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Cycad Aulacaspis Scale, a Newly Introduced Insect Pest in Indonesia

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Cycad aulacaspis scale (*Aulacaspis yasumatsui* Takagi (Hemiptera: Diaspididae)) is native to Thailand and Vietnam. Since the early 1990s it has been spreading around the world due to the trade in cycad plants for ornamental use. Infestation by this scale can kill cycads in only a few months. Its accidental introduction to Florida endangered the ornamental cycad-growing industry; and in Guam and Taiwan, endemic cycads (*Cycas micronesica* and *C. taitungensis*, respectively) are currently threatened with extinction by cycad aulacaspis scale. In November 2011, an introduced scale was discovered damaging cycads in the Bogor Botanic Garden. Samples from Bogor were taken for identification of the scale, and the material was kept for some time to rear out any insect parasitoids that were present. Both the scale insects and parasitoids were prepared on microscope slides and studied microscopically for authoritative identification. The scale was confirmed as *A. yasumatsui*. The parasitoid *Arrhenophagus chionaspidis* Aurivillius (Hymenoptera: Encyrtidae) and the hyperparasitoid *Signiphora bifasciata* Ashmead (Hymenoptera: Signiphoridae) were identified from the samples. Unless immediate remedial measures are taken, several endemic species of cycad in Indonesia may be endangered by infestation by cycad aulacaspis scale.

Key words: cycad aulacaspis scale, *Aulacaspis yasumatsui*, Hemiptera, Diaspididae, Indonesia

INTRODUCTION

The cycad aulacaspis scale (CAS), *Aulacaspis yasumatsui* Takagi (Hemiptera: Diaspididae), is a pest of cycads that originated from Southeast Asia (Heu & Chun 2000), specifically from the region between Thailand and peninsular Malaysia in the west and Vietnam in the east (Haynes 2005). It was first collected in Bangkok, Thailand, by K. Yasumatsu in 1972 and was described in 1977 by Takagi (1977). In the Oriental Region, CAS was introduced to southern China in the 1990s through the importation of infested *Cycas inermis* Lour. (Cycadaceae) from Vietnam. It later spread from China to Hong Kong, where it caused significant damage to cycads in 1992 (Hodgson & Martin 2001). CAS spread from Hong Kong to Taiwan in the early 2000s through commercial shipment of cycads (Haynes 2005), and has also been recorded from Singapore (Hodgson & Martin 2001) and Malaysia (see http://www.sel.barc.usda.gov/catalogs/diaspidi/Aulacaspisyasumatsui.htm). When not controlled, CAS is highly destructive and often lethal to its host plants, killing mature cycads in a matter of months (Howard *et al*. 1999). As a result of introductions, CAS is threatening the extinction of the endemic cycads *C. micronesica* K.D. Hill in Guam (Marler & Lawrence 2012) and *C. taitungensis* C.F. Shen, K.D. Hill, C.H. Tsou & C.J. Chen in Taiwan.

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In the western hemisphere, CAS was introduced inadvertently to South Miami, Florida in the early 1990s either through the transportation of cycad plants to botanical gardens or by people smuggling cycad plants from Southeast Asia (Haynes 2005). In 1995, residents of south Florida noticed white scale insects infesting *C. rumphii* Miq. and *C. revoluta* Thunb. (Walters *et al*. 1997). The identity of the scale in Florida was confirmed in 1996, and it was found to have infested 22 species of cycads, causing serious problems in parks, gardens, and elsewhere (Howard *et al*. 1999). Since then, CAS has spread to Alabama, Georgia, Louisiana, South Carolina, and Texas along the Gulf Coast (Haynes 2005). Occasional discoveries of CAS in Californian nurseries are always eradicated - the scale is not established in California. CAS has also spread to Hawaii, Guam, Palau, and the Northern Mariana Is (Rota) in the Pacific; Puerto Rico, U.S. Virgin Islands, St. Kitts, Vieques and Culebra, and Cayman Islands in the Caribbean; Bermuda; and Costa Rica in Central America, through the commercial shipment of infested *C. revoluta* plants from Florida (Haynes 2005, partly based on specimens in the California State Collection of Arthropods). It has also been recorded from Bulgaria, France and the former Yugoslavia (under glass) (see http://www.sel.barc.usda.gov/catalogs/diaspidi/Aulacaspisyasumatsui.htm).

