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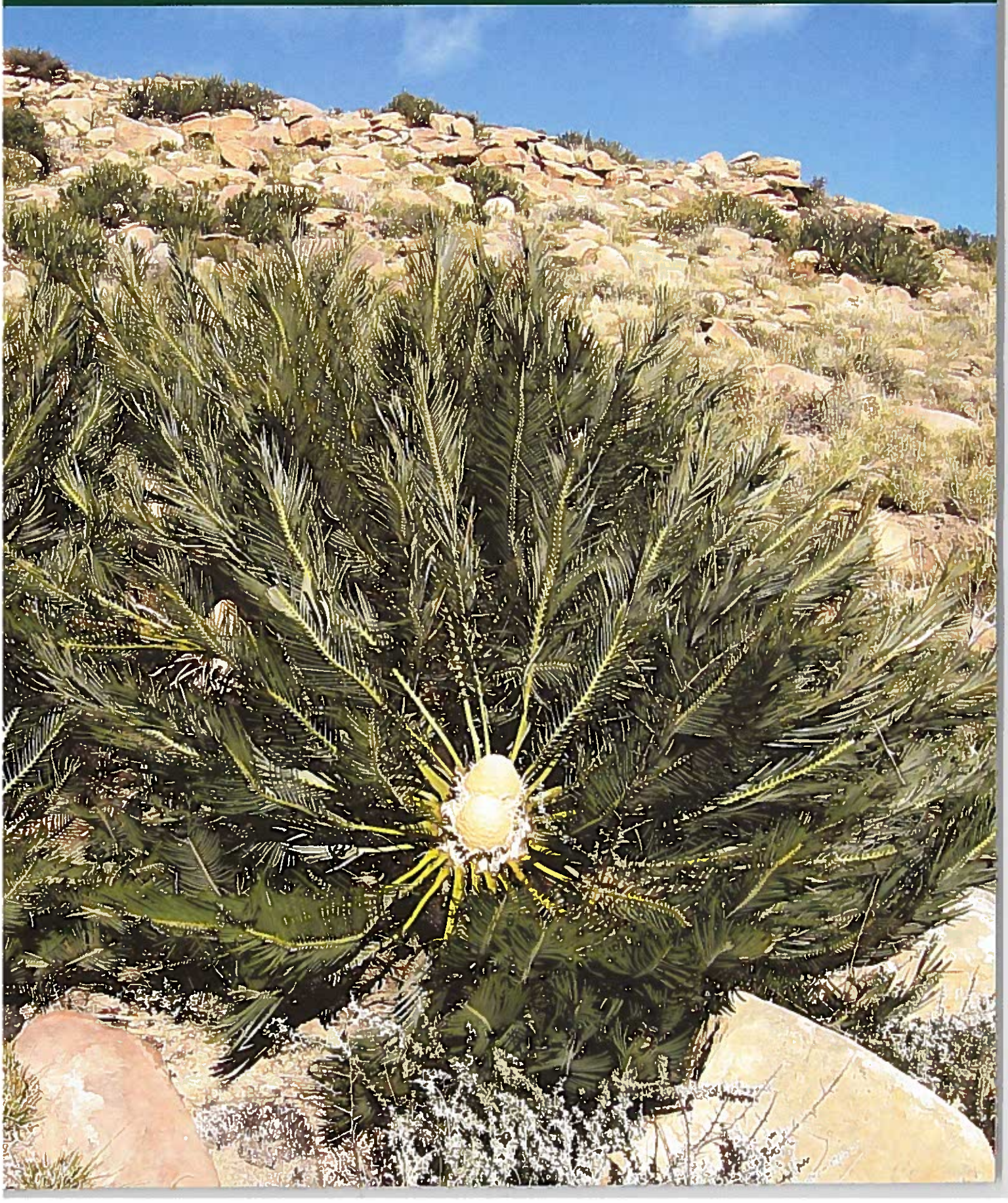

