sup>(2)</sup> , <i>Chionaspis</i> <i>americana</i> <sup>(2,4)</sup> , <i>C. Furfura</i> <sup>(2)</sup> , <i>C.</i> sp. <sup>(2)</sup> , <i>Coccus hesperidum</i> <sup>(2)</sup> , <i>Diaspidiotus ancyclus</i> <sup>(2,4)</sup> , <i>D. uvae</i> <sup>(2,4)</sup> , <i>Lecanium</i> <i>nigrofasciatum</i> <sup>(2)</sup> , <i>Melanaspis</i> <i>obscurus</i> <sup>(2,4)</sup> , <i>Nuculaspis</i> <i>californica</i> <sup>(2,4)</sup> , <i>Phenacaspis</i>

		<i>pinifoliae</i> <sup>(2,4)</sup> , <i>Quadraspidotus juglanregiae</i> <sup>(2,4)</sup> , <i>Q. perniciosus</i> <sup>(2,4)</sup> , <i>Quernaspis quercus</i> <sup>(2)</sup>
<i>Coccobius viggianii</i> <sup>(2)</sup>	Italy <sup>(2)</sup>	<i>Evallaspis ampelodesmae</i> <sup>(2)</sup>
References Listed		
1. Viggiani, 1990 2. Hayat, 1984	3. Evans & Pedata, 1997 4. Krombein, et al., 1979	5. Yasnosh & Mustafaeva, 1992 6. Myartseva, 2000

*Encarsia elongata* was introduced into California from China in 1948 to control *Insulaspis gloverii* (Glover scale). This resulted in a successful biological control program (Viggiani, 1990). The San Jose scale strain of *Encarsia perniciosi* was introduced into the United States from the Far East. This resulted in a very successful biological program for *Quadraspidotus perniciosus* (San Jose scale). It has spread over the USA. *Encarsia* sp. nr. *diaspidicola* was introduced into New England for control of *Unaspis euonymi* (Van Driesche, et al., 1998).

Other introductions of exotic *Encarsia* species into various countries for the control of various species of scales are listed in Table 5:

<i>Encarsia</i> species	Host Scale/ Whitefly	Country of Origin	Country Released	Reference
<i>Encarsia aurantii</i>	<i>Melanaspis obscura</i>	Texas	California	Nechols, et al., 1995
<i>Encarsia berlesei</i>	<i>Pseudaulacaspis pentagona</i>	Oriental region	Europe	Viggiani, 1990
<i>Encarsia elongata</i>	<i>Insulaspis gloverii</i>	China	California	Viggiani, 1990
<i>Encarsia inaron</i>	<i>Siphoninus phillyreae</i>	Italy, Israel	California	Nechols, et al., 1995
<i>Encarsia perniciosi</i>	<i>Quadraspidotus perniciosus</i>	Far East	USA	Viggiani, 1990
<i>Encarsia portoricensis</i>	<i>Comstockiella sabalis</i>	USA, Florida	Bermuda	Bartlett, et al., 1978
<i>Encarsia</i> sp. nr. <i>diaspidicola</i>	<i>Unaspis euonymi</i> , <i>Quadraspidotus perniciosus</i> (in Lab in Calif.)	China	USA (New England)	Van Driesche, et al., 1998

*Coccobius fulvus* was introduced into California from India to control *Pinnaspis strachani*. *Coccobius testaceus* was also introduced into California to control various scales (Hayat, 1984). *Coccobius* sp. nr. *fulvus* was introduced into New England from China to control *Unaspis euonymi* (Van Driesche, et al., 1998).

Other introductions of exotic *Coccobius* species into various countries for the control of various species of scales are listed in Table 6:

<i>Coccobius</i> species	Host Scale	Country of Origin	Country Released	Reference
<i>Coccobius</i>	<i>Antonina</i>	Philippines <sup>(1,2)</sup>	USA, Texas <sup>(1,2)</sup>	1. Hayat, 1984