The report by Haynes (2005) of the accidental introduction of CAS to Bogor Botanical Gardens in

Indonesia in the 1980s, causing decimation of its cycad collection, and the infestation having gone unreported for two decades, is incorrect. Lindstorm *et al.* (2009) also reported CAS to be present in Java, Bali and Timor; however, their statement, "that this pest was introduced many years ago as the once extensive *Cycas* collection in Bogor Botanic Garden, was completely wiped out long ago" is questionable. The authors (GWW in July 1997, and RM and AR in May 2008) who visited the Bogor Botanical Garden found it extant and free of CAS.

On November 7, 2011 the authors (RM and AR) visited Bogor Botanic Garden again and found that the collection of cycads, especially those in the genus *Cycas* spp., *Zamia loddigesii* Miq. and *Macrozamia miquelii* (F.Muell.) were heavily infested by CAS. Subsequently, a few more cycads (*Cycas revoluta* Thunb.) in Bogor city were also found to be infested by the scale. The implications of this new introduction are discussed below.

MATERIALS AND METHODS

Recording the Impact of *Aulacaspis yasumatsui* on Cycads. Infested cycads in the Bogor Botanic Garden and other parts of Bogor were observed on two occasions, on November 7, 2011 and again on January 7, 2012. On each occasion, photographs were taken to show the extent and distribution of the infestation on the plants.

Identification of the Scale and Parasitoids. Scale-infested cycad leaves from Bogor Botanic Garden were taken to the Department of Crop Protection, Bogor Agricultural University, trimmed, placed in vials of 75% alcohol, labeled, stood in freshly boiled water for 20 minutes to denature enzymes and ensure optimal preservation, and were shipped to the California Department of Food and Agriculture (CDFA) for identification. In the CDFA laboratory the insects were prepared as archival-quality slide mounts. This involved maceration of the body contents in 10% KOH, staining the cuticle with acid Fuchsin, and mounting the specimens in Canada balsam using the methods described in Watson and Chandler (2000) and Watson and Kubiriba (2005), before examination for diagnostic characters. The scales were identified using the key in Watson (2002). A permanent slide mount of CAS was deposited at Bogor Agricultural University, and another was kept in the California State Collection of Arthropods.

In addition, CAS-infested leaves in Bogor were incubated in closed plastic bags for the emergence of parasitoids. Two days later, the bags were examined under a binocular dissection microscope, and adult parasitoids were collected, preserved in 75% alcohol, labeled, and shipped to GAE (author) at USDA-APHIS, Beltsville, Maryland, for identification. There, specimens were mounted on slides and examined for diagnostic characters.

RESULTS

The Impact of *Aulacaspis yasumatsui* Infestation on Cycads. Initially, the scales settled mostly on the lower leaf surfaces (Figure 1). As the population increased, the scales covered both leaf (and other) surfaces, making them look white (Figure 2). The infested leaf tissue died due to saliva toxicity, turning yellow (Figure 3a) and then brown (Figure 3b).

Identification of the Scale and Parasitoids. At CDFA, NvE and GWW (authors) examined the slide-mounted scales and confirmed them to be *Aulacaspis yasumatsui*. Appearance in life: in both sexes, first-instar exuviae at one end of scale cover transparent, pale yellow-brown. Secreted part of immature male scale cover matt white, elongate, almost parallel-sided, with two or three longitudinal ridges (Figure 4). Adult female scale cover about 2.0 mm long, larger than that of male, broadly oval to mussel- or oyster-shaped, pearly white with some very fine fibrous texture (Figure 4); exuviae of second instar translucent light brown, situated near one end of the scale and partly covered by first-instar exuviae. When scale cover is lifted, exposed live adult female reddish brown; eggs beneath scale cover pale yellow when first laid, becoming reddish brown with age (Figure 5).

Figure 1. Lower leaf surface of cycad infested with *Aulacaspis yasumatsui* in Bogor, Java, Indonesia. Photograph by Aunu Rauf, Bogor Agricultural University.

Figure 2. Male cycad in Bogor Botanic Garden, Java, Indonesia in 2011, with a heavy infestation of *Aulacaspis yasumatsui* giving the cone of microsporophylls a whiteish appearance. Photograph by Amer Fayad, IPM CRSP, OIRED, Virginia Tech.

