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General News

Status and Biological Control of Cycad Aulacaspis Scale

According to the IUCN/SSC* Cycad Specialist Group's action plan (http://data.iucn.org/dbtw-wpd/edocs/2003-010.pdf), cycads are the most ancient seed plants still living today and the extant c. 297 taxa form one of the world's most threatened groups. The invasive cycad aulacaspis scale, *Aulacaspis yasumatsui* (CAS), is a threat to native cycad populations worldwide as well as a costly pest for horticultural industries. The diaspidid or armoured scale, CAS, is already documented as threatening the extinction of the endemic cycads *Cycas micronesica* in Guam and *C. taitungensis* in Taiwan (www.cycadsg.org/pages/CAS.htm). A few species – notably *C. revoluta* – are important ornamentals globally and trade in whole plants has been the pathway for CAS spread between countries, although local spread can occur via wind dispersal of first-instars also. This article outlines the limitations of all but the most stringent import restrictions, and then looks at the current status of CAS and its control in some invaded countries, focusing on biological control and its prospects.

CAS attacks primarily *Cycas* species and is native to an area of South-east Asia between Thailand and peninsular Malaysia in the west and Vietnam in the east. It has spread within Asia, becoming a pest in southern China in the 1990s through the importation of infested *C. inermis* from Vietnam; later spreading to Hong Kong in 1992, where it caused significant damage to cycads; to Taiwan in the early 2000s; and to Singapore, Malaysia and Indonesia[1].

Outside Asia, CAS was first identified in south Florida in 1996 following accidental introduction on cycads legally imported for botanical gardens. By the time it was identified it had infested 22 cycad species. It has since spread north to South Carolina and west as far as Texas. Cycads of Florida origin have probably been responsible for the scale's spread to some Caribbean islands and Costa Rica, and to Hawaii (first reported in 1998), Guam (2003), Rota in the North Marianas (2007) and Palau (2008) in the Pacific. It has also been reported from a few European countries (France, Croatia and Bulgaria)[1]. In its introduced range, CAS is highly destructive. Long-term infestations lead to sequential defoliations, with leaves of each successive flush being smaller and fewer, ultimately leading to plant death, even of mature cycads and sometimes within only a few months of becoming infested.

The IUCN/SSC Cycad Specialist Group proposes preventing introduction as the most effective way of combating this pest. Its three alternatives for preventing entry centre on quarantine measures: (i) prohibiting entry of host cycad plants from countries known or suspected of having infestations; (ii) mandatory insecticide treatment as a condition of entry for host plants coming from infected countries; or (iii) close inspection of host plants for scale infestations with subsequent insecticide treatment if infestations are found (www.cycadsg.org/publications/CAS/Cycad-Aulacaspis-Scale-Pest-Alert.pdf). However, the minute size of the first-instar crawlers allows them to reach plant tissues not accessible to inspection[2]. The unique morphology of *C. revoluta* stems and cataphylls (thickened leaves that protect the apical meristem), together with hidden root surfaces, mean that even the most thorough quarantine inspection will not find all the scales. The efficacy of insecticide treatments cannot be guaranteed for the same reason. Thus the best hope for prevention is prohibition of entry from infested areas. However, even where this is implemented – as in Palau - there is no guarantee that CAS will be kept out indefinitely. Strict quarantine is also essential: CAS infestation progresses rapidly and scale covers are easily detected on leaves within a few weeks of crawlers settling. Imported cycads truly need to be quarantined, rather than just inspected and released. If CAS evades quarantine, by the time this becomes apparent in the field and its identity is confirmed the insect may have been established for a year or more, by which time all hope of eradication is long past.

Continental USA

In Florida, the thriving, multi-million-dollar cycad nursery industry combines mechanical, cultural, chemical and biological control methods to mitigate CAS damage. Natural enemies already present, including the predatory beetle *Cybocephalus nipponicus* and the coccinellid *Rhyzobius lophanthae* (introduced previously from Australia to control diaspidid pests) did not provide adequate control.

From surveys in Thailand, Richard Baranowski (University of Florida), with Banpot Napompeth (National Biological Control Research Center, Thailand), identified and released in Florida two natural enemies of CAS: *Cy. nipponicus* and an aphelinid parasitoid, *Coccobius fulvus*.

