Biocontrol News and Information ***26***(*2*)*, 41N–58N*
pest.cabweb.org

General News

Saltcedar Biocontrol: a Success Story in the Making

The invasion of saltcedar, a.k.a. tamarisk (*Tamarix* spp.), into riparian areas and wetlands is one of the most critical resource management issues in western North America, but managing this invader is fraught with complexity and controversy. Originally introduced into the region from Eurasia and northern Africa in the early 1800s, saltcedar expanded tremendously during the early and mid 1900s following the widespread damming and diversion of arid region rivers. Elimination of natural flooding that formerly kept it at bay has contributed, along with widespread riparian habitat destruction and other anthropogenic factors, to the replacement of willows (*Salix* spp.), cottonwoods (*Populus* spp.), mesquite (*Prosopis* spp.) and other native riparian plants by saltcedar. Saltcedar also now occupies many western environments that are relatively intact or could still support native species and provide wildland values. This invasive taxon encompasses at least six species and various hybrids of them according to John Gaskin (US Department of Agriculture – Agricultural Research Service [USDA-ARS], Sidney, Montana), including the surprising discovery of hybridization between deciduous taxa and the evergreen athel (*T. aphylla*) in the desert southwest. A survey across 17 western US states led by Jonathan Friedman of the US Geological Survey determined that saltcedar is now the USA's third most abundant woody riparian plant. It occupies roughly 0.5 to 0.8 million hectares, where it alters erosion and sedimentation dynamics, promotes wildfires, depletes groundwater through excessive evapo-transpiration, and reduces habitat quality for numerous wildlife species.

These and other impacts were extensively covered in the September 2001 issue of *BNI* [**22**(3), 51N–54N, Saltcedar biocontrol: reconciling risks] by Jack DeLoach (USDA-ARS, Temple, Texas), who has led the biological control programme against tamarisk since 1987. That report outlined the many ways that biocontrol could reduce these impacts and enhance riparian ecosystems. DeLoach further discussed numerous conflicts, including potential impacts to nontarget native species such as the distantly related alkali heath (*Frankenia salina*) and its congeners, and the endangered southwestern willow flycatcher (*Empidonax traillii extimus*), now nesting to some extent in tamarisk in Arizona and adjacent regions. At that time we had just released the saltcedar leaf beetle (Chrysomelidae: *Diorhabda elongata*) at eight test sites in six states following 2 or more years of field cage testing by researchers cooperating as part of the Saltcedar Biological Control Consortium. At each site an extensive monitoring plan is now in place to document anticipated insect population expansion and impacts on target plants, and recovery responses by associated plants and wildlife. This report is an update on the rather exciting results of our biocontrol programme.

Beetles Take Off

Late in the 2002 field season we started seeing many defoliated plants at the Humboldt River test site in northern Nevada, corresponding to feeding by larvae of the second generation of beetles. The defoliated zone remained very distinct because adults are highly aggregative, and following swarming appear to move only a short distance to oviposit on nearby green plants. This created a 'wave' of defoliation that could be easily tracked. Conveniently, feeding action of larvae and adults results in desiccation of tissue beyond the feeding point, so that a moderate amount of consumption typically leads to near-100% loss of foliage. Both pupation and adult overwintering take place in the litter beneath the host plants, and depending on weather conditions two to three generations can be produced in a season.

Upon emergence the following spring the zone of defoliation increased dramatically, from approximately 2 ha in 2002 to almost 200 ha by autumn 2003. Then in 2004 we saw the same two orders of magnitude expansion with roughly 20,000 ha defoliated! Although flying beetles drop down to the vegetation when it is windy, sustained high winds probably assisted the population expansion as insect dispersal was documented north and south of the release site to about 140 km in linear extent. These data were from direct observations by our research team, including Nevada Department of Agriculture site manager Jeff Knight, and from field testing of chemical attractants by Earl Andress (USDA-APHIS [Animal and Plant Health Inspection Service], Brawley, California). The attractants included saltcedar-derived volatile compounds and male-produced aggregation pheromones (which attract both males and females) developed by Robert Bartelt and Allard Cossé of the USDA-ARS laboratory in Peoria, Illinois, who along with Dan Bean (University of California, Davis) have shown their usefulness not only for documenting presence in the field but also for collecting quantities of live insects and for encouraging the aggregation that seems to be critical for establishing new populations on target infestations.

Time to Kill

Unfortunately, saltcedar is not easily killed, and regrowth of foliage occurs within a few weeks of damage. Furthermore, it appeared in 2003 that the initial defoliation zone was avoided by beetles, suggesting a possible induced defence against herbivores. Student researcher Andrea Caires found that larval growth and mortality were poorer on this regrowth foliage than on undamaged material but the mechanism behind this remains undetermined. Nevertheless, refoliated trees were eventually defoliated again and trees from the original release site have experienced more than six defoliation events with almost no mortality!

The trees in Nevada do gradually die back, first as the distal portions of branches no longer produce foliage, and eventually new growth occurs only from the basal crown. Flower production is greatly diminished or absent on defoliated branches, so far fewer of the short-lived seeds would be available should suitable germination conditions occur. By the third season most target plants had experienced a more than 90% decrease in photosynthetic tissue production. Robert Pattison, a postdoctoral researcher with the University of Nevada and now with USDA-ARS in Reno, has been tracking annual growth rings as an indicator of herbivore damage, and preliminary results do show significant reduction in growth in the year following initial attack. Along with Allen Knutson and Jeremy Hudgeons from Texas A&M University he is also tracking non-structural carbohydrates in plant tissues, which is an index of plant metabolite storage, to measure herbivore-induced stress.

Light Dawns on Importance of Biotype

Similar results were observed at another Nevada site on the Walker River, and by collaborators in Wyoming (David Kazmer, USDA-ARS, Sidney, Montana), Colorado (Debra Eberts, US Bureau of Reclamation, Denver) and Utah. However an interesting pattern emerged, which had been hinted at by earlier cage studies. *Diorhabda* establishment was only successful in northern sites, whereas south of approximately 38°N beetles ceased feeding in midsummer even though there was still plenty of good *Tamarix* foliage. As DeLoach speculated in his earlier report and Dan Bean subsequently illustrated in elaborate detail, latitude is a strong determinant of establishment success. The agents released at research sites came from approximately 44°N in central Asia, and it turns out are developmentally constrained by their genetically-encoded response to daylength. When the receding daylength reaches about 14.5 hours the insects enter into reproductive diapause and soon descend into the litter to 'overwinter' in a quiescent stage. This cue arrives earlier as one goes south, and when weather remains warm the beetles deplete their metabolic reserves. Thus, their impact on target plants is poor, and at lower latitudes they are increasingly unable to survive until the following spring.

We now have cultures of eight geographic biotypes of *Diorhabda*, representing populations from various latitudes ranging from 44°N in northern China and Kazakhstan to 34°N in Tunisia and including insects from Uzbekistan and Greece. They have gone through host range testing and four have been released, in particular a population from 35°N in Crete, at research sites in California, Colorado, New Mexico and Texas. It is too early to know whether these releases have been successful, but the goal is to target the best adapted agent biotypes to different tamarisk-infested regions of North America. To provide more comprehensive evaluation of which biotypes should go where, we are initiating research in which several *Diorhabda* biotypes will be maintained in experimental cages at 2-degree intervals along a North-South latitudinal gradient spanning the western states. Once performance is evaluated in cages, the best agent will be proposed for release in each region.

An additional complexity concerns the target *Tamarix* genotype, because we have found in field experiments that *T. parviflora*, a common invader in central California and some other regions, is a poorer host than the more common *T. 'ramossisima'* (actually most infestations involve hybrids between *T. ramosissima* and *T. chinensis*). Thus, more studies are needed to determine not only the best-suited beetle for each geographic region, but also whether, for example, a Mediterranean *Diorhabda* biotype may be better able to use the western Asian *T. parviflora* than the central Asian beetles are able to do.

To complement these field studies, Dave Kazmer is conducting mitochondrial and nuclear DNA studies and James Tracy (USDA-ARS, Temple, Texas) is doing morphological analyses to determine phylogenetic relationships among the beetles. Their studies generally conclude that five deep lineages, consistent with species-level differentiation, are present within the *Diorhabda 'elongata'* complex. These relationships are also borne out in laboratory breeding studies by Dave Thompson (New Mexico State University) and Dan Bean (now with Colorado Department of Agriculture) who find that fertile offspring are produced by crosses within each lineage, although fertile offspring are sometimes produced in crosses between lineages while other crosses produce sterile F_1 hybrids. The question remains of whether to seek useful adaptive variation by allowing or even promoting hybridization in the field or to discourage such hybridization from occurring.

Putting the Ecosystem Back Together Again

It remains too early in the programme to see substantial improvement of saltcedar-infested ecosystems. Nevertheless, some elements of recovery are becoming apparent following 3 years of biocontrol. Plant dieback is allowing more light to penetrate to the ground surface, so understorey plants are increasing at the northern Nevada site. In the more extreme winter of the Wyoming site, dieback is more extensive with near-complete killing of aboveground material so light availability is even greater. Some beneficial native and forage plants like saltgrass (*Distichlis spicata*) are starting the recovery process. Unfortunately, other noxious invaders like the whitetops (*Lepidium latifolium* and *Cardaria draba*), Russian knapweed (*Acroptilon repens*), kochia (*Kochia scoparia*) or giant reed (*Arundo donax*) may also benefit from reductions in saltcedar dominance. Debra Eberts found that in wet years annual weeds have increased, whereas drought favours native plants that may be better adapted to the periodic drought conditions that characterize western North America. We are reminded of the importance of taking a more holistic approach to managing these ecosystems rather than simply treating individual weed species.