Figure 3. a. Cycads in Bogor, Java, Indonesia, infested with *Aulacaspis yasumatsui* in November 2011. b. Dying cycads infested with *Aulacaspis yasumatsui* in Bogor, Java, Indonesia, photographed two months later. Photographs by Aunu Rauf, Bogor Agricultural University.

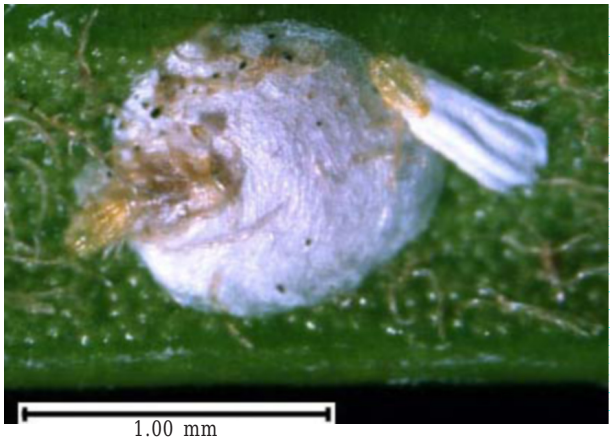

Figure 4. External appearance of adult female and immature male *Aulacaspis yasumatsui* in life. Photograph of material from Florida taken by Gillian W Watson, California Department of Food & Agriculture.

Diagnosis of slide-mounted adult female: body about 1.0 mm long, widest just anterior to anterior spiracles; prosoma swollen and rounded, lacking any lateral tubercles; pygidium with median lobes linked by a sclerosis and without any setae present between them; median lobes with inner margins longer than outer margins, so forming a notch at apex of abdomen; pygidial segment VI bearing a row of 1-4 submedian macroducts on each side, approximately level with the anal opening (Watson 2002).

At the USDA-APHIS, Beltsville laboratory, GAE (author) identified *Arrhenophagus chionaspidis* Aurivillius (Hymenoptera: Encyrtidae), a parasitoid of male armored scales, and *Signiphora bifasciata* Ashmead (Hymenoptera: Signiphoridae), a hyperparasitoid of New World origin.

Figure 5. *Aulacaspis yasumatsui* with scale cover removed to expose the live adult female and eggs. Photograph of material from Florida taken by Gillian W Watson, California Department of Food & Agriculture.

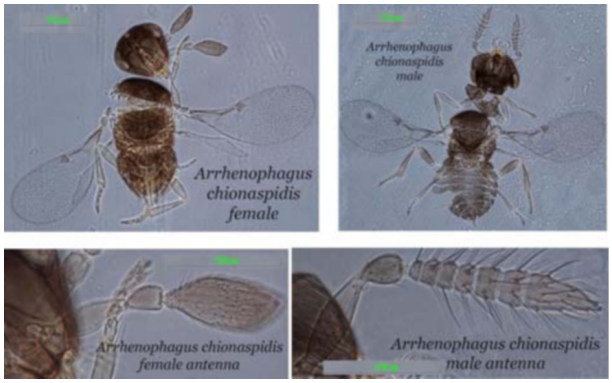

Figure 6. *Arrhenophagus chionaspidis* female, female antenna, male, and male antenna. Photograph by Gregory A. Evans, USDA/APHIS/NIS, Beltsville, Maryland.

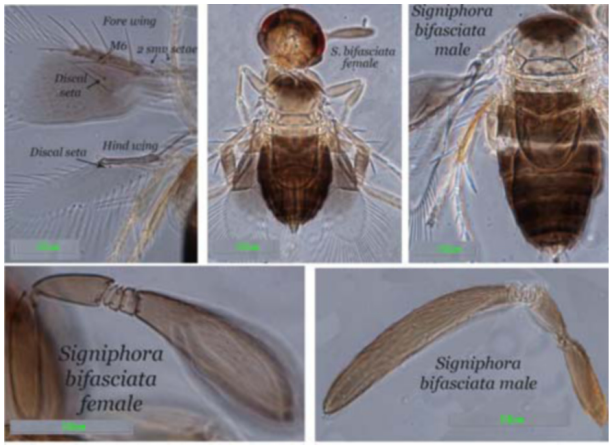

Figure 7. *Signiphora bifasciata* fore wing, hind wing, female, male, female antenna, and male antenna. Photograph by Gregory A. Evans, USDA/APHIS/NIS, Beltsville, Maryland.