Ronald Cave (University of Florida) and Ru Nguyen (Florida Department of Agriculture) found *Co. fulvus* in northern Vietnam. This was released (after climate matching) in northern Florida in 2007, and established and spread. From 2003 to 2011, *Co. fulvus* was the only parasitoid observed in CAS in Florida; although high rates of parasitism by it have been seen recently in northern Florida, it seems unable to provide satisfactory control. The impact of both *Cy. nipponicus* and *Co. fulvus* may be affected by hyperparasitism although the extent is unknown: *Co. fulvus* is hyperparasitized by *Ablerus* sp. and *Cy. nipponicus* is attacked by the prepupal-pupal parasitoid *Aphanogmus albicoxalis*.

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An encyrtid parasitoid commonly found by Cave and Nguyen in China, Vietnam and Thailand in 2006, 2007 and 2009 surveys was *Arrhenophagus chionaspidis*. This wasp had been reported attacking another diaspidid, white peach scale (*Pseudaulacaspis pentagona*), in Florida many years before but had not at that time been recorded from CAS there. It was found in CAS in Florida in 2012 but although rates of parasitism were in some cases very high, it has no apparent control impact on CAS populations.

During the survey in Thailand in 2007, an undescribed coccinellid (subsequently named *Phaenochilus kashaya)* was discovered at two localities where scale infestations were light. This species is under investigation in Florida. No-choice testing indicated it would feed on early instars of some other groups, including aphids and mealybugs, and small larvae of *Cy. nipponicus*, *R. lophanthae*, and CAS mummified by *Co. fulvus*, but choice tests suggest it is normally a specialist on armoured scales including CAS. Mixed colonies of *P. kashaya* and *Cy. nipponicus* perform well in the laboratory. It is notable that *Cy. nipponicus*, *Co. fulvus* and *P. kashaya* are all found in Thailand, but during exploration only *A. chionaspidis*, *Cy. nipponicus*, and *P. kashaya* were seen on plants at the same locality. Another factor makes *P. kashaya* an exciting discovery: preliminary results suggest that the reproductive rate of CAS outstrips the consumption rate of *Cy. nipponicus*, *Co. fulvus* and *R. lophanthae;* but *P. kashaya* consumes CAS faster than the scale reproduces (which does create problems for quarantine testing, as the predator wipes out the scale colony).

Among other natural enemies tested, the fungus *Isaria fumosorosea* performed well in the laboratory[3], as did entomopathogenic nematodes, but similar results could not be obtained in the field and funding is not currently available to pursue this work.

CAS was detected in Texas in 2006, but is being controlled by fortuitous establishment of *R. lophanthae* and the aphelinid parasitoid *Aphytis lingnanensis*[4]. Nurseries in California very occasionally find CAS but it is always eradicated when found.

Hawaii

CAS was first detected in Hawaii in 1998 and found to be under biological control by a pre-existing population of *R. lophanthae*[5]. It was only a decade later, in 2008, that two parasitoids were first seen attacking CAS there. They were identified as the aphelinids *A. lingnanensis* and *Pteroptrix* n. sp. near *leptocera*, with *A. lingnanenis* being the most numerous[6]. *Aphytis lingnanensis* was purposefully introduced to Hawaii as a biocontrol agent in 1952. The parasitoid attacking CAS in Hawaii may be a recent, fortuitous introduction of a new biotype of *A. lingnanensis*[6].

Guam

Since its discovery on ornamental cycads in Guam in 2003, CAS has decimated imported cycads there. However, of greater concern is its spread to the native *Cycas micronesica*, a dominant component of Guam's limestone and ravine forests, which it has also devastated. Without treatment, the mortality rate for the native cycads is 100% within one year of infestation. After six years of CAS attack no recruitment is occurring among the survivors, even after the introduction of a biocontrol agent. *Rhizobius lophanthae* was introduced from Hawaii in 2005 and is protecting mature plants, but seedlings are still severely impacted. Research has uncovered a number of factors contributing to control breakdown: there is a disparity in size between pest and predator which means that CAS occupying tiny spaces escape predation[2]. In addition, CAS feeding on *C. revoluta* are protected from predation by the plant's trichomes[7]. Possibly seedlings and young cycads are particularly susceptible to mortality from CAS infestation because *R. lophanthae* predation rate is reduced near the ground[8]. Although many mature trees died in the interval between arrival of the scale and establishment of the beetle, *R. lophanthae* has been responsible for the survival of mature trees; but no seedlings are surviving[9].