RECENT ADVANCES IN THE BIOLOGICAL CONTROL OF CYCAD AULACASPIS SCALE

William Tang * and Ronald D. Cave **

Aulacaspis yasumatsui, commonly known as cycad aulacaspis scale (CAS), is an insect pest with the potential to inflict great damage on cultivated cycads and to cause extinction in wild populations of cycads. It is therefore of great concern to anyone with an interest in these plants. CAS is native to mainland Southeast Asia where it feeds on *Cycas* spp. In this region there appears to be a natural balance between this insect and its hosts. Host *Cycas* populations here typically exhibit a level of natural resistance to this pest (Tang et al. 1997, Tang, pers. observation) and in addition a range of insect predators appear to feed on the scale and keep its numbers in check. As a result CAS typically occurs in low to moderate numbers in *Cycas* populations in mainland Southeast Asia. However, when taken outside of its natural habitat CAS has exhibited the propensity to rapidly destroy ornamental plantings of *Cycas* and threaten wild populations of *Cycas* with extinction. This lethality was demonstrated in its outbreak in Florida in the 1990's when thousands of *Cycas revoluta* and *C. rumphii* plants died, after just two years of heavy infestation (Howard et al. 1999). CAS will attack a wide range of cycad taxa, including *Stangeria* and *Encephalartos*, and is a continuing threat to conservation collections of these plants, such as those at the Montgomery Botanical Center in Coral Gables, Florida. CAS spread to Guam in 2003 and has devastated wild populations of *Cycas micronesica*. Based on rates of decline, this species is projected to become extinct in the wild by 2019 (Marler & Lawrence 2012). CAS reached the wild population of *Cycas taitungensis* in Taiwan in 2004 and by 2010 had caused an estimated 37% mortality (Chao et al. 2010). Efforts have been made to stop the spread of this pest with pest alerts (see Tang 2006) and legislation, but CAS continues to spread, probably through the global trade of infected *Cycas revoluta* (Marler and Moore 2010). Recently, Roux & Millar (2014) reported that CAS has reached South Africa, a region of high cycad diversity and endemism.

Chemical management of this pest in ornamental plantings is difficult because expensive pesticides must be applied frequently and regularly (Hodges et al. 2003, Caldwell 2005, Webb 2009) and such a labor-intensive approach is not feasible in natural populations, where most plants are in steep or remote terrain and would be difficult to access, and damage to non-target organism (especially in nature reserves) is likely to be unacceptable. The best hope for controlling CAS infestations in areas where CAS has been introduced lies with biological control agents. For the most part, these are organisms that feed on CAS in its native range. Listed below are known biological control agents of CAS, regions where they have been used and level of success. The effectiveness of these agents varies from region to region and is probably influenced by climate and complex interactions with other existing organisms.

1. *Cybocephalus nipponicus* (Cybocephalidae): First identified from surveys in Thailand by Richard Baranowski (University of Florida), with Banpot Napompeth (National Biological Control Research Center, Thailand), this natural predator of CAS was released in Florida, but has not provided adequate control on plants of *Cycas revoluta*.

2. *Rhyzobius lophanthae* (Coccinellidae) (Figs. 1-2): Introduced to Florida and Hawaii prior to the outbreak of CAS, this beetle does not provide effect

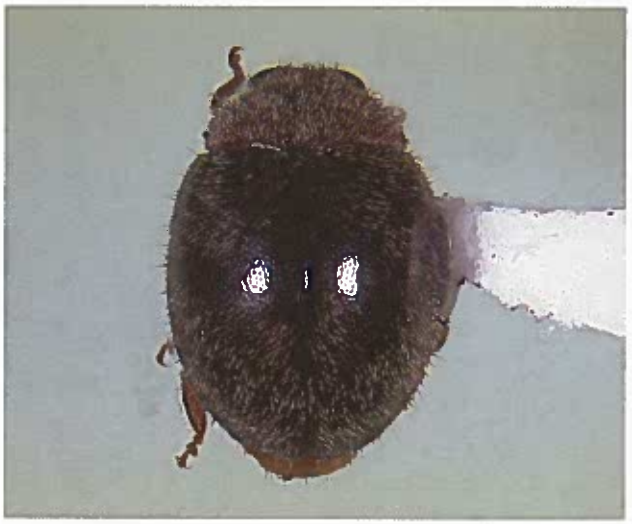

Figure 1. *Rhyzobius lophanthae* adult; this predatory beetle has been an effective biocontrol agent for CAS in Guam and Texas, but not in Taiwan and Florida; Photo by R. Cave

Figure 2. Larva of the predatory beetle *Rhyzobius lophanthae* with female and male CAS; the female CAS (white oval shapes) are 3 mm long; Photo by R. Cave.