Arrhenophagus chionaspidis Aurivillius parasitizes male armored scales. The body of both the adult male and female is entirely dark brown in color and the wings are hyaline (clear, not infuscated). Unlike almost all other encyrtids, which have 5-segmented tarsi, *Arrhenophagus* species have tarsi with only four segments. The flagellum of the antenna of the adult female consists of 2-4 short anelliform segments and 1 very long club segment, and the forewing is very broad (Figure 6).

Signiphora bifasciata Ashmead is most likely a hyperparasitoid. The family Signiphoridae can be recognized by having the surface of the fore and hind wings without setae, except occasionally a single discal seta present under the marginal vein; the antennae of both sexes consisting of a single, long and unsegmented club and 1-4 short, annelliform funicle segments; and all tarsi being 5-segmented. The genus *Signiphora* is distinguished from the other three genera in the family by having the M6 seta present on the marginal vein of the forewing and the calcar on the tibia of the first leg with a comb of fine setae. *Signiphora bifasciata* can be distinguished from other species of *Signiphora* by having a discal seta present on both the forewing and hindwing; forewing infuscate from the wing base to the distal end of the stigmal vein; the submarginal vein with 2 setae; marginal vein of hind wing with 1 seta; female antenna with 2-3 annelli; marginal fringe of forewing very long; thorax brown except scutellum and metanotum, which are pale tan, yellow or white; mesoscutum with about 16 setae; and scutellum with 6 setae (Figure 7).

DISCUSSION

***Aulacaspis yasumatsui* Biology.** CAS has been recorded feeding on the cycad genera *Dioon, Encephalartos*, *Microcycas, Strangeria*, *Macrozamia* and *Ceratozamia* (see http://www.sel.barc.usda.gov/catalogs/diaspidi/Aulacaspisyasumatsui.htm); members of the genus *Cycas* are the most susceptible to damage by this insect (Howard *et al*. 1999; also see http://www.sel.barc.usda.gov/catalogs/diaspidi/Aulacaspisyasumatsui.htm). CAS is an armored scale covered with a non-living test made of white wax and cast cuticles. Each female is capable of laying over 100 eggs under the protective cover. At 24.5 °C, the egg stage from oviposition to eclosion takes 8 to 12 days; the average duration of the first and second instars is 16 and 28 days, respectively; and adult females live up to 75 days (Howard *et al*. 1999).

The spread of CAS to new areas is mainly through movement of infested plants, while locally it is due to wind dispersal of first instar crawlers. The scales can be extremely difficult to detect on whole cycad plants at plant quarantine inspection due to their small size and ability to hide in deep crevices or even on the roots (Marler & Moore 2010).

Cycas is the only genus of Cycadaceae that occurs in Indonesia naturally. Ten species are native, of which five are found only in Indonesia: *C. falcata* K.D. Hill, *C. glauca* hort. ex Miq., *C. javana* (Miq.) de Laub., *C. montana* A. Lindstr. & K.D. Hill, and *C. sundaica* Miq. ex A. Lindstr. & K.D. Hill. These species may be threatened with extinction by CAS. The other five species, which occur in other countries as well as Indonesia, are *C. apoa* K.D. Hill, *C. scratchleyana* F. Muell., *C. rumphii* Miq., *C. edentata* de Laub., and *C. papuana* F. Muell. (Lindstrom *et al*. 2009).

Biological Control. Often a species becomes invasive when it is introduced to a new place without its natural enemies, whereas natural enemies keep the species in equilibrium in its native range. In Florida, where there is a thriving, multi-million-dollar cycad nursery industry, mechanical, cultural, and biological control methods are used to mitigate CAS damage. Mechanical and cultural methods involve removing heavily infested leaves and disposing of them safely to prevent further spread. Washing the infested plants with high pressure water jets to dislodge scales and drown crawlers can also reduce the severity of scale damage. Insecticides ranging from horticultural oils, systemic organophosphorus chemicals like malathion and dimethoate, to the growth regulator imidacloprid, have been tested and recommended for use in Florida to protect cycads in nurseries and landscape horticulture (Emshousen & Mannion 2004). However, mechanical, cultural, and chemical control methods are expensive, temporary, and difficult to apply in the native habitats of cycads. The only method that is economical, effective, and long lasting is classical biological control. It is possible that some local Indonesian generalist parasitoids and predators may attack this introduced pest; however, suppression of an introduced pest by local natural enemies alone is extremely rare. It has already been shown that local natural enemies are insufficient to suppress the population of CAS in countries where the scale has established outside of its native range.