Long-term prospects are not good. A study monitoring *C. micronesica*, which was initially a healthy, stable population, concluded that Guam has already lost over 90% of its *C. micronesica* to CAS, and the trend line predicts extinction in the wild by 2019[10]. This is a first-class ecological disaster that few people know about, and one that was predicted as far back as 2000[11] but unfortunately discounted at the time. In a 2002 forest survey of Guam, *C. micronesica* was listed as the most numerous plant with a stem diameter greater than five inches [12.5 cm]. By 2006, the plant was on the IUCN Red List.

Small numbers of a second biocontrol agent, *Coccobius fulvus*, were imported to Guam from Florida and released in 2005 but the parasitoid did not establish. Current efforts are focused on trying to import *A. lingnanensis* from Hawaii, selected because it coexists with *R. lophanthae* as a natural enemy of CAS in Texas and Hawaii. This parasitoid is much smaller than *R. lophanthae*; it is hoped that it will attack CAS in refuges too small for the coccinellids to access, and will do a better job at protecting cycad seedlings.

Palau

News from Palau is currently more promising, although there is concern about the future of native cycads there also. Following the arrival of CAS in Guam in 2003, Palau banned imports of cycads in an effort to prevent invasion, but the scale eventually evaded quarantine restrictions and was found in Palau in 2008. While introduced cycads on the main islands of Koror and Babeldaob were initially infested, the main concern was for the future of the abundant native cycads found on the isolated Rock Islands.

Rhyzobius lophanthae was obtained from Guam and released in Palau in 2009 (but not in the Rock Islands, as erroneously reported in *BNI* 31(1), March 2010, pp. 2N-3N); it established and dispersed well. Once the biocontrol agent had begun to disperse, no further releases were necessary and project activity ceased. The last project survey, conducted in October 2009, found no scales on the native cycads in the Rock Islands, so no releases were made there. Awareness activities also ceased in December 2009, and the biocontrol agent rearing programme was wound down.

As of December 2012, ornamental cycads (mainly *Cycas revoluta*) in Koror and elsewhere show no obvious signs of scale infestation or damage: plants which were severely infested in 2008–09 now look healthy. The native cycads in the Rock Islands remain at risk, but there is little that can be done to protect them except regular checks for CAS infestation.

Taiwan[12]

First found in Taiwan in 2000, CAS has since spread throughout the island. An estimated 110,000 cycads (of various ages) in nurseries in Taoyuan County were killed by the pest during the first year. Of particular concern is the scale's impact in Taitung Cycad Nature Reserve (290 ha), where it was first reported in 2004. This area was designated in 1986 specifically to protect the endemic Taitung cycad, *C. taitungensis*, a species on the IUCN Red List.

A preliminary survey in 2005 showed that 90% of Taitung cycads in sampling plots were infested, and accumulated mortality in the plots reached 37% by May 2010. The huge number of first instars sampled indicated a continuously growing and dispersing population of CAS and an increasing potential for damage to Taitung cycad. However, a high proportion of CAS (37%) was found to be parasitized by the encyrtid parasitic wasp *Arrhenophagus chionaspidis*, although there was a disparity between the sexes with parasitization rates for female scales averaging only 7% (maximum 14%).

The predatory beetle *Cybocephalus nipponicus* was introduced from Thailand in 2005. However, it was not an effective agent against the scale and interest is now focused on *A. chionaspidis*.

Indonesia

CAS was recorded from Indonesia recently; cycads in Bogor Botanical Garden and Bogor City were found to be heavily infested in late 2011[1]. The pest was recorded from various sites in Indonesia in the past, and herbarium specimens from the Bogor *Cycas* collection from over 100 years ago contain armoured scales that may be CAS; but there is no mention of infestations on cycads in the early Dutch literature. If the scale was in Bogor years ago, it disappeared for several decades, possibly due to a lack of host plants there, and has either re-emerged or been re-introduced recently. There are five endemic species of *Cycas* in Indonesia which could be threatened with extinction by CAS.

Existing natural enemies appear unlikely to contribute to control in Indonesia. *Arrhenophagus chionaspidis* mainly parasitizes male CAS and its impact is reduced by a hyperparasitoid, *Signiphora bifasciata*[1].