While we anticipate that some ecosystems will recover through passive re-establishment of native plants, in other highly altered or dry upland sites active restoration will probably be important following biocontrol of tamarisk. To this end, Ken Lair (US Bureau of Reclamation) and co-operators have been conducting studies in Arizona, New Mexico and Texas on how to restore large areas where mesquite or salt-bush (*Atriplex* spp.) are more appropriate replacement vegetation types than the typical cottonwood/willow woodlands of more mesic sites. Herbicides and some mechanical methods are used to simulate herbivory, with follow-up soil and seeding or replanting treatments, including use of mycorrhizal organisms to promote establishment. In some cases biocontrol is anticipated to provide control of saltcedar resprouts following traditional control methods.

At another level, a major effort to develop hyperspectral remote sensing of saltcedar abundance and *Diorhabda* impact has been pursued by USDA-ARS scientists Raymond Carruthers and Ernest Delfosse. Such technologies will likely provide a valuable tool for documenting biocontrol effects in the future, but for the present the beetles are flying ahead of the technology. On the other hand, at this stage it is not yet certain that *Tamarix* biocontrol will yield fundamental improvements in riparian biodiversity and ecosystem functions although preliminary results are tantalizing.

Possibly of greater interest to resource managers is a reduction in groundwater loss to evapo-transpiration following biocontrol, since this is the primary concern driving saltcedar control programmes in the arid West and elsewhere in the world. Robert Pattison has been carrying out studies of water use at the northern Nevada site by attaching devices that measure the flow of water through branches (and thus out of foliar stomata). He has found that over the course of a season, a reduction in water use of roughly 75% is seen during the first year, with greater reductions in subsequent years. This seems to be attendant with a slight local rise in the depth to the water table, and we anticipate more significant groundwater responses as impacts by herbivores increase over time.

Also very interesting in light of concerns by wildlife managers that saltcedar biocontrol will remove a low-quality, but beneficial, wildlife habitat feature, at sites where beetles have established we instead see a substantial increase in the use of this habitat by many wildlife species, especially small mammals and migratory birds, and even bats according to US Bureau of Reclamation wildlife specialists. Faecal samples are packed full of beetle parts, and the beetles are avidly sought out by numerous insectivores, including dragonflies which are often our indicator from a distance that beetles have colonized a locale. If impacts by agents cause gradual host dieback rather than rapid eradication, this means that wildlife can benefit greatly from the biocontrol programme while replacement (hopefully native) vegetation gradually re-establishes at a site to yield a more sustainable form of ecosystem recovery.

In particular, we anticipate that wildlife protection agencies will develop a more sophisticated attitude toward the use of biological control to manage invasive species in wildland ecosystems if we can illustrate the complexity of the control and recovery process. To this end, studies are being initiated by Bill Longland (USDA-ARS, Reno), Murrelet Halterman (University of Nevada, Reno) and Robert Pattison to use behavioural observations and stable isotopes to evaluate the importance of the biocontrol agents in vertebrate diets and habitat utilization. This work is being supported through USDA Invasive Species Council representative Hilda Diaz-Soltero, and should provide the field data to bring about a new perspective within wildlife agencies regarding the potential biodiversity benefits of biocontrol.

One concern that we believe is finally being put to rest is the potential for nontarget impacts to the native *Frankenia* spp. Rigorous host range tests in cages such as those carried out by Lindsay Milbraeth, Phil Lewis, John Herr, Ray Carruthers and other USDA-ARS researchers in Texas and California routinely showed moderate feeding and development by *Diorhabda* on this genus, particularly the native salt marsh inhabitant, *F. salina*. However, in parallel tests with Dave Kazmer, in which *Frankenia* was transplanted into research sites where beetles would be abundant and very hungry after defoliating adjacent saltcedars, we have found little or no feeding and no oviposition at all under open field conditions in Nevada and Wyoming; Debra Eberts showed the same non-utilization of the shrub *F. palmeri* in Colorado. It is clear that as ecological realism is increased, anomalous behaviours such as feeding on atypical plants decline and our confidence in the safety of saltcedar biocontrol is enhanced.

On the other hand, implementation in the borderlands with Mexico is sensitive because athel (*T. aphylla*) is considered a moderately valuable shade tree in the region. Host range studies continue in Texas to better evaluate potential impacts to this evergreen tamarisk, which was formerly considered not to reproduce sexually in North America (although it is an invasive pest in Australia). Now that it has been determined to be germinating and invading in the Colorado River system, we may need to again re-evaluate its status within the context of the control programme.

Where To From Here?

Despite the temptation to call the saltcedar biocontrol programme a success, many obstacles to widespread implementation of the programme still exist. As noted above, more releases to date have failed or remain inconclusive than have led to substantial establishment and control. Needing to comply with US Fish & Wildlife Service limitations on where research is allowed, it has not been possible to evaluate field performance of agents in some of the most highly infested ecosystems, particularly in the southern deserts from California to New Mexico. Meanwhile, in light of a request by USDA-APHIS to implement releases of the Chinese *Diorhabda* biotype north of 38°N in 18 western states, we simply do not have adequate information on which biotypes are most suited to the geographic areas and target *Tamarix* genotypes across the whole region. Thus, researchers are stuck in the middle of the competing demands of two federal regulatory agencies.

Furthermore, the need to complete testing with *Diorhabda* has put other candidate agents on the back burner, and factors like predation, poor host matching or inundation of some sites may make it necessary to explore other options. Some efforts do continue at reduced pace to develop other insects, such as the previously-approved mealybug, *Trabutina mannipara*, from the Dead Sea area, the foliage-feeding European weevil, *Coniatus tamarisci*, stem-galling midges of the genus *Psectrosema*, and another chrysomelid, *Cryptocephalus sinaita*, which builds a caddis-like case that may help reduce ant predation. Several other potential agents exist, as reported earlier by DeLoach, but first it seems critical to illustrate to wildlife agencies that biocontrol will help, not hinder, conservation of these sensitive ecosystems that have been so degraded by invasion of weeds like saltcedar.

I thank the many people mentioned in this note, and many others, because this programme has truly been a multi-headed operation that would not have occurred without their great commitment and cooperation. Senator Harry Reid of Nevada has also been critical owing to his sustained efforts to provide adequate funding for saltcedar control research. Also, we sadly note that two of our favorite colleagues, Scott Stenquist and John Taylor of the US Fish & Wildlife Service, have passed along, but not without truly important contributions to the efforts to eliminate saltcedar and restore riparian areas of the American West.

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Saving Coconuts with Classical Biological Control

The spread of a serious invasive coconut pest, the leaf beetle *Brontispa longissima*, is being tackled through classical biological control in Technical Cooperation Projects led by FAO-RAP (UN Food and Agriculture Organization – Regional Office for Asia and the Pacific. The history of the pest and its biological control in Southeast Asia and the Pacific, dating back to the 1930s, was described in the December 2004 issue of *BNI* [**25**(4), 84N, Coconut community highlights hispine beetle pest].

The beetle has invaded coconut plantations in the Maldives, Nauru, Thailand, Viet Nam, the Lao's People's Democratic Republic, Myanmar and China, causing massive losses to local coconut industries. Coconut palms provide many basic products ranging from fresh drink, food, oil, fibre, oleochemicals and household utensils to timber and building materials. Coconut is also, in tourist areas, an emblematic amenity tree. Coconuts therefore play an important role in the environment and in the health, food security and livelihoods of many people in the region.

In the Maldives, economic losses caused by the pest are significant. There, coconut is not only an important local food crop, but is perhaps even more important for the tourism industry. Management in one resort island estimated losses between June 2000 and February 2003 at US$237,000 owing to a decline in tourism because of unhealthy palm trees and a shift in labour from productive activities to insecticide application. Losses in revenue from coconut sales and drinks were estimated at a further $33,000 for the same period.

A study commissioned by FAO found that in Viet Nam alone the beetle infestation, if left uncontrolled, would cause in excess of $1 billion in damage, seriously threatening the survival of the country's coconut industry. Assessments of the damage in the other affected countries indicate similar potential impacts.

The control of the pest has therefore become of international concern and is of highest priority to the governments of the countries in the region. In China, the pest has been elevated to the status of second most important forestry pest, even though only a few provinces have a sufficiently warm climate to allow the coconut to grow.

Government authorities in the region responded quickly to the incursion and launched control programmes involving the application of insecticides to the crown and stem of infested trees. In the Maldives and China, large numbers of seedlings and even mature trees were also removed and destroyed. However, the pest continued to spread and chemical control proved not only expensive and ineffective but also a serious health risk to farmers, families and consumers (coconut plantings are often situated near homes). Classical biological control was seen as the most promising long-term sustainable solution.

Through the FAO biological control projects, the eulophid larval parasitoid *Asecodes hispinarum* was collected in Samoa in 2003 and introduced, reared and released in Viet Nam, the Maldives and Nauru. The parasitoid is now established in all three countries, with promising prospects for achieving control of the beetle. Releases are also being made in Thailand and are planned for China (Hainan Island).