To minimize the adverse impact of CAS on the cycad nursery industry in Florida and on the native cycads in Guam and Taiwan, classical biological control programs have been initiated. When CAS established in Florida and threatened the cycad-growing industry, Dr. Richard Baranowski of the University of Florida in collaboration with Dr. Banpot Napompeth of the National Biological Control Research Center in Thailand, identified two natural enemies of CAS in Thailand – the parasitoid, *Coccobius fulvus* (Compere & Annecke) (Hymenoptera: Aphelinidae) and the predatory beetle, *Cybocephalus nipponicus* (Endrody-Younga) (Coleoptera: Cybocephalidae). These were imported from Thailand, tested for host specificity in a quarantine facility, and field-released in Florida in 1998 (Howard *et al*. 1999; Haynes 2005). Although both these natural enemies have established there, they seem unable to provide satisfactory control (Cave 2005). However, it is interesting to note that both this parasitoid and the predatory beetle had been introduced to the U.S. much earlier for the control of other insect pests. *C. fulvus* was introduced into California in the 1980s from India to control *Pinnaspis strachani* (Cooley) (Hemiptera: Diaspididae) and into New England from China in the 1990s to control *Unaspis euonyomi* (Comstock) (Hemiptera: Diaspididae) (Van

Driesche *et al*. 1998; Meyerdirk 2002). *C. nipponicus* was also introduced to the U.S. much earlier, and has been present in Florida since at least 1990 (Smith & Cave 2006). In Hawaii, an armored scale-feeding lady beetle, *Rhyzobius lophanthae* (Blaisdell) (Coleoptera: Coccinellidae) introduced in 1894 has been providing some control of CAS. It also is known to have been present in Florida since the 1930s but has not provided effective control there (Emshousen & Mannion 2004). This beetle was imported from Hawaii to Guam in 2005 and released for the control of CAS. Additionally, the parasitoid *C. fulvus* was also imported from Florida and released in Guam in 2005 (Moore *et al*. 2005). The establishment of *C. fulvus* on Guam is uncertain; however, *R. lophanthae* has established well and is providing some control of CAS.

The predatory beetle, *C. nipponicus,* was imported from Thailand to Taiwan and released in 2005; its effect on the CAS population is yet to be assessed. Other hymenopteran parasitoids collected from CAS in China: *Arrhenophagus chionaspidis* Aurivillius and *Thomsonisca sankarani* Subba Rao (Encyrtidae), and *Pteroptrix chinensis* (Howard) and *Aphytis lepidosaphes* Compere (Aphelinidae), are being cultured at the quarantine facilities of the Florida Department of Agriculture at Gainesville, Florida. Dr. Ru Nguyen of Florida Department of Agriculture and Consumer Services has also observed the hymenopteran parasitoids, *Aprostocetus* sp. possibly *purpureus* Girault (Eulophidae) and *Encarsia* sp. (Aphelinidae), parasitizing CAS in Vietnam (Emshousen & Mannion 2004).

The natural enemies utilized thus far in different countries for the control of CAS are not providing satisfactory results. The impact of *A. chionaspidis* on CAS in Indonesia is limited because it attacks only the male scales, and the hyperparasitoid *Signiphora bifasciata* is reducing its population.

Preventive and Control Measures. Experience in Florida and other regions have proved that it is difficult to control *Aulacaspis yasumatsui* by any one of the currently available methods. The obvious control method to adopt in a country where CAS is not yet present is to enforce strict quarantine regulations by prohibiting importation of cycad plants from infested countries. Since the scale is already established in West Java, it would be prudent to conduct a survey of CAS throughout the country and impose a quarantine on movement of infested cycad materials to non-infested islands. CAS infests every part of the cycad plant including the roots; one or two gravid females hidden on the fibrous stem or roots can easily escape detection in quarantine examinations. To create awareness of the seriousness of this pest and the importance of saving the endemic cycads, the Government of Indonesia should be alerted. An all-out campaign should be mobilized to prevent its further spread and control measures should be implemented where CAS has already established. It is desirable to adopt an approach that will provide long-term control, so an integrated pest management approach including cultural, chemical, and biological control should be devised.