Since the scale is already established in West Java and has probably spread further afield, a survey of CAS throughout the country is warranted. It is critical for the government to be alerted to the seriousness of this pest, and for the importance of saving the endemic cycads to be publicized. Given the difficulty of implementing quarantine inspections in Indonesia's many islands, the most effective action would be to establish classical biological control to maintain CAS populations at low levels that do not endanger the native cycad species.

*IUCN/SSN: The World Conservation Union/Species Survival Commission.

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Untapped Potential for Conservation Biological Control in Developing Countries

The geographical spread of the authors of this review[1] is a first indication of its global scope. In this paper, the authors set out to assess what is known, where the research opportunities are, and what existing practices could be turned into practical pest management solutions for local farmers. As they point out, conservation biological control (CBC) is frequently cited as the area of biological control with most potential in developing countries, yet in most such countries there has been little research attention paid to it. Moreover, in places where CBC has been used with great success in past decades – for example in South-east Asian rice – its use has dramatically declined.

The authors define developing countries as outside North America, Australia, New Zealand, Japan and western Europe (i.e. where most research on CBC has been concentrated), and they confine themselves to arthropod natural enemies and their effect in controlling agricultural pest populations. By doing so, they identified 390 CBC-related records from 53 countries and more than 50 crops, including many that were less accessible or not published in English to make the review as comprehensive as possible. A lot of the papers come from three countries: Brazil China and Cuba, which they say could be indicative of a genuine focus on CBC in these countries.

The review is organized to give a clear indication of what is known and not known for natural enemy groups, pest groups, crops and geographical areas. The research literature is dealt with in a series of topics: (i) effect of non-prey foods on natural enemy fitness; (ii) identification of alternative host, food and prey associations; (iii) role of artificial food supplements (food sprays); (iv) effects of structural habitat manipulation on resident natural enemies (including inter/cover cropping); (v) effects of deliberate manipulation of disturbance regimes including tillage and pesticide use; (vi) effects of germplasm on natural enemy abundance and performance; and (vii) CBC at the farm and landscape scale.

Overall, the vast majority of CBC studies were conducted in a restricted set of crops, notably rice, cotton, and maize. Also, fruit and vegetable crops have been little researched apart from important commodities such as coffee and citrus; the same gap in research was noted for forage crops and many key staples including tuber crops, millet, lentils and bananas/plantains. A broad range of pests have been the subject of CBC research, but the authors highlight the tremendous potential for CBC to help control species that are susceptible to developing pesticide resistance, of which >70% have not been studied.

The authors note that the largest area of CBC research has been habitat manipulation (including inter/cover cropping) which is dealt with in 151 papers out of the total of 390, although its impact on pest suppression is less well studied than its effects on natural enemy populations. The impact of deliberate manipulation of disturbance is also well characterized for many crop systems. On the other hand research on natural enemies was more limited in scope, with two popular areas: survey and identification of potentially useful natural enemies, and on-farm evaluation of CBC schemes. There is an absence of information on natural enemies for some key pests (e.g. whiteflies) as well as some crops, which it will be necessary to acquire before CBC practices can be developed. The authors call for well-designed ecological experiments that go beyond natural enemy surveys to assess their role and their impact on pests, as these are rare in all systems.

The authors draw attention to the economic benefits that could accrue from an investment in CBC research and implementation, given the large sums spent in many developing countries on imported agricultural pesticides. They also highlight adverse impact of increasing mechanization in developing countries on potential for CBC and call for farmers' knowledge to be documented and brought into play. They conclude by describing the potential for well-designed regional projects that draw on historical information and fill knowledge gaps to devise workable CBC measures to integrate into pest management schemes.

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Cactus Biocontrol Agent Delivers Another Knock-Out Blow

Four years ago, scientists from South Africa's ARC-PPRI (Agricultural Research Council - Plant Protection Research Institute) reported that control of the chain-fruit cholla cactus (*Cylindropuntia fulgida* var. *fulgida*), achieved by introducing a specific biotype of the cochineal insect *Dactylopius tomentosus,* had exceeded all expectations in its speed and magnitude (see *BNI* 30(2), 17N–19N). Now they report control of a closely related species, boxing-glove cactus (*C. fulgida* var. *mamillata*), using the same agent.

The initiative to control chain-fruit cholla cactus was championed by that eminence grise of South African weed biological control, Helmuth Zimmermann, following a promise made to his wife after they had seen some of the worst infestations, in Northern Cape Province, where dead rabbits and small antelopes were impaled on the terrible spines of the invasive cactus, and livestock had become covered in spines to the point where they were unable to walk. That promise took eight years to fulfil and involved overcoming obstacles such as re-identification of the target cactus and a hiatus in funding, but when the agent was finally released – by which time Helmuth had retired and Hildegard Klein was managing the project – control was spectacular.