Results from southern Viet Nam, where *A. hispinarum* was released in August 2003, confirm the establishment of the parasitoid. Observations at and near release sites indicate that there have been significant reductions in beetle densities and damage to coconut palms; trees showed clear signs of recovery, returning to pre-infestation production levels. Surveys have shown that the dispersal rate of the parasitoid from the release sites is some 5–8 km in 2 months. A recent study on the costs and benefits shows a return of US$11 dollars for every dollar invested.

In the Maldives and Nauru, field establishment of the parasitoid was confirmed 2 and 5 months after initial field releases in February and November 2004, respectively.

Although experts believe that biological control is the best avenue to follow, most affected countries lack expertise in biological control in general and of this pest in particular. To build capacity in these countries in biological control of pests and increase public awareness on non-chemical, environment-friendly control methods, FAO is helping them develop IPM programmes that follow international standards set by FAO. This support has assisted the countries in identifying the coconut hispine beetle, collecting and importing natural enemies of the beetle from Samoa, rearing them in captivity for evaluation, and releasing them in the field.

Spreading Threat

As the *BNI* December 2004 article indicated, the threat goes well beyond the countries currently affected. Although widespread in areas of Indonesia, Malaysia, Papua New Guinea and a number of Pacific island countries, *B. longissima* is new to continental Southeast Asia where, in the absence of natural enemies, it is spreading rapidly and causing massive damage. It was detected for the first time in Viet Nam, the Maldives and China within the last 5 years, and is believed to have been imported with ornamental palm trees. With its foothold in Southeast Asia, the invasive pest also presents a potent threat to the plantation and smallholder coconut sectors of Bangladesh, India and Sri Lanka, putting at risk the livelihoods of a great number of people.

Creating awareness, together with building capacity and providing training to combat the imminent threat will give all these countries the best chance of minimizing the impact of *B. longissima* on their coconut industries.

Source: FAO news release, 7 April 2005. Saving coconuts in Southeast Asia and Pacific islands. Biological pest control enlists natural enemy to combat coconut beetle.
www.fao.or.th/Press_Releases/press_releases.htm

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See also: Forest invasive species network meets in Viet Nam, Conference reports, this issue.

Fungal Pathogens for Biocontrol of the Varroa Mite

The varroa mite, *Varroa destructor* (Acari, Mesostigmata), is an ectoparasite of the European honey bee, *Apis mellifera*. It is part of a species complex of mites that originated in Asia as a result of a host shift by *Varroa jacobsoni* from the eastern hive bee, *Apis cerana*, to European bees. Over recent decades bee importation and migratory beekeeping practices have served to rapidly spread *V. destructor* on *A. mellifera* so that it now has an almost global distribution. It entered Europe in the 1970s, the USA in 1987 and the UK in 1992. Varroa mites feed on the haemolymph of bee pupae and adults, and activate and transmit diseases which reduce the life expectancy of the bees and cause the colony to decline. Varroa mites are highly damaging to *A. mellifera* populations, and the loss of honey bee colonies has had a knock on effect on the pollination of wild plants and commercial crops. Beekeepers usually attempt to control varroa with chemical pesticides, but resistant mite populations are now established in many countries, including the UK. Therefore, sustainable methods of control are required urgently.

Ongoing collaborative research in the UK at Warwick University and Rothamsted Research, funded by the UK Department for Environment, Food and Rural Affairs, is investigating entomopathogenic fungi as biological control agents of varroa. This is a considerable challenge because, although biological control has been used very successfully against a range of other mite species, natural enemies were not considered to play an important role in regulating varroa mite populations in bee colonies[1]. This may have been because bee colonies are a physical barrier to the entry of natural enemies, or because they represent a hostile environment for any natural enemies that do make it inside. From all potential natural enemies, we identified entomopathogenic fungi as the best candidates for testing against varroa, because of their virulence to a wide range of mite species[2], and the potential to improve their efficacy in harsh environments using formulation and application technologies.

Isolates of fungi with reported activity against Acari were requested from culture collections around the world and their pathogenicity against varroa compared in novel laboratory bioassays. In a series of assays we found that many isolates of entomopathogenic fungi, from several species, were able to kill varroa even under temperature and humidity conditions similar to those that occur within bee colonies[3]. The impact of selected isolates against nontargets, including honey bees, was also evaluated in assays where the inoculum was applied directly to the bees or was fed to them in pollen. Although a range of effects was recorded, isolates which were active against varroa but had a low impact on bees were identified. Low humidity, which often limits the activity of entomopathogenic fungi, was found not to affect fungal infectivity to varroa in our assays. However, the high temperatures that occur in bee colonies are likely to have a negative effect on fungal efficacy. As a result, a mathematical model of fungal thermal biology was developed in order to identify isolates with favourable temperature characteristics, and to help us predict the effects of temperature on fungal activity in bee colonies[4]. Using all these data we have been able to identify a number of lead isolates to evaluate in more detail. In particular we are currently evaluating transfer of inoculum between bees and to mites to underpin application strategies, quantifying persistence of inoculum under colony conditions and developing molecular techniques to assess the fate of inoculum in the environment and in bee products. We will soon be starting experiments to evaluate the strategy at increasing spatial scales culminating in trials with mite infested nucleus bee colonies in flight rooms. These trials should demonstrate 'proof of concept' and pave the way for field scale evaluation.

The results that we have obtained so far are very encouraging and, while it is unlikely that a fungal control agent alone would provide a 'magic bullet' solution to varroa, it has great potential if used as part of an integrated management programme. Availability of a fungal agent that is able to safely reduce varroa populations below a damage threshold could make a valuable contribution to sustainable varroa management, especially given the onset of pesticide resistance.

[1]Chandler, D., Sunderland, K.D., Ball, B.V. & Davidson, G.D. (2001) Prospective biological control agents of *Varroa destructor* n. sp., an important pest of the European honeybee, *Apis mellifera. Biocontrol Science and Technology* 11, 429–448.

[2]Chandler, D., Davidson, G., Pell, J.K., Ball, B.V., Shaw, K.V. & Sunderland, K.D. (2000) Fungal biocontrol of Acari. *Biocontrol Science and Technology* 10, 357–384.

[3]Shaw, K.E., Davidson, G., Clark, S.J., Ball, B.V., Pell, J.K., Chandler, D. & Sunderland, K. (2002) Laboratory bioassays to assess the pathogenicity of Mitosporic fungi to *Varroa destructor* (sp. nov) (Acari: Mesostigmata), an ectoparasitic mite of the honeybee, *Apis mellifera* L. *Biological Control* 24, 266–76.

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Not to Mention Biopesticidal Activity...

More than 10 years' work and half a million dollars lie behind two new biopesticides recently registered by the US Environmental Protection Agency (EPA) for use against fungal pathogens that attack plant roots. The new products have applications against major fungal diseases that cause extensive damage to greenhouse, nursery, turf and agricultural crops. The successful commercial development and launch of the new products is evidence both for the huge cost of developing and registering a biopesticide, and that it can be done. It is worth noting that the new biopesticides have applications in high-value crops and the lucrative turf sector, which provide the necessary large markets to allow the costs to be recouped.

The biopesticides grew from University of Idaho researcher Don Crawford's study of the bacteria that colonize linseed plant roots. These bacteria produce chemical defences at the specific points where disease fungi attack, delivering microdoses of antibiotics to specific targets at specific times. Bacteria have excited interest as an alternative to chemical fungicides, which tend to have nontarget effects on other organisms. The strain *Streptomyces lydicus* WYEC108, which was developed into the new biopesticides, was isolated and patented by Crawford with graduate student Hyung-Won Suh in 1995. The strain caught their attention because it enhanced plant growth when added to soil and was active against a wide spectrum of economically damaging fungal diseases of plant roots.

Also key to the development of the biopesticides was investment and support from the Houston (Texas) based company, Natural Industries. Efforts by company founder Bill Kowalski, who died 3 years ago, to market the product began more than a decade ago. The business is now led by his son, company president Matt Kowalski. It is a long, hard journey from promising microbe to commercial biopesticide, and Crawford credits the Kowalskis for their support and perseverance in bringing the product to market.

Natural Industries markets Actinovate SP, the first commercial product, and shepherded the product through EPA registration, a 5-year effort. In January 2005, the company's early work produced a bonus. The granular formulation of *S. lydicus*, Actino-Iron, won EPA registration approval in January, months earlier than anticipated and just in time for spring. As a result, production has soared at the small Moscow (Idaho) spin-off company, Innovative Bio-Systems, which produces the bacteria commercially.

Financing the half-million dollar bill for the project was at times a nerve-wracking challenge. Nonetheless, everything was paid for on cash flow. Kowalski and Crawford's conviction that the bacteria could combat pathogenic fungi led to early seed and soil inoculants, based on tests that showed plants grew better with help from the bacterium. These were marketed as soil amendments, and generated sufficient sales not only to sustain the company, pay employees and satisfy investors, but also to pay for registration. This was testament to the early support for the product, even before EPA registration opened larger markets, for the company and its distributors could not talk about biopesticidal activity in relation to these products. Although the most promising future for the bacterium was in biopesticides, this relied on obtaining EPA registration. Products containing *S. lydicus* could be sold as soil amendments without registration—but their biopesticidal activity could not be alluded to without violating federal law.

Throughout it all Crawford's baby has become 'the little microbe that could', overcoming many obstacles that would have left an inferior of its kind to sit out eternity as a footnote in some big corporation's 'Failed Technology' file. In the coming years, the world of agriculture will be hearing much more about *Streptomyces lydicus* WYEC 108.