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REFERENCES

Cave RD. 2005. Biological control of *Aulacaspis yasumatsui*. *Cycad Newsl* 28:8-9.

Emshousen C, Mannion C. 2004. Taming Asian cycad scale (*Aulacaspis yasumatsui*). *Cycad Newsl* 21:8-10.

Haynes J. 2005. Cycad aulacaspis scale: A global perspective. *Cycad Newsl* 28:3-6.

Heu RA, Chun ME. 2000. Sago palm scale. New Pest Advisory no. 99-01. Honolulu: State of Hawaii Department of Agriculture.

Hodgson CJ, Martin JH. 2001. Three noteworthy scale insects (Hemiptera : Coccoidea) from Hong Kong and Singapore, including *Cribropulvinaria tailungensis*, new genus and species (Coccidae), and the status of the cycad-feeding *Aulacaspis yasumatsui* (Diaspididae). *Raffles Bull Zool* 49:227-250.

Howard FW, Hamon A, Mclaughlin M, Weissling T, Yang SL. 1999. *Aulacaspis yasumatsui* (Hemiptera: Sternorrhyncha: Diaspididae), a scale insect pest of cycads recently introduced into Florida. *Florida Entomol* 82:14-27. http://dx.doi.org/10.2307/3495833

Lindstrom AJ, Hill KD, Stanberg LC. 2009. The genus *Cycas* (Cycadaceae) in Indonesia. *Telopea* 12:385-418.

Marler TE, Lawrence JH. 2012. Demography of *Cycas micronesica* on Guam following introduction of the armoured scale *Aulacaspis yasumatsui*. *J Trop Ecol* 28:233-242. http://dx.doi.org/10.1017/S0266467412000119

Marler TE, Moore A. 2010. Cryptic scale infestations on *Cycas revoluta* facilitate scale invasions. *Hort Science* 45:837-839.

Meyerdirk DE. 2002. Control of cycad scale, *Aulacaspis yasumatsui* (Homoptera: Diaspididae). Maryland: USDA Environmental Assessment.

Moore A, Marler T, Miller RH, Muniappan R. 2005. Biological control of cycad aulacaspis scale on Guam. *Cycad Newsl* 28:6-8.

Smith TR, Cave RD. 2006. Pesticide susceptibility of *Cybocephalus nipponicus* and *Rhyzobius lophanthae* (Coleoptera: Cybocephalidae, Coccinellidae). *Florida Entomol* 89:502-507. http://dx.doi.org/10.1653/0015-4040(2006)89[502:PSOCNA]2.0.CO;2

Takagi S. 1977. A new species of *Aulacaspis* associated with a cycad in Thailand (Homoptera: Cocoidea). *Insecta Matsumurana* 11:63-72.

Van Driesche RG, Idoine R, Bryan M. 1998. Release, establishment and spread of Asian natural enemies of euonymus scale (Homoptera: Diaspididae) in New England. *Florida Entomol* 81:1-9. http://dx.doi.org/10.2307/3495990

Walters T, Shroyer E, Anderson L. 1997. Scale and south Florida *Cycas*. *Cycad Newsl* 20:13-15.

Watson GW. 2002. Arthropods of economic importance: Diaspididae of the world. An illustrated identification guide and information source. CD-ROM (illustrated). Expert Center for Taxonomic Identification (ETI), University of Amsterdam, the Netherlands. ISBN No. 90-75000-48-0. Minimally illustrated version accessed online on 24 March 2012 at http://wbd.etibioinformatics.nl/bis/diaspididae.php?menuentry=soorten&id=90

Watson GW, Chandler LR. 2000. Identification of mealybugs important in the Caribbean region. Second edition (revised). 40 pp. Egham, UK: CABI Bioscience.

Watson GW, Kubiriba J. 2005. Identification of mealybugs (Hemiptera: Pseudococcidae) on banana and plantain in Africa. *African Entomol* 13:35-47.