The re-identification of the target had led Helmuth to look in the home range of chain-fruit cholla for effective biocontrol agents; he collected *D. tomentosus* from *C. fulgida* var. *fulgida* in Arizona's Sonora Desert – but also from the related *C. cholla* in Baja California Sur, Mexico. Subsequent studies by Catherine Mathenge, then at the University of Cape Town, showed unexpectedly that the latter culture was the more damaging to chain-fruit cholla, and this was the biotype released against it in 2008. However, its original *C. cholla* host is very similar to boxing-glove cactus. Infestations of this cactus are wide-spread, occurring in most provinces of South Africa, especially in the arid regions and, like chain-fruit cholla, it produces sterile chain fruit and reproduces only vegetatively in South Africa. The two are, however, very different in growth form: chain-fruit cholla is a branched, jointed cactus with long, dense, whitish spines, while boxing-glove cactus is lower-growing with characteristic flattened, distorted (crested) growth, and it has shorter and more sparsely distributed spines that are not barbed and have tightly fitting sheaths.

Despite the fact that several stem segments per plant are hugely distorted and flattened and often spineless, boxing-glove cactus still produces large numbers of small, spiny, easily detachable segments which either take root around the mother plant, or are dragged around by animals until they become dislodged and take root wherever they drop. Goats frequently pick up such detached segments in or around their mouths, resulting in festering sores.

Boxing-glove cactus in Northern Cape Province was first inoculated with the 'cholla' cochineal biotype during October 2011 in collaboration with the Early Detection and Rapid Response programme (EDRR) of the South African National Biodiversity Institute (SANBI). By July 2012 it was clear that the cochineal is just as damaging to boxing-glove cactus as it is to chain-fruit cholla. Overwhelming numbers of cochineal were present on the infested plants, ready to be harvested for redistribution to other cactus stands – as cochineal insects do not disperse well, the insects are distributed manually from one cactus patch to another on infested pieces of host plant.

The project to control chain-fruit cholla was conducted with financial assistance from the then Department of Agriculture. The mass-rearing, release and post-release monitoring of the 'cholla' biotype of *D. tomentosus* is now being funded by the Working for Water Programme within the Department of Environmental Affairs.

Source: Klein, H. (2012) Two biocontrol successes for the cost of one. *Plant Protection News* No. 93, pp. 1–2. Newsletter of the Plant Protection Research Institute (PPRI), an institute in the Natural Resources and Engineering Division of the Agricultural Research Council (ARC) Plant Protection Research Institute.

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Biocontrol of Papaya Mealybug in Sri Lanka and India

India is the latest country to announce that papaya mealybug, *Paracoccus marginatus*, has been brought under control with the aid of imported natural enemies. The mealybug, which has its centre of origin in Mexico, has spread around the world to the Caribbean, South America, the Pacific, Southeast and South Asia and West Africa. It is a highly polyphagous species, recorded from plants in 20 families including numerous crops. The USDA-APHIS (US Department of Agriculture – Animal and Plant Health Inspection Service) parasitoid-rearing laboratory in Puerto Rico supplies the parasitoids *Acerophagus papayae*, *Anagyrus loecki* and *Pseudleptomastix mexicana* to countries requesting them. Many countries have successfully deployed these biocontrol agents.

Control was a rapid success in Sri Lanka, and a recent island-wide survey for mealybugs indicates the biocontrol agents' role in protecting native flora. Papaya mealybug was first reported in two districts in July 2008, infesting some 6200 ha of commercial papaya plantations as well as 40 other species. After other control measures failed and the pest had been definitively identified as *Paracoccus marginata*, the Horticultural Crops Research and Development Institute and the Plant Protection Service of the Department of Agriculture of Sri Lanka, requested USDA-APHIS to supply the three parasitoids, which were released in four districts in May 2009. By September that year the pest had been brought under control.

The recent survey revealed papaya mealybug in virtually all agro-ecological zones attacking even endemic plants, but the parasitoids are dispersing with the mealybugs and are keeping it under control. A culture of *Acerophagus papayae* is being maintained, and parasitoids were recently supplied to the Maldives.