Adapted from: Loftus, B. (2005) Pesticide relies on bacterium to fight root-damaging fungi. University of Idaho news release. 3 March 2005.
Web: info.ag.uidaho.edu

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A New Biocontrol Agent for Mimosa in Australia

Mimosa (*Mimosa pigra*) or the giant sensitive plant forms impenetrable thickets over more than 800 km^2 of the Northern Territory of Australia, threatening the World Heritage listed Kakadu National Park and other tropical wetlands in Australia and Asia. It has also made an appearance in north Queensland. Such is the extent of the problem that mimosa is now one of Australia's 20 Weeds of National Significance.

A small moth has now joined the battle against this weed. In late 2004, the Australian Government gave approval for the release of the geometrid moth, *Leuciris fimbriaria,* from quarantine in Brisbane where it had been undergoing intensive testing. The larvae of this moth are looper caterpillars that feed on the leaves of mimosa. Testing showed that the caterpillars cannot feed or grow on any plant other than mimosa. This insect was first found feeding on mimosa in 1985 by a CSIRO entomologist working in Mexico. Because it was believed that exposed foliage feeders are poor agents because of their susceptibility to predators such as ants, it was low on the list of priorities until 2001 when the need for a foliage feeder became apparent.

Leuciris fimbriaria is an abundant and damaging defoliator of *M. pigra* in its native range of the American tropics. Free of its own natural enemies, it has the potential to be even more damaging in Australia. The adults are non-feeding, short-lived moths but the larvae feed on leaves of all ages. Because generation times are short and fecundity is high, released populations should increase rapidly.

CSIRO Entomology scientist Dr Tim Heard made the first releases near the Alligator River in the Northern Territory in December 2004. If populations of this insect build up, their feeding will reduce plant growth and seed production, making mimosa easier to manage or even knocking it back to the extent that it is no longer a problem.

Mimosa was introduced to Australia from tropical America in the late 1800s as a curiosity. People were fascinated by the fact that, when the leaves were touched, they folded up. But the plant escaped from the Royal Darwin Botanic Gardens and entered the Adelaide River system, east of Darwin in the Northern Territory. Now it blankets the wetlands, reduces biodiversity, competes with pastures and hinders access to water. It is also a serious conservation problem because of its ability to completely alter the landscape of the floodplain.

In its home range, which stretches from Mexico to northern Argentina, mimosa occurs in small patches of inconspicuous and straggly plants, but in Australia it grows to 6 metres tall and forms impenetrable thorny thickets. It spreads at an alarming rate. A large plant is able to produce up to 220,000 seeds annually and, after good rain, infestations can double in just over a year as the seeds are spread by floodwaters. These seeds can remain dormant in the ground for a number of years before conditions are right for germination. Seeds can also be spread by vehicles, machinery, stock and contaminated earth.

Eleven insect species and two fungal pathogen species have already been released in Australia over the last 22 years and are now having a noticeable impact on this recalcitrant weed. Four of these insects are well established and abundant. They are the twig and stem-mining moths, *Neurostrota gunniella* and *Carmenta mimosa*, the flower-feeding weevil, *Coelocephalapion pigrae*, and the seed-feeding beetle, *Acanthoscelides puniceus.* These agents have been specially chosen to attack different parts of the weed. Recent research has shown that *Carmenta mimosa* is having a major impact on seed production and seed banks, thereby indirectly enhancing the survival of competing vegetation. The introduction of complimentary agents, particularly leaf feeders such as *L. fimbriaria,* should boost the already significant effect of *C. mimosa.*

The CSIRO scientists will continue to collaborate with the Weed Management Branch of the Northern Territory's Department of Infrastructure Planning and Environment, which will begin a mass rearing, release and evaluation programme for the moth in the Northern Territory. The research was funded by The Australian Government's Natural Heritage Trust through their Weeds of National Significance programme.

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Bud-Gall Fly Released for Biocontrol of Melaleuca in Florida

A bud-gall fly recently released as a biological control agent against the Australian melaleuca tree, *Melaleuca quinquenervia,* is the third insect species to be released as part of an areawide melaleuca management programme in south Florida (USA) [also see: Melapaleuza 2005, Training News, this issue]. An obligate mutualistic relationship between the bud-gall fly and a nematode makes this release a milestone in biological control; this is the first mutualism approved for release as a natural enemy pair in the USA.

Since its introduction into south Florida in the late 1800s, melaleuca has invaded more than 200,000 ha (*ca.* 7.8 ha/day over the past century) of wetlands comprising the Florida Everglades. Efforts to implement classical biological control of the tree began in 1986. The arthropod community associated with melaleuca in eastern Australia was surveyed, resulting in the identification of >450 herbivorous species. Of these, the melaleuca weevil (*Oxyops vitiosa*) and the melaleuca psyllid (*Boreioglycapsis melaleucae*) were two taxa considered to be top candidates for release as biological control agents. Following intensive host-specificity tests in quarantine, *O. vitiosa* and *B. melaleucae* were approved for release in south Florida in 1997 and 2002, respectively. Both insects have since become widely distributed in melaleuca stands throughout south Florida. Laboratory and field studies have indicated that damage caused by the feeding of each insect can inhibit both growth and reproductive capabilities of the plant.

A third biological control candidate, the melaleuca bud-gall fly (*Fergusonina turneri*), has also cleared quarantine-based host-specificity testing. This fly deposits its eggs, along with a nematode symbiont (*Fergusobia quinquenerviae*) in the interior of young melaleuca buds via an elongated ovipositor. The nematode appears to cause a proliferation of cell growth to occur within the bud. The resulting gall prohibits normal growth of leaf or flower tissues from the bud and provides the necessary food source for developing nematodes and fly larvae. Nematodes re-invade the ovaries of female flies during the fly's pupal stage, and adult flies emerge through 'windows' which appear on the gall surface during fly pupation.

The US Department of Agriculture - Animal and Plant Health Inspection Service (USDA-APHIS) has issued a permit for the release of *F. turneri* (+ *F. quinquenerviae*), and releases have now been made at six sites in south Florida. At each site, one of three release methods was used:

1. Adult flies released. Adult female and male flies were transported together in a nylon mesh-covered Petri dish. The cover was removed in the vicinity of melaleuca plants having ample bud growth. Releases of 75–90 adult females and 50–65 adult males have been made at each of two sites (Hendry County [Co.] and Lee Co.).

2. Plants with galls placed in field. Melaleuca plants exhibiting new bud growth were exposed to flies in the glasshouse. Once windows appeared, plants with numerous galls were selected and transported to each of two field sites. Plants with a total of 50–60 galls were released at each of two sites (Dade Co. and Collier Co.).

3. Adult flies caged on melaleuca plants in field. Melaleuca plant branches with new bud growth were selected at each of two field sites. Nylon mesh sleeve cages were affixed to each branch. Adult female and male flies were again transported in a nylon mesh-covered Petri dish. A total of 49 female and 26 male flies were aspirated into 16 cages at one site (Broward Co.), and 57 female and 20 male flies were aspirated into 18 cages at a second site (West Palm Beach Co.). Cages were removed once all adult flies were observed dead in each cage.

Monitoring and analysis of *F. turneri* emergence, establishment, dispersal, and within-plant distribution are scheduled in the upcoming months. Complimentary laboratory studies are also planned to investigate the impacts of *F. turneri* infestation on melaleuca plant physiological processes, factors influencing host plant choice by *F. turneri*, and aspects associated with competition between *F. turneri* and *O. vitiosa*, *B. melaleucae* and the rust fungus, *Puccinia psidii.*

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Halting the Ascent of Climbing Fern

The first biological agent to be introduced to the USA against Old World climbing fern (*Lygodium microphyllum*) was released in Florida on 14 February 2005. An aggressive invasive weed in natural wetland habitats in southern and central Florida, climbing fern is a prime candidate for biological control because it grows among other plants in complex natural vegetation that would be damaged by most control methods. The fern continues to spread and increase in abundance and is considered by many experts to be the most dangerous invasive weed in Florida.

Old World climbing fern has been the subject of a biological control initiative of USDA-ARS (US Department of Agriculture – Agricultural Research

Service) Invasive Plant Research Laboratory since 1997. The early stages of the project were described in *BNI* in 2002 [*BNI* **23**(3), 67N–68N, Getting on top of climbing fern]. Although climbing fern has a large native range (occurring in much of the Old World tropics) and surveys were conducted in many parts of the world, they focused on Australia and Southeast Asia because these regions have the highest diversity of *Lygodium* species, which correlates with a higher arthropod herbivore richness.

In all, two mite and 20 insect species were found feeding on a number of *Lygodium* species. Of these, some six to eight may have potential as biocontrol agents of *L. microphyllum*. The majority of the *Lygodium* herbivores found were Lepidoptera (moths), while Coleoptera (beetles) and Hemiptera were under-represented. Given the amount of survey work, the number of species found was small – including in parts of its home range in Africa and, more predictably, New Zealand and the New World – and they generally occurred at low densities. Nonetheless, if introduced, species may build up higher densities in south Florida in the absence of their own natural enemies. The paucity of herbivores is not specific to Old World climbing fern, but has been noted for ferns in other biological control programmes. Indeed, ferns were once thought to be almost free of insect herbivores. Nonetheless, 8 years of surveys has revealed a number of potentially useful agents, although few diseases were encountered.