<i>flaviventris</i> <sup>(1,2)</sup>	<i>graminis</i> <sup>(1)</sup> , <i>Aonidiella aurantii</i> <sup>(2)</sup>			2. Myartseva, 2000
<i>ccobius fulvus</i> <sup>(1,2)</sup>	<i>Lepidosaphes beckii</i> <sup>(1,2,3)</sup> , <i>Pinnaaspis strachani</i> , <i>Unaspis yanonensis</i> , (?) <i>Planococcus citri</i>	India <sup>(1)</sup> , China <sup>(2,3)</sup>	Japan <sup>(1,3)</sup> USA <sup>(1,2)</sup> , California <sup>(1,2,3)</sup>	1. Hayat, 1984 2. Bartlett, et al., 1978 3. Myartseva, 2000
<i>Coccobius</i> sp. nr. <i>fulvus</i>	<i>Unaspis euonyomi</i>	China	USA (New England)	Van Driesche, et al., 1998
<i>Coccobius hawaiiensis</i>	?	Japan	USA, Hawaii	Ishihara, 1977
<i>Coccobius intermedius</i>	<i>Aonidiella aurantii</i> , <i>Aspidiotus destructor</i>	Indonesia	Fiji	
<i>Coccobius seminotus</i>	<i>Aulacaspis tegalensis</i>	Ethiopia	Thailand	Hayat, 1984
			Mauritius	Viggiani, 1990
<i>Coccobius subflavus</i>	<i>Aulacaspis tegalensis</i> , <i>Melanaspis glomerata</i>	Tanzania, Kenya	India, Mauritius, Thailand	Hayat, 1984
<i>Coccobius testaceus</i> <sup>(1,2)</sup>	<i>Lepidosaphes ulmi</i> <sup>(1,2)</sup> , <i>Lepidosaphes conchiformis</i> <sup>(3)</sup>	Europe <sup>(1,3)</sup> , Italy <sup>(2)</sup>	California <sup>(1,2,3)</sup>	1. Hayat, 1984 2. Bartlett, et al., 1978 3. Myartseva, 2000

No release of exotic *Encarsia* or *Coccobius* species have been reported to have an adverse impact on the environment or human health. The risk to threatened and endangered species, to other biological control agents, the impacts on health of humans and animals and the impacts from previous releases of species of *Encarsia* or *Coccobius* remain the same as for the original environmental assessment; that there is no risk involved.

#### Risk to threatened and endangered species

Scales are the only known hosts of the species of *Coccobius* and *Encarsia* that are candidates for introduction into the United States by the preferred alternative. No scale species are federally listed as threatened or endangered, and, in fact, no members of the Order Homoptera to which scales belong are so listed (U.S. Fish and Wildlife Service, 1998). Scales often are important items in the predatory host feeding of certain wasps, and at times they may be important in the diet of lady beetles, lacewings, Cecidomyiid flies, thrips, and mites (Rosen, 1990). However, no such insects are federally listed as threatened or endangered and as far as is known, scales are not a significant food item in the diets of threatened or endangered species.

#### Risk to other biological control agents

All known species of *Coccobius* and *Encarsia* wasps are obligate primary parasites and not hyperparasites (i.e., they do not parasitize other parasites). Hence, there is no danger that

introduced species of *Coccobius* and *Encarsia* proposed by the preferred alternative might cause harm by attacking parasites of other pest species.

#### Impacts on health of humans and animals

The status of selected species of *Coccobius* and *Encarsia* wasps as obligate parasites of scales precludes any adverse effects on human or animal health. They do not sting humans or other vertebrates, since they are stingless and only one or two millimeters in length. People who handle some insects in confinement may develop allergic reactions. However, the greatest allergic risk is presented by scales from the bodies of other types of insects like moths. This allergic risk has not been observed with these wasps and it would not be expected that these tiny wasps would pose a significant risk of any sort.

In compliance with Executive Order 12898 (Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations) and Executive Order 13045 (Protection of Children From Environmental Health Risks and Safety Factors), APHIS analyzed potential impacts to different subgroups of the populations from the preferred program alternative. Based upon the proposed biological control program, neither disproportionately high nor adverse human health and environmental effects were determined for minority populations, low-income populations, and children. The proposed releases of biological control agents may, in fact, preserve the livelihood of workers whose income depends on the cultivation, collection and packing of these same plants for the cycad trade.

#### Impacts from previous releases of species of *Coccobius* and *Encarsia* wasps against pest mealybugs

No adverse impacts were reported after releases of *Encarisa elongata* and *Encarisa perniciosi* in California, for control of *Insulaspis gloverii* and *Quadraspidiotus perniciosus*, respectively. Likewise there have been no adverse impacts in Europe for *Encarisa berlesei* for control of *Pseudaulacaspis pentagona*. Nor have there been adverse impacts for any species of *Coccobius* in the USA, including *Coccobius fulvus* in California for control of several species of scales or *Coccobius testaceus* for control of *Quadraspidiotus perniciosus* and *Coccobius flaviventris* for control of *Aonidiella aurantii* in Texas. There were also no adverse impacts from the release of *Coccobius* species in Japan, Fiji, Thailand, Mauritius Islands, or India for control of various scale insects. See Table 2. There were, however, tremendous economic benefits from the release of these parasites in all of these countries. (Hayat, 1984; Viggiani, 1990)

It is possible that a host shift could occur and these exotic parasites could begin attacking other scale species or whiteflies (non targeted hosts), but this is a low risk, considering the existing known and limited host range of these parasites that have evolved to date. Indirect impacts could occur when existing scale population densities are reduced, such as other scale species or insects could fill the empty niche vacated by the pest scale, or parasitization of other scales could impact other pest complexes. This could be a positive impact when reducing population densities of other scale species to a lower level, or negatively displace (competitively reduce populations of) other local parasites which would normally utilize these scale species and would be more efficient in so doing.