In India, a truly massive response has brought the pest under control. Papaya mealybug was first reported on papaya in Coimbatore in the southern Indian state of Tamil Nadu in 2008. It subsequently spread to Kerala, Andhra Pradesh, Karnataka, Maharashtra and parts of Tripura and was found on over 100 other host plants including economic crops such as tapioca, mulberry and teak. Important industries such as papain, sago and silkworm were threatened by the pest.

In 2010, a biological control programme was initiated by the National Bureau of Agriculturally Important Insects (NBAII) at Bangalore in Karnataka. Five shipments of parasitoids were supplied from July to October 2010 to NBAII from the USDA-APHIS laboratory in Puerto Rico, and these were reared in NBAII's laboratory. With the granting of a permit from the Directorate of Plant Protection in 2011, releases could begin, and from mid 2011 the insects were released on a large scale in mealybug-infested areas.

The strategic plan for rapid production, distribution and conservation of the parasitoids was headed by Dr R. J. Rabindra, then Director of NBAII, while Tamil Nadu Agricultural University (TNAU) led the initiative to mass-rear and distribute the biocontrol agents. Once the nucleus culture was received at TNAU from NBAII, rapid action led to the training of 56 entomologists from seven colleges, 36 research stations and 14 Krishi Vigyan Kendras (KVKs – farm science centres) within a fortnight to provide the necessary infrastructure for mass production of parasitoids in a war footing manner. Dr E. I. Jonathan, Director, Centre for Plant Protection Studies (CPPS) in association with Dr S. Suresh, Professor of Agricultural Entomology, periodically monitored the progress of mass production and field release of parasitoids wherever papaya mealybug infestation was very high. Farmers were also sensitized not to spray any pesticides in order to conserve the parasitoids. In addition, entomologists of TNAU visited fields where parasitoids had been released at regular intervals and demonstrated the activity of the parasitoids to the farmers.

Over a period of eight months, approximately 800,000 parasitoids were released across Tamil Nadu state. Within five months of the biocontrol agents' first release, papaya mealybug was under control in Tamil Nadu, and the key role of *A. papayae* was becoming apparent. By the end of 2012, this parasitoid had established well in farmers' fields in Tamil Nadu, Karnataka and Maharashtra. It was present in enormous numbers and the impact of the mealybug was reduced drastically where it was present. Parasitoids were collected from these sites and distributed to fields of other farmers, and the biocontrol agent is dispersing to adjacent areas.

It is anticipated that inside a year the pest problem will be solved on a long-term basis throughout papaya mealybug's range in India. Reduced pesticide use gives substantial benefits in health, environment and economic terms; in Tamil Nadu, elimination of pesticide sprays against the mealybug gives an annual saving of US$35 million for three crops alone – cassava, papaya and mulberry. In contrast, the mass-rearing operation at TNAU cost US$200,000.

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Biocontrol Agent Approved for Madagascar Fireweed in Hawaii

Entomologists at the Hawaii State Department of Agriculture (HDOA) have stepped up production of a biocontrol agent for fireweed (*Senecio madagascariensis*) following long-awaited approval by the US Department of Agriculture in early December 2012. The first release of *Secusio extensa*, a leaf-feeding arctiid moth from Madagascar, is slated for early 2013, with the exact timing depending on how rearing progresses; the culture had been on a maintenance footing in quarantine since the State of Hawaii approved release in 2010. Now it can be reared outside containment, and with the help of ranchers and others, HDOA hopes to release more than one million moths and larvae in 2013.

Fireweed, which is native to southern Africa and Madagascar, is an annual or short-lived perennial that competes strongly with pasture species. It is toxic to livestock, particularly horses and cattle. Plants can regenerate from stem fragments but fireweed has a prodigious seed production capacity. Fireweed is also a serious invasive weed in Australia, Japan and a number of South American countries.

The introduction of *S. extensa* to Hawaii marks the first release of a biocontrol agent against fireweed worldwide. Its release will also be the culmination of more than 13 years research by HDOA, during which time its entomologists and researchers have literally searched the world for a natural enemy of the weed that would meet safety criteria for Hawaii. While this research was going on, the impact of fireweed became increasingly evident in Hawaii as an extended period of drought allowed it become even more aggressive. It currently infests more than 850,000 acres [344,000 ha] of prime pasture, mainly on Maui and Hawaii Islands. In some areas it has reduced forage production by as much as 60%.