Two pyraloid moths and an eriophyoid mite, all from the fern's Australian/Asian range, were prioritized for further study. They have since undergone extensive evaluation and host-specificity testing. One moth has received approval for release in the USA and applications for permission to release the other two agents are on-going. Host-specificity testing was conducted in the USDA-ARS Australian Biological Control Laboratory in Brisbane, Queensland (a cooperative laboratory with CSIRO in Australia) and in the Florida Division of Plant Industry Quarantine in Gainesville, where part of Invasive Plant Research Laboratory is located (in cooperative work with the University of Florida).

The Australian species *Austromusotima camptonozale* (formerly *Cataclysta camptonozale*) is one of a complex of pyraloid moths that has evolved with *Lygodium* ferns. The larvae eat the leaves of the plant and can at high densities completely defoliate the fern. The moth can have a generation every month during the summer and every 2–3 months in the winter depending on temperature. Host-specificity testing in Australia and Florida showed it to be a very narrow specialist, able to use only a few *Lygodium* ferns. It is a tropical insect unable to survive in the temperate part of eastern North America where the only native *Lygodium* (*L. palmatum)* grows. It was also unable to use any of the four *Lygodium* species native to the Caribbean. A petition for its release was submitted to USDA-APHIS (Animal and Plant Health Inspection Service) in February 2003. A release permit was granted in August 2004 and first releases have been made. Florida Department of Environmental Protection is providing funding for mass rearing and release.

The eriophyid gall mite *Floracarus perrepare* is native to Australia and tropical Asia. Adult feeding on new leaves causes the leaf margin to roll and thicken, forming a leaf roll gall into which eggs are laid and a colony of the mites develops. Galls can be physiological sinks which can cause photosynthate to go to the gall instead of new growth. Controlled potted plant studies in Australia showed that mite infestation reduced climbing fern growth. Host-specificity testing in Australia showed the mite to be a narrow specialist with host races (subgroups that have narrower host ranges than the species as a whole) limited to two *Lygodium* ferns including *L. microphyllum*. A release petition was submitted in February 2004, and the federal interagency scientific review body, the Technical Advisory Group for Biological Control of Weeds, recommended in November 2004 that its release be approved. A USDA-APHIS Environmental Assessment is in preparation, with a release date by the end of 2005 a possibility.

The second pyraloid moth, *Neomusotima conspurcatalis*, is native to tropical Asia east to northern Australia. The damage, biology and host specificity are all similar to those of *A. camptonozale*. A release petition is expected to be submitted in spring 2005.

What Next?

With the completion of the research necessary to apply for the above natural enemies to be released in Florida, attention is focusing on other agents that could be added to the portfolio. Three of these are now under investigation in quarantine in Australia or Florida.

Of considerable interest are what are probably two species of pyralid moths which bore into the stems of *Lygodium*. One, *Siamusotima aranea*, attacks *L. flexuosum* in Thailand and the other, an apparently undescribed species from Singapore, attacks *L. microphyllum*. The stem above the boring larvae is killed because the vascular tissue is cut. However, rearing these moths in quarantine is proving a challenge and attempts to do so in both Australia and Florida have so far been unsuccessful. Larval development takes many months and the larvae seem to require larger stem diameters than can be easily obtained with potted plants. There are also questions about host races and taxonomy. These moths are the highest priority for research for the overseas part of the programme.

A sawfly, *Neostrombocerus albicomus*, native to Thailand, is another leaf feeder which has just arrived in Florida quarantine. This insect is larger than the moths and can eat a larger amount of leaf during its development. If the sawfly is eventually released in Florida, it may be escape attack by parasitoids because there are relatively few sawflies in Florida to generate sawfly parasitoids.

Other insect natural enemies found include a thrips, *Octothrips lygodii*, which damages the leaves. The thrips is probably a specialist but opinions on the value of thrips as potential biological control agents vary. A brown leaf disease found in Sri Lanka needs to be identified and evaluated. If it proves to belong to a taxonomic group with specialist diseases, it should also be evaluated as a potential agent.

With the search for further natural enemies continuing, future surveys will focus on Sumatra in Indonesia, and the Malayan Peninsula including Singapore. Additional surveys in India are also being considered.

Outlook

It is expected that *A. camptonozale* will establish in Florida. How much impact it has on *L. microphyllum* depends largely on the mortality that it experiences, particularly from ants and parasitic wasps that may move onto it from related pyraloid moths. It is not expected to be a 'silver bullet', however, and a complex of agents will be needed to subdue *L. microphyllum*. The mite *F. perrepare* may be in the field by the end of 2005, and the second moth, *Neomusotima conspurcatalis*, may follow in 2006. It is not possible to predict what impact they will have but the combined effects of these agents acting in somewhat different ways may help reduce the abundance of the weed. As noted, other potential agents are in the pipeline. The stem-boring moths may hold the most promise if they can be successfully reared and evaluated.

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Latest Word on Corn Rootworm

Two recent publications on the western corn rootworm, *Diabrotica virgifera* ssp. *virgifera* (WCR) make significant contributions to the understanding of this chrysomelid beetle, a serious pest in both North America and Europe, and may ultimately help the search for a sustainable control strategy. One is discussed below, the other, 'Rootworm directory', is reviewed in the 'New books' section of this issue.

Native to South and Central America, WCR reached the 'corn belt' of the American Midwest in the early years of the twentieth century. Together with the native species *D. barberi* (northern corn rootworm), it is now the most important pest of maize in the USA and Canada. It causes yield losses and chemical control costs of up to one billion US dollars annually. Granular soil insecticides such as terbufos or isofenphos can be applied at planting, but routine application has led to the emergence of insecticide resistance. An alternative strategy, a 2-year maize/soyabean rotation has been overcome in some cases by both species; *D. barberi* has been found to lay eggs with an extended diapause, and WCR adults to feed and lay eggs in soyabean fields, which hatch in maize the following season. These findings point to the importance of finding additional control strategies.

In the early 1990s WCR was accidentally introduced from the USA to southeastern Europe. The beetle was first found in 1992 in Serbia, close to the Belgrade international airport, although it had probably been in the country since at least the mid 1980s. Fears that it would become a serious invasive pest proved well founded. It has since spread through the continent and now infests more than 310,000 km^2. It has been reported from most countries south of Scandinavia, with the worst economic damage inflicted in Central and Eastern Europe. It is anticipated that the pest will eventually invade all maize-producing countries in Eurasia. Management of WCR impact and spread has therefore become a priority in Europe.

Nematodes Scent Diabrotica Damage

A recent article in *Nature*[1] describes a phenomenon that not only offers promise for a new control strategy for WCR, but is also a scientific 'first'. The authors report the first identification of an insect-induced below-ground plant signal. Produced by maize roots in response to feeding by WCR, the sesquiterpene (E)-β-caryophyllene was shown to strongly attract entomopathogenic nematodes (*Heterorhabditis megidis*).

While plant leaves often emit volatile chemicals in response to arthropod attack, which then attract arthropod natural enemies, this is the first time the mechanism has been demonstrated in plant roots. The attractivity of WCR-attacked maize roots to the nematodes, together with the identity of the volatile component responsible, was first demonstrated in olfactometer experiments. (E)-β-caryophyllene was also shown to have the ability to diffuse rapidly through moist sand, and thus to be an effective below-ground signal.

Field experiments in Hungary (where WCR is an established pest) corroborated the laboratory results. Nematodes infected many more WCR larvae near a variety that produced (E)-β-caryophyllene than near a 'non-producing' variety. In addition, the number of adult beetles emerging near non-producing plants that had been spiked with the sesquiterpene was less than half that for plants of the same variety that had no (E)-β-caryophyllene added, suggesting that the mechanism has potential for exploitation in a control strategy.

The authors went on to demonstrate how different maize varieties differ in their ability to produce (E)-β-caryophyllene, and found that this has implications for the role nematodes currently play in WCR ecology in North America and Europe. They found that most varieties used in North America no longer emit the compound. In contrast, European lines, together with the wild maize ancestor teosinte (*Zea mays* ssp. *parviglumis*) emit varying but significant amounts of (E)-β-caryophyllene. The authors conclude that the ability to produce this compound has been lost during breeding in North America but retained, serendipitously, in Europe. This is the first time the loss of an indirect plant defence signal through breeding has been demonstrated.

The results reported in the paper may explain why attempts to control WCR with nematodes in North America have met with mixed success. The inference is that planting varieties that do emit the chemical signal would attract larger populations of nematodes and thus contribute to natural control of WCR there. And focusing breeding activities on this trait could lead to varieties with greater functional resistance to WCR through their ability to attract its nematode natural enemies.

The study was a collaborative effort between researchers at the University of Neuchâtel, Switzerland, CABI Bioscience, Delémont, Switzerland and The Max-Planck Institute for Chemical Ecology, Jena, Germany. Principal funding was provided by the Swiss National Centre of Competence in Research 'Plant Survival'.

[1]Rasmann, S., Kölner, T.G., Degenhardt, J., Hiltpold, I., Toepfer, S., Kuhlmann, U., Gershenzon, J. & Turling, T.C.J. (2005) Recruitment of entomopathogenic nematodes by insect-damaged maize roots. *Nature* 434, 732–737.

US Building Capacity

Out of necessity, biological control scientists are generally very good at working in the most basic of conditions and with improvised equipment. Nonetheless, most opt for better facilities when they are available. Recognizing that international trade and travel have dramatically increased the risk of invasive pest introductions, and the threat that these pose to US agriculture and the environment, US and state governments have been investing in providing state-of-the-art facilities for work on invasive species and their biological control.