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Figure 3. *Coccobius fulvus* larva feeding inside an adult female CAS; when parasitoid wasps such as this kill female scales they will reduce egg production in the scale population and slow the spread of CAS; unfortunately this species has not been successful in providing adequate protection for *Cycas* from CAS in Florida or Guam; Photo by R. Cave.

Figure 4. *Phaenochilus kashaya* larva; the larva of this ladybird beetle will typically eat between 13-21 CAS a day and between 144-420 CAS during the entire larva stage, with consumption rates of CAS varying with temperature (Manrique et al. 2012); photo by Veronica Manrique.

control of CAS in Florida (Cave 2006), but appears to provide effective control in Hawaii. In Taiwan it does not provide effective control of CAS in the wild population of *C. taitungensis*. In Texas, in conjunction with an aphelinid wasp, *Aphytis lingnanensis*, it provides effective control (Flores and Carlson 2009). Introduced into Guam in 2005 it provides some protection for mature plants, but not to seedlings near ground level (Marler et al. 2013).

3. *Arrhenophagus chionaspidis* (Encrytidae): Ronald Cave (University of Florida) and Ru Nguyen (Florida Department of Agriculture) observed this parasitic

Figure 5. Adult *Phaenochilus kashaya* feeding on CAS on a wild *Cycas siamensis* in Thailand; this predatory beetle is estimated to consume 4700 scales during its adult stage (Manrique et al. 2012); Photo by R. Cave.

wasp attacking CAS in China, Thailand, and Vietnam. It was previously established in Florida to control San Jose scale, but was not detected attacking CAS until 2009. It now appears widespread throughout the southern half of the state, but provides no control since it attacks only the male scales. In Taiwan 37% of CAS in the wild population of *C. taitungensis* were found to be parasitized by this wasp.

4. *Coccobius fulvus* (Aphelinidae)(Fig. 3): First identified from surveys in Thailand by Richard Baranowski (University of Florida), with Banpot Napompeth (National Biological Control Research Center, Thailand), this wasp parasitoid of CAS was released in Florida. Although high rates of parasitism have been observed, it has not provided satisfactory control of CAS. This wasp was introduced into Guam in 2005 but did not become established.

5. Other aphelinid wasps: In Hawaii, *Pteroptrix* n. sp. near *leptocera*, and *Aphytis lingnanensis* have been observed attacking CAS. However, it is not yet clear how much they contribute to the control of CAS (Cave et al. 2013).

6. *Isaria fumosorosea* (entomopathogenic fungus): In laboratory trials, this fungus achieved over 70% infection rates of CAS (Castillo et al. 2011). Limited field trials have been inconclusive and it is uncertain how commercial products of this organism might be employed and whether or not it would also attack biocontrol organisms used to control CAS.

Promising new biocontrol agent:

1. *Phaenochilus kashaya* (Coccinellidae)(Figs. 4-5): Ronald Cave (University of Florida) and Ru Nguyen (Florida Department of Agriculture) found this beetle feeding on CAS on wild *Cycas siamensis* populations in Thailand (Giorgi and Vandenberg 2012). Laboratory trials (Manrique et al. 2012) have demonstrated that the larvae and adults of this beetle are voracious predators of CAS, with each individual beetle estimated to consume over 5000 CAS over its lifespan. Although the release of this predatory beetle has been denied in Florida, permission might be granted for its release on the island of Guam.

For further details please read Cave et al. 2013 (see link below) and the CAS pest alert at: http://entomology.ifas.ufl.edu/pestalert/Cycad_Aulacaspis_Scale_Pest_Alert.pdf

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