The results of initial searches were frustrating. HDOA's exploratory entomologist, Dr Mohsen Ramadan, travelled to Australia, South Africa and Madagascar in 1999 and returned with 14 insects and one fungus, but when tested under quarantine conditions these were found to be either ineffective or not sufficiently host specific for Hawaii. A long-running biocontrol programme against fireweed in Australia began in 1991, but this has been hampered by the need to find agents that do not pose a threat to Australia's native *Senecio* species. In contrast, all *Senecio* species found in Hawaii are non-native and weedy. Nonetheless, this did not make the Hawaiian task easy.

Mohsen returned to the same countries in 2005, 2007, 2011 and 2012, looking for more potential biocontrol agents for fireweed and other weed targets. These surveys led to the discovery of *Secusio extensa* and other potential biocontrol agents. Field observations indicated that *S. extensa* fed only on *Senecio madagascariensis* in the native range. The moth was tested against 71 endemic and naturalized species (52 genera) in 12 tribes of Asteraceae and 17 species of non-Asteraceae including six native shrubs and trees considered key components of Hawaiian ecosystems before it was deemed safe to release. The high levels of feeding damage observed on potted fireweed plants suggest that *Secusio extensa* may have a significant impact on the weed.

At the current time, HDOA is testing four other potential natural enemies of fireweed: two tephritid fruit flies and a phycitid moth that feed on the flowers and a curculionid stem borer. If they pass safety and regulatory hurdles, they could provide a useful suite of biocontrol agents for fireweed in Hawaii.

Sources: Hawaii Department of Agriculture.
Web: http://hawaii.gov/hdoa

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Water Hyacinth Weevils Are Only Half the Picture

Neochetina weevils have been associated with some of the most spectacular control efforts against water hyacinth (*Eichhornia crassipes*). When the plant is hard hit by the weevils, it has been observed that it may also appear diseased and that this may be contributing to plant death. Now a study in South Africa[1] has uncovered evidence that microorganisms are responsible for an unexpectedly large part of the observed impact.

The *Neochetina* weevils' action has been shown to decrease plant size, vegetative reproduction, and flower and seed production. Their larvae tunnel in the petioles and crown of plants, while adults chew holes in photosynthetic surfaces. Together this feeding decreases leaf photosynthetic rate – but the effect is larger than would be expected from loss of photosynthetic surface area alone. It has been suggested that weevil feeding could facilitate microorganism access and damage; introductions resulting from herbivory have been previously demonstrated for *N. eichhorniae* feeding on water hyacinth.

This study confirmed that the adult *N. eichhorniae* weevil carries and transfers fungi and bacteria to leaves on which it feeds. The study then evaluated the relative contribution of weevil feeding and microbes, using surface sterilization with 3.5% chlorine bleach to eliminate microorganisms (which was shown not to affect the weevil's plant consumption). The impact of surface sterilized and unsterilized weevils on the plant's photosynthetic rate, as measured by gas exchange, was compared in a polytunnel situation. Results indicated that the highest reduction (37%) occurred with unsterilized weevils, but that weevil feeding (18%) and microbial action (19%) contributed almost equally to the overall reduction.

The authors conclude that maximizing the effectiveness of plant surface-feeding arthropods means understanding their role in vectoring microorganisms. They also point out that the size of the microbial contribution in this system puts a question mark over studies that use 'clipping' as a means of simulating herbivory.

[1]Venter, N., Hill, M.P., Hutchinson, S.-L. and Ripley, B.S. (2013) Weevil borne microbes contribute as much to the reduction of photosynthesis in water hyacinth as does herbivory. *Biological Control* 64, 138–142.

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Developing Cold-tolerant Nematodes for Codling Moth Control

Codling moth, *Cydia pomonella*, is the most harmful pest of apples and other pome fruit worldwide. Pupation occurs in spring, with emerging moths laying eggs on leaves, and hatching larvae boring into the developing fruit. Early control to reduce the spring population is critical. Lower populations are more amenable to mating disruption, which is the mainstay of codling moth integrated pest management. Minimizing codling moth damage is all the more important because acceptance of damage is low in many markets: one infested apple in 100 may be enough to have a consignment rejected.