Delta Biocontrol Lab Takes Wing

The new USDA-ARS (US Department of Agriculture – Agricultural Research Service) National Biological Control Laboratory (NBCL) in Stoneville, Mississippi was officially dedicated on 31 March 2005. Opened in late 2004, the NBCL is part of the USDA-ARS Jamie Whitten Delta States Research Station. It will initially focus on the problems of the Mississippi Delta area, but in the long-term the technologies developed may be deployed on a national scale.

The building has been designed for fully integrated research in biological control, with separate compartmented wings for macrobial (insect) and microbial work. The Insect Wing includes offices, research laboratories, multi-species rearing facilities and a pilot plant area for commercial development. The Microbial Wing also includes offices and research laboratories, as well as mass-culturing facilities, growth rooms and harvesting areas, and a second pilot plant area.

Florida Contains Invasive Plant Research

Florida's tropical environment has made it an unwelcome host to a significant number of invasive weeds from various parts of the world. Support for biological control initiatives against them from a wide spectrum of government agencies has allowed new research facilities to be opened over the last 2 years. These complement the existing containment facilities in Gainesville by providing extra quarantine space and are greatly expanding opportunities for conducting classical biological control research and implementation in Florida.

The latest quarantine facility, the USDA-ARS Invasive Plant Research Laboratory (IPRL) in Davie, was opened on 8 April 2005. Built by the Army Corps of Engineers with US Department of the Interior (USDI) funding, and additional funding provided by the South Florida Water Management District, the new quarantine facility is located at the University of Florida's Fort Lauderdale Research and Education Center. It complements the IPRL in Gainesville (at the Florida Division of Plant Industry Quarantine Laboratory), where domestic quarantine studies have been done to date; scientists will now be able to use both quarantine facilities.

This followed the opening of the University of Florida's Institute of Food and Agricultural Sciences (IFAS) state-funded, purpose-built Biological Control Research & Containment Laboratory (BCRCL) in Fort Pierce, which began operations last year [see: *BNI* **25**(3), 54N-55N, (September 2004), New Florida home for biocontrol].

Some funding for biological control research comes from federal sources, for example USDA-ARS facilities and programmes, and USDI through the Everglades National Park; some comes from state and county sources through agencies such as the South Florida Water Management District, the Southwest Florida Water Management District, and the Florida Department of Environmental Protection, which provide essential support to specific projects. Project funds are also provided by Miami-Dade County Department of Environmental Resource Management. Hence a spectrum of government agencies supports biological control research in Florida. This wide funding base facilitates projects against some key target weeds. Two covered elsewhere in this issue are melaleuca – *Melaleuca quinquenervia* (see: Bud-gall fly released for biocontrol of *Melaleuca* in Florida & Melapaleuza 2005, General News & Training News, respectively, this issue) and Old World climbing fern – *Lygodium microphyllum* (see: Halting the ascent of climbing fern, General News, this issue), three more will be familiar to regular readers (giant salvinia – *Salvinia molesta*, water hyacinth – *Eichhornia crassipes* and air potato – *Dioscorea bulbifera*) while others we have yet to feature (e.g. pepper tree – *Schinus terebinthifolius,* skunk vine – *Paederia foetida*, and two insect pests of Everglades plants, the lobate lac scale – *Paratachardina* lobata and the Mexican bromeliad weevil – *Metamasius callizona*).

IPM Systems

This section covers integrated pest management (IPM) including biological control, and techniques that are compatible with the use of biological control or minimize negative impact on natural enemies.

IPM of Lettuce Aphid in Tasmania

A rapid response to a new lettuce pest in the Australian island state of Tasmania has not only demonstrated that this threat to the industry can be contained, but also highlighted how IPM can provide a viable alternative to insecticide drenching, with its associated nontarget effects, which has implications for control of the complex of other pests of lettuce.

Lettuce aphid (*Nasonovia ribis-nigri*) is a relatively recent introduction into Australia, and has probably arrived from New Zealand either by wind currents (likely) or on plant material (less likely). It is currently only known from Tasmania. The initial reaction from growers and their advisors was to apply a heavy regime of insecticides, and to follow the New Zealand example of drenching with a very high rate of Confidor (imidacloprid) – 55 ml/1000 seedlings in nursery trays. Confidor is also used to control other sucking insects (including other species of aphids) but at a much lower rate, which does not have such devastating effects on predators

The use of IPM to control lettuce aphid was given lip-service but the generally accepted recommendation was to drench seedlings with this high dose of insecticide. The fact that such drenching would kill key predators of aphids did not seem to be welcome information when lettuce aphid arrived in the country in early 2004. IPM Technologies Pty Ltd was alone in suggesting that a true IPM strategy could be a better option.

A trial to demonstrate IPM and to assess an IPM approach to dealing with lettuce aphid was set up in Devonport, Tasmania, where the pest is well established. Tasmanian government entomologist Lionel Hill (DPIWE – Department of Primary Industries, Water and Environment) has been working with IPM Technologies Pty Ltd (Dr Paul Horne and Jessica Page) to set up a trial to both demonstrate IPM and assess the value in terms of lettuce aphid control.

Nine plantings of lettuce (0.1 ha per planting) at 2-week intervals will be planted and so far eight plantings have been planted and harvested. The trial is being carried out at Forthside farm (DPIWE Research Farm) so that all available options concerning control can be assessed.

A combination of susceptible and resistant varieties has been planted. All inputs (fungicides and insecticides) have been decided upon in terms of their impact on beneficial species as well as effects on pests and diseases and cost. That is, an IPM approach is being implemented and evaluated. Recommendations on what to do have been made fortnightly by IPM Technologies Pty Ltd. Lionel Hill and his team have carried out all control measures and monitored all relevant insect numbers and assessed the level of control of all pests.

Three field days (at 2-week intervals) have been conducted, and attended by growers and agronomists and entomologists.

- *Field Day 1* found high levels of lettuce aphid and high levels of ladybird and lacewing (adults). The expectation from experienced Tasmanian agronomists and growers was that this level of lettuce aphid would result in unacceptable contamination at harvest.
- *Field Day 2* found much lower levels of aphid and much higher levels of brown lacewing and other beneficials. The growers and agronomists that had attended the first field day were very surprised at the high degree of control of lettuce aphid that had been achieved but still expected problems at harvest. They were particularly interested in the *decrease* in lettuce aphid numbers per lettuce rather than the level of control. They still expected rejection despite the trend we could see.
- *Field Day 3 (Harvest)* was extremely interesting. Growers were invited to assess the level of lettuce aphid by destructive sampling and to offer advice as to whether or not the crop grown at Forthside without insecticide would meet, or not meet, their own commercial standards for insect contamination. Significantly, all growers present assessed the crop as meeting their standards.

Equally, significantly, all plantings have been harvested commercially and sold without any rejections for lettuce aphid.

This trial has achieved two of its primary aims. Growers and agronomists in Tasmania now accept and agree that drenching with Confidor is not necessarily the only option to control lettuce aphid. The level of control achieved in susceptible varieties of lettuce, without insecticide, has been equal to that currently achieved by Confidor drenches. The demonstration has shown that IPM is a viable alternative to routine pesticide applications. Growers and agronomists attending the trial now agree that they have a better alternative to a totally insecticide-based option and can understand how control of other pests fits within an overall strategy.

At this stage we can say that an IPM approach has worked and is at least equal to industry standards. We still need to prove that an IPM approach can deliver results throughout the growing season and this work is underway. Currently seven of nine plantings have been harvested and sold without lettuce aphid problems.

In commercial crops using Confidor drenches (in both Tasmania and Victoria) we have seen massively reduced numbers of predators (lacewings and ladybirds) and increased levels of pests (*Helicoverpa* (*Heliothis*) caterpillars). There have also been plantings that have had to be destroyed because of lettuce aphid. It does not matter whether it was inappropriate irrigation or drenching procedure that caused the problem, the end result is that reliance on insecticides alone has led to failure. Reliance on true IPM has led to control. We expect massively increased problems with western flower thrips (*Frankliniella occidentalis*) where Confidor is used, because of non-target effects on predators.

The trials in Tasmania so far demonstrate hope that a commercially viable alternative to drenches with high rates of Confidor is probable if IPM is adopted. The positive reaction of growers and agronomists present was the most encouraging aspect of the trial so far. All growers attending the trial agreed that the crop would pass their specifications for insect control.

This trial has demonstrated how effective true IPM can be in controlling pests. To us in IPM Technologies Pty Ltd the term IPM is very much abused, and is used by people to describe things such as pest monitoring, resistance management strategies, and very rarely integrating biological, cultural and chemical options for all pests in a compatible way.

Funding support for this work was provided by AusVeg, Horticulture Australia Ltd and IPM Technologies Pty Ltd.

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Training News

In this section we welcome all your experiences in working directly with the end-users of arthropod and microbial biocontrol agents or in educational activities on natural enemies aimed at students, farmers, extension staff or policymakers.

Melapaleuza 2005

TAME Melaleuca (The Areawide Management and Evaluation of Melaleuca) just wrapped up Melapaleuza 2005, a series of educational events showcasing management options for the notorious Everglades-invading tree *Melaleuca quinquenervia* (melaleuca).

TAME is a 5-year demonstration and research project to promote areawide, integrated management of melaleuca based on biological control. The project, managed and funded by the US Department of Agriculture – Agricultural Research Service (USDA-ARS), is a partnership between USDA-ARS, the South Florida Water Management District and the University of Florida's Institute of Food and Agriculture Services.