## **B. Impacts of the “no-action” alternative**

If APHIS takes no action at all to suppress the CS infestation, and if CS becomes a serious problem on its hosts in areas where its natural predators and parasites are not present, chemical pesticides may be the primary means of control. Repeated, increasingly costly applications may be required as the scale develops resistance. Eventually, when satisfactory control becomes impossible, severe infestations may have a major impact on horticulture dependent on any of the main CS hosts in the continental United States. Chemical treatments may exacerbate scale damage by destroying any indigenous natural enemies of CS that may be present and upset secondary pest populations. Cycads may be eliminated from regions dominated by the CS.

## **C. Impact of the use of alternative types of biological control agents**

Predators - As stated above, the nitidulid *Cybocephalus binotatus* is in use as a biocontrol agent with the parasitic wasp *Coccobius fulvus* in Florida. Together, these two have been very successful in reducing the population of cycad scales on cycads to the point where they are almost free of scales (Baranowski & Glenn, 2001).

Nonindigenous lady beetles, lacewings, and other predatory insects might be used in place of parasitic wasps and *Cybocephalus binotatus*. However, these predators probably would yield less effective control than parasitic wasps, and are not as specific predators as *Cybocephalus binotatus* for the cycad aulacaspis scale, raising again the need for insecticidal pesticide treatments with all the concomitant risks discussed in the preceding paragraph.

Viruses - As stated in III.B, there are no viruses available for armored scales and in particular, of CS. Research to date has not yet targeted armored scales.

Bacteria - As stated in III.B, there are no bacteria available for armored scales and in particular, of CS.

Fungi - As stated in III.B, there is only one fungus known which attacks *Aulacaspis tegalensis*, the sugar cane scale. It is not known if this fungus would attack other species of the genus *Aulacaspis*.

In conclusion, releases of nonindigenous species of *Coccobius fulvus* and *Cybocephalus binotatus* and potentially *Encarisa* specific for CS offer a more environmentally safe and effective, preferred alternative than the use of other biological control agents in controlling the cycad aulacaspis scale

## **D. Impact of the use of the Pesticide Alternative**

The use of chemicals as an alternative to suppressing CS infestations would have the following undesirable effects:

- It would release pesticides into the environment, thus increasing the hazards to man and animals in the local area where released, or at least rendering it undesirable for a period of time.
- It would result in the eventual development of resistance to the pesticides used and an increasing need for larger amounts per application or application of more toxic pesticides over time. Other, untargeted pests could also increase their resistance to the pesticides used, compounding the problems involved.
- Such increases in pesticide usage would increase costs.
- Use of pesticides would also kill parasites and predators and result in a population explosion of the scale population, and create secondary pest outbreaks of other pest species, thus defeating the reason for the pesticide applications.

## **E. Impact of the Use of the Cultural Control Alternative**

The use of Cultural Control alternatives to suppress CS infestations would have the following undesirable effects:

- Almost all of these cultural control alternatives are labor intensive and can only be used in small areas on limited numbers of host.
- The consequence of cultural controls alone would be to permit the CS to otherwise spread unchecked through commercial quantities of host and inflict damage almost without hindrance.

## **F. Impact of the use of Crop Modification**

The use of Crop Modification to suppress CS infestations would have the following undesirable effect:

- This approach would have to be done for all host species of CS. This would require many years for the necessary research and development, and more years for implementation to be fully effective. Control requirements are needed now in order to counter the current damaging losses and begin some effective means to control increasing CS infestations.

## **G. Impact of Integrated Pest Management**

The use of an Integrated Pest Management plan would have the following undesirable effect:

- This approach would not be considered self-sustaining and would require continual input to maintain control. Some aspects of IPM may well be utilized by persons using cultural control

methods or oils for small areas or special hosts, but they would not address most large areas affected by the CS infestations and thus would not be effective in suppressing the CS population density.

## V. Agencies and Persons Consulted

This environmental assessment was prepared by USDA, APHIS, Environmental Analysis and Documentation, and Plant Protection and Quarantine Units (all at USDA, APHIS, Riverdale, MD).

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