Autumn applications of the nematode *Steinernema feltiae* can be used to control overwintering larvae of the codling moth, but efficacy may be limited by low temperature. As screening, hybridization and selective breeding have been successfully applied to entomopathogenic nematodes to increase beneficial traits, a recent study[1] investigated whether this approach had anything to offer in the codling moth system. Initial studies demonstrated *S. feltiae* to be more suitable than *S. carpocapsae* at temperatures down to 8°C. The next stage was to search for low temperature activity among 21 wild type populations of different geographical origin and one commercial hybrid strain of *S. feltiae*. The five most active of these strains were crossed, and the resulting strain that proved most active at low temperatures was used for selective breeding, using virulence in codling moth cocoons and reproductive fitness as parameters.

This process led to a lowering of the temperature at which 50% of dauer juveniles (DJs) were active, from a mean of 3.83°C in the 22 strains tested to 2.5°C for the most active strain (FIN1), and to 0.52°C for the hybridized strain (FIN1 × ISR1 = HYB01). These promising results show the potential for a breeding programme to improve performance of *S. feltiae* at low temperature, but more research is needed. The results indicate which strain's DJs move most at low temperatures; it needs to be demonstrated that this corresponds to improved control potential, although preliminary assessments conducted as part of this study were promising. In addition, conducting the experiment highlighted an issue with breeding the nematodes: temperature tolerance in HYB01 was lost after a few generations in the host *Galleria mellonella*, although it was restored after seven selection cycles involving exposure to lowering temperatures.

[1]Nimkingrat, P., Khanam, S., Strauch, O. and Ehlers, R.-U. (2012) Hybridisation and selective breeding for improvement of low temperature activity of the entomopathogenic nematode *Steinernema feltiae*. *BioControl* Online First, online 25 November 2012. DOI 10.1007/s10526-012-9497-4

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Dr H. Nagaraja: *Trichogramma* Expert

Internationally renowned insect taxonomist Dr H. Nagaraja died on 4 November 2012. In collaboration with Dr Sudha Nagarkatti he revolutionized the field of *Trichogramma* taxonomy in the late 1960s, discovering for the first time stable morphological characters allowing species to be distinguished. In the years that followed the publication of this landmark paper there was a flurry of activity in laboratories around the world leading to the discovery and description of many new species. In true Mayrian tradition they suggested and resorted to crossing experiments to establish reproductive isolation to distinguish between cryptic species. Some 76–80% of the *Trichogramma* and *Trichogrammatoidea* known from India today were described by Dr Nagaraja alone or along with his associates.

Dr Nagaraja honed his taxonomic skills when on the staff of the Commonwealth Institute of Biological Control in Bangalore. He later headed *Trichogramma* based biological control programmes in the Philippines and Papua New Guinea. On his return to India he helped establish Biotech International, a commercial biocontrol enterprise at Bangalore. Subsequently he joined the National Bureau of Agriculturally Important Insects (NBAII) at Bangalore as an Expert Consultant on *Trichogramma* taxonomy. For the last few years he had been working from home on consolidating information on the *Trichogramma* and *Trichogrammatoidea* fauna of India.

Awards Galore

The International Organization for Biological Control, IOBC Global, elected some new honorary members during its meeting in the Republic of Korea in recognition of their contributions to biological control: Rachel McFadyen from Australia, Vanda Bueno from Brazil, Dave Gillespie and Les Shipp from Canada, Heikki Hokkanen from Finland, Franz Bigler from Switzerland, Rangaswamy Muniappan and Catherine and Maurice Tauber from the USA, and last but not least, former CABI stalwart Jeff Waage, and CABI's current Chief Scientist, Matthew Cock.

Meanwhile, the IOBC Nearctic Regional Section (NRS) named Marshall Johnson of the University of California, Riverside as its Distinguished Scientist of the Year, recognizing his contributions to entomology, biological control and integrated pest management in terms of research, teaching, extension, administration and leadership.

And at ICIPE in Nairobi, the first Thomas Risley Odhiambo Distinguished Research Fellow (TRO DRF) was announced in November 2012 as Dr Z. R. Khan for his "scientific creativity and agricultural innovation". His pioneering work helped establish the push–pull system that enhances the activity of natural enemies against cereal stem boring pests and reduces *Striga* infestations.

Fourth BIOCICON Conference

The Fourth Biopesticide International Conference (BIOCICON2013) will be held on 28–30 November 2013 in Tamil Nadu, India with the theme: 'Ecofriendly plant protection and production for food security, food safety and the role of biopesticides in global economy'.

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