One of the primary objectives of the TAME Melaleuca project is to take the most current information on effective melaleuca management strategies and present it to property owners and land managers. Several aspects of the invasive tree's biology, such as its large size, prolific seed production, rapid growth and vegetative regrowth, make multiple treatments necessary for long-term suppression. TAME therefore encourages an integrated approach based on biological control but also including chemical and mechanical controls when financially and logistically feasible.

Much progress has been made in the last two decades in refining chemical, mechanical and physical techniques for killing melaleuca, and in developing effective management strategies based on those techniques. Implementation of these strategies on publicly managed lands has significantly reduced melaleuca infestations in these areas to the point where maintenance control is now practised. However, infestations in remote and sensitive areas remain a challenge to contain. In addition, infestations on privately held properties, where funding and motivation for melaleuca removal may be limited, continue to expand at a pace comparable to that of removal on public lands. Biological control was recognized early on as an important long-term management tool for melaleuca because of its potential both to contain the spread of the weed tree in areas where, for logistical or financial reasons, it was not being managed, and to prevent re-invasion of areas already treated.

The search for potential melaleuca biological control agents began in the mid 1980s by USDA-ARS. The project, based at the Australian Biological Control Laboratory in Brisbane, Queensland and the Invasive Plant Research Laboratory in Fort Lauderdale, Florida, has successfully introduced two bioagents. The melaleuca snout weevil *Oxyops vitiosa* was introduced in 1997 [See: *BNI* **21**(2), 'Florida Stripper' June 2000] and the melaleuca psyllid *Boreioglycaspis melaleucae* was introduced in 2002. Both agents are well established and widespread throughout melaleuca-infested regions of south Florida. Both are leaf feeders and primarily attack newly expanding foliage, resulting in reduced flowering and seed production, defoliation, stunted growth, and in some cases death of small seedlings.

The outreach component of the TAME Melaleuca project centres around five treatment demonstration sites located in as many south Florida counties. Project demonstration sites range in size from 3 ha to more than 40 ha and represent a variety of ownerships, habitats and melaleuca infestation levels. Biological, chemical and mechanical controls were applied alone and in different combinations at each site. Chemical treatments used include foliar herbicide applications by helicopter and herbicide application by hand to cut stumps left after felling trees and to girdle wounds on standing trees. Three types of heavy machinery demonstrated mechanical options for felling, grinding and chipping trees. And weevils and psyllids were released to demonstrate their impacts on standing trees as well as on regrowth and seedling recruitment that often follows mechanical and chemical treatments.

Melapaleuza 2005 consisted of a series of educational workshops conducted at the TAME project demonstration sites. Two types of workshops were developed, one for professional land managers and one for homeowners and other interested members of the public. Professional workshops lasted all day and offered continuing education credits for certified pesticide applicators, arborists and horticulturalists. The morning session consisted of classroom presentations on the impacts of melaleuca and management options. The afternoon session was a guided walking tour of treatment plots at one of the demonstration sites where participants could see for themselves the results of various control tactics. While the classroom sessions provided a formal educational experience, the field portion of the day allowed for greater interaction between and among attendees and presenters, often resulting in lively and mutually edifying discussions.

Workshops for the public were truncated versions of the professional format, lasting 3–4 hours but still consisting of a classroom session followed by a field tour of treatment plots. Classroom presentations were tailored to the interests and knowledge level of homeowners, with more explanation of what invasive plants are, why melaleuca is a problem and what private citizens can do to help. Field tours were limited to herbicide and mechanical treatments appropriate for homeowners and biological control treatments. Participants were also encouraged to collect insects from the field site if they wished.

Melapaleuza 2005 ran from February to April, during which TAME hosted at least one workshop at each of its five demonstration sites, for a total of four professional and three public workshops. Attending the professional events were arborists, landscapers and horticulturalists, and land and resource managers responsible for vegetation control on over half a million hectares of the state's natural areas. Seventy private citizens from three counties attended the events for the public. Many of these were environmental educators and active members of their communities who will pass the information they learned on to others. Of all Melapaleuza participants surveyed, 83% said they were already using or were interested in using biological control for melaleuca and 32% signed up to have biological control releases made on their property or property they manage. Fifty-three participants requested a free copy of TAME's 18-minute informational video on melaleuca, management options and the TAME project.

Melapaleuza will be repeated in 2006 so participants can see the effects of demonstration treatments more than one year after implementation and make assessments on longer-term impacts. In addition, by 2006 the third biological control agent for melaleuca, the gall fly *Fergusonina turneri*, is expected to be established and incorporated into demonstration site treatments [See: Bud-gall fly released for biocontrol of *Melaleuca* in Florida, General News, this issue].

For more information on TAME Melaleuca and Melapaleuza, please visit our website at: http://tame.ifas.ufl.edu

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Announcements

Are you producing a newsletter, holding a meeting, running an organization or rearing a natural enemy that you want other biocontrol workers to know about? Send us the details and we will announce it in BNI.

Bacterial Plant Disease Biocontrol Symposium

The 1st International Symposium on Biological Control of Bacterial Plant Diseases will take place on 23–26 October in Darmstadt, Germany. Organized by the Institute for Biological Control of the Federal Biological Research Centre for Agriculture and Forestry (BBA), together with the University of Darmstadt, the meeting is being held under the auspices of the German Phytomedical Society.

Following the first successful commercial development in the 1980s of strain K-84 of *Agrobacterium radiobacter* against crown rot of stone fruit in Australia, extensive work on biocontrol of bacterial diseases on many other plants has been undertaken. In the case of fire blight, the potential replacement of the antibiotic streptomycin, which is not allowed in most European countries, has stimulated research in biological control of this disease. Biocontrol methods are also needed for other bacterial diseases in field and horticultural crops. This symposium provides an opportunity to evaluate the status of biocontrol measures in commercial crops.

Further information:
Email: symposium2005@bba.de
Web: http://idw-online.de/pages/de/event13523

Flying Off the Page

The 20th printed issue of the IWSN (International Whitefly Studies Network) Newsletter is the last – on paper, that is. With growing interest in the network and activities of members, the network has now become truly international and has some 150 scientific and industrial members worldwide.

All future issues of the newsletter will be in electronic format only, downloadable from the network's 'new look' website. By following a straightforward online registering process, a wide range of topical information can be accessed, and users will also be encouraged to submit information and research articles through the site. An on-line discussion forum is already up and running. The main drawback of electronic newsletters – readers may forget when they are due – is to be overcome through email alerts, which will also be able to keep subscribers up to date on other new additions to the site.

Web: www.whitefly.org
Email: iwsn@whitefly.org

UK Tracks Alien Ladybird

Following the discovery of *Harmonia axyridis* in the UK in September 2004 [see *BNI* **25**(4), 81N–82N (December 2004), Ladybird strikes discordant note], a country-wide survey to track its movements has been launched by researchers from the University of Cambridge, Anglia Polytechnic University, the Centre for Ecology and Hydrology, the Natural History Museum and The Wildlife Trusts. Sightings (grid reference/postcode, date, ladybird numbers + photograph if possible) can be reported at:

www.harlequin-survey.org

BCPC 2005

The 2005 BCPC (British Crop Protection Council) International Congress and Exhibition is being held in Glasgow on 31 October – 2 November. The broad themes of the meeting, to be addressed in a mix of invited and offered presentations, are:

- Crop protection
- Environment and regulation
- Crop production and the food chain

Traditional areas covered include international pesticide regulations, pest, disease, weed and resistance management, and new compounds, concepts and uses, as well as emerging research areas such as biodiversity, risk management and ecotoxicology. Problems arising from the withdrawal of pesticides, food quality (including mycotoxins) and harmonization of minimum residue levels (MRLs) will also be covered.

Contact: BPCP Congress Registration, 7 Omni Business Centre, Omega Park, Alton, Hampshire, GU34 2QD, UK.
Email: becky.dyer@bcpc.org
Fax: +44 1420 593209
Web: www.bcpc.org/congress2005/

Potatoes Heart of Dundee Conference

The next biennial Dundee Conference, organized by the Association for Crop Protection in Northern Britain, will take place on 28 February – 1 March 2006. Sessions will cover agri-environmental and economic topics and combinable crops, with the second day devoted largely to potatoes.

Contact: Tim Heilbronn, CPNB Administrator,
74a Errol Road, Invergowrie, Dundee DD2 5AF, UK.
Email: Tim@cpnb.org
Web: www.cpnb.org

Conference Report

Have you held or attended a meeting that you want other biocontrol workers to know about? Send us a report and we will include it in BNI.

Forest Invasive Species Network Meets in Viet Nam

The Asia–Pacific Forest Invasive Species Network Workshop was held in Ho Chi Minh City, Viet Nam on 22–25 February 2005. Twenty-six representatives from ten countries in the region participated in the deliberations of the workshop. There were three sessions. Session 1 mainly considered *Brontispa longissima;* four general papers, and the status of management of *B. longissima* in Viet Nam, China, Thailand and Cambodia were presented. In Session II, four papers were presented on invasive species and the role of quarantine. In Session III, four papers were presented concerning forest ecosystems and invasive species. Different Working Groups were formed to formulate or fine-tune the recommendations.

The major recommendations concerning *B. longissima* include:

- Strengthen the taxonomy of the hispine beetles found on palms and enhance the exploration for and use of microbial agents in a sustainable manner.
- Centres of excellence for the management of palm hispine beetles be planned and established to enhance the skills and capabilities of national scientists to meet the challenges of invasive species.
- Biological control agents can be recovered from the field and numbers produced to be dispatched to

recipient countries. Such activities will greatly reflect the strength of the network.

• A database should be set up to strengthen pest alert notifications. A regional cooperation programme will greatly enhance this capacity building and access to such a database.

• Capacity building for biological control should be addressed at three levels, i.e. scientists, service providers (extension, NGOs, etc), and farmers and farmer groups.

All details of sessions, working groups, papers presented and recommendations are available:
Anonymous (2005) Asia-Pacific Forest Invasive Species Network Workshop – Developing an Asia-Pacific Strategy for Forest Invasive Species: the Coconut Beetle Problem – Bridging Agriculture and Forestry, 22–25 February 2005, Ho Chi Minh, Viet Nam, 115 pp. Available in print (bound, without continuous pagination), and also electronically at:
www.apafri.org/mod/APFISN/APFISNWorkshop_html

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New Books

Rootworm Directory

Increasing public and governmental concern within the European Union (EU) about the impact of WCR on maize production [also see: Latest word on corn rootworm, General News, this issue] led to EU funding for a multi-country project, WCR Ecology and Management in Europe (QLRT-1999-01110), which began in 2000. At the conclusion of the project in spring 2003, an international symposium held in Göttingen, Germany, brought together scientists from Europe and North and South America to review current knowledge of the ecology and management of the pest. This meeting and the discussions that followed formed the basis of a book, which has now been published.

The book begins with an overview of the invasive species concept, which summarizes the nature of the threat from invasive species globally and pathways of introduction, then describes the four key management options (prevention, eradication, containment and control). The next chapter chronicles the spread and economic impact of WCR in Europe, also describing the monitoring network and how its purpose changed over time.

Subsequent chapters assess what is known about various aspects of WCR's ecology that are relevant to understanding the pest's spread and impact, and to the development of management plans.

• In-depth knowledge of adult and larval nutritional ecology in North America is supplemented with new information from Europe. This is discussed in relation to resistance management plans for transgenic maize, the development of resistance to insecticides and crop rotations – a key issue in North America – and to the invasion process and possible management strategies in Europe.

• The relationship between WCR and members of the plant family Cucurbitacae, and the role of chemical attractants and feeding stimulants (cucurbitacins) are explored, together with the potential for exploiting this in pest management.

• Natural mortality factors acting on WCR in North America and Europe are compared (of particular interest is whether natural enemies 'followed' the pest into North America and if so, whether any cause significant mortality). Statistically reliable life table information gathered over the last 40 years in North America and more recently in Europe (Hungary) is summarized. For the various life stages, key mortality factors are identified that influence population growth and could potentially be exploited for the pest's control.

• Understanding pest behaviour is a key requirement for successful management. Reviewing knowledge of the movement, dispersal and behaviour of WCR in North American maize/soyabean rotation fields, human activity, the pest's mobility and movement patterns, and host switching in the adult are identified as key elements in its 'success'.

• *Diabrotica* species are not evenly distributed in fields. Aggregation makes sampling and quantification of populations difficult. Evaluations of within-field variation in populations of the related indigenous North American pest, *D. barberi* (northern corn rootworm), and of the sampling devices and decision rules used to predict subsequent maize damage both serve to clarify possible management strategies.

• Various mathematical models for explaining the geographical spread of maize/soyabean rotation-resistant WCR in North America, and examining strategies for delaying the development of resistance are discussed. Heterogeneity is identified as the best means of delaying resistance because it reduces selection pressure – heterogeneity in space *and* time: an extensive area of a maize-soyabean rotation may be less heterogeneous than a patchwork of continuous maize cropping and maize-soyabean rotation in terms of preserving rotation as a management tool.

• Moving to Europe, a chapter is devoted to considering the North American rotations and, in the light of 3 years field rotation studies in Hungary, which, if any, would contribute to a decrease in WCR populations in space and time in Europe. Given the greater heterogeneity of the European landscape, compared with the US corn belt, crop rotations will deliver less selection pressure, but the effect of providing 'refuges' of continuous maize cropping within rotation areas is suggested for further study.

Later chapters look at other management options.

- Five programmes to evaluate the efficacy of the areawide concept of management using semiochemical-based insecticide baits in the eastern Midwest of the USA are described. Overall, a consistent decrease in pest populations was not obtained, neither did crop yields increase consistently. The mobility of WCR was identified as one constraint – the whole area would have to be much larger, and field-by-field decisions are not appropriate. A bigger constraint was the performance of the bait, and a longer period of activity is required.
- A case study on the potential for genetically modified maize (Yieldguard®) for managing WCR is presented, which examines current management strategies and their limitations in US maize production systems. Factors considered in assessing the food, feed and environmental safety of the genetically modified maize are described, and its performance and potential benefits are discussed.
- Possibilities for the control of WCR in Europe though classical biological control (CBC) are reviewed. The four-step approach used in CBC programmes (surveys for natural enemies in invaded area, surveys in area of origin, selection of candidate biological control agents, testing for host specificity) are described in relation to the research carried out for WCR so far. Specific natural enemies were not found in Europe. Surveys in Central and South America revealed only one parasitoid on WCR, *Celatoria compressa*, a tachinid fly that proved to be restricted to WCR and closely related species. Further research looked at its biology, especially reproductive biology with a view to developing a rearing method, and host specificity. The authors consider it would be safe to introduce as its direct and indirect nontarget effects would be extremely low. The question of whether CBC could provide a sustainable solution is still open. Results so far are promising but further work is essential to complete the assessment of its likely efficacy.

North America has now lived with WCR for a long time, but the stimulus for the EU project was the fear that the pest could decimate maize production in Europe. The final chapter in the book analyses the distribution and extent of maize production in the different European countries, an assessment that will form a baseline for modelling yield losses and economic damage in high-risk areas in Europe. The predictions of increasing economic impact in the coming years in countries where maize is a key crop is a sobering reminder, if one were needed, of the importance of learning how to manage WCR in Europe effectively, a task for which this book is an invaluable aid.

Aside from the direct benefits of research on WCR for the development of control strategies, there is much to be learnt from this invasive pest species in more general terms. Recent research on WCR has given insight into evolutionary aspects of pest species, adaptations to changing environments, and management options to counterbalance these adaptations.

The book is therefore invaluable for anyone working with *Diabrotica* species and their management, but has wider appeal as a comprehensive account of the ecology of a key invasive pest insect in relation to its management.

Vidal, S.; Kuhlmann, U. & Edwards, C.R. (*eds*) (2005) Western corn rootworm: ecology and management. CABI Publishing, Wallingford, UK. 320 pp. ISBN 0 85199 817 8. Hbk. Price: UK£65.00/ US$120.00.
Web: www.cabi-publishing.org/

From Runaway Success to Runaway: Containing Cactoblastis

Views of the cactus moth, *Cactoblastis cactorum*, have undergone some shifts in recent years. Long one of the big success stories of weed biological control, it is now recognized as an invasive threat, particularly to the indigenous *Opuntia* cacti of Mexico [see *BNI* **23**(3), 63N–64N (September 2002), *Cactoblastis*: classical beauty or invasive beast]. Containment of the agent-turned-pest to prevent its further spread has become a priority, and has been the stimulus for this small but useful book, published under the auspices of the Joint FAO/IAEA (Food and Agriculture Organization of the UN/International Atomic Energy Agency) Programme of Nuclear Techniques in Food and Agriculture.

The first two chapters give accounts of the taxonomy and biology of *C. cactorum*. The next chapter identifies its host plants in native and adventive ranges, and summarizes its impacts outside its natural range. The fourth chapter lists biological control introductions, and gives a short history of the various biological control programmes in which *C. cactorum* has been used. Some striking before-and-after photographs illustrate the successes. Instances where introductions (initially in some cases) failed to achieve control are also discussed. The second part of the chapter describes *C. cactorum*'s inadvertent/ unregulated dispersal within the Caribbean Region and to mainland North America. Chapter five deals with the threat the moth presents to biodiversity in the USA and biodiversity and the economy in Mexico. The photographs in this chapter of natural vegetation dominated by cactus, and of thriving cactus plantations make for uneasy comparisons with the photographs in the previous one. Potential threats to other countries are also summarized. The final chapter considers surveillance and control options for *C. cactorum*. Possible control options (some already used in countries in the native or adventive range where *Opuntia* is a crop) include crop management, biological, chemical and integrated control, and the sterile insect technique (SIT). The book concludes by underlining the uncertainties of the future speed of spread and actual impact of *C. cactorum* in North America, and stresses that the emphasis for control, for the present, will be on eradication or containment.

The dozens of colour illustrations, (clear maps and diagrams as well as photographs) backed up by accessible yet authoritative and well-referenced text make this publication a very readable summary of the *Cactoblastis* story and the issues surrounding it.

It will be a useful tool in the publicity campaign to draw attention to the threat *Cactoblastis* poses in North America (and of course the role that SIT could play). It is worth a look, even if you are not interested in *Cactoblastis,* as it is an excellent example of a publication designed to raise awareness about an invasive species.

Zimmermann, H.G., Bloem, S. & Klein, H. (2004) Biology, history, threat, surveillance and control of the cactus moth, *Cactoblastis cactorum*. Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture, Vienna, Austria.
44 pp. ISBN 92 0 108304 1.
Web: www-pub.iaea.org/MTCD/publications/PDF/faobsc_web.pdf

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