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General News

Weed Biocontrol in Europe: End of the Wilderness Years?

A milestone was reached this October when CABI submitted an application to the UK Department of Environment, Food and Rural Affairs (Defra) for permission to release an exotic psyllid (*Aphalara itadori*) for the biological control of Japanese knotweed (*Fallopia japonica*) in the UK. If approval is given, it will pave the way for the first official release of an exotic biological control agent for weed control anywhere in Europe. This potential 'first' may seem extraordinary to readers almost anywhere else in the world, but Europe can be hostile to novel technology (as the biotechnology sector learnt to its cost) and the general public remains largely unaware of the benefits of biological weed control (though surprisingly knowledgeable about the cane toad; see 'Beyond the cane toad', this issue).

The last weed to come under serious consideration in the UK for biological control by exotic agents was bracken (*Pteridium aquilinum*), a native species now a major weed of marginal and hill land in western and northern regions. A paper written 20 years ago noted that although biological and technical obstacles had been largely overcome, there was "a host of political, legal, environmental and socio-economic problems that must be confronted before biological control of bracken in Britain can be attempted."[1] Confronted they were, but not overcome, and biological control of bracken in the UK was abandoned – but not forgotten since a paper entitled 'Whatever happened to bracken biocontrol?' was presented by Djami Djeddour and Dick Shaw (CABI Europe – UK) at the EWRS (European Weed Research Society) International Symposium, 'Intractable Weeds and Plant Invaders' in the Azores in July 2006.

Japanese knotweed has urban and rural impacts. Introduced in the 1820s as an ornamental garden plant, it can grow as much as three metres in as many months. Its extraordinarily strong growth, which allows it to grow through tarmac and causes serious damage to buildings, paving, drainage and archaeological sites, has given it a 'concrete-busting' reputation. It can add more than 10% to the total costs of developing a building site – and in that context is impacting on the 2012 Olympics site. From time to time newspapers carry photos of Japanese knotweed plants growing up through tarmac, through stone walls, and even appearing in living rooms as it emerges through the floors of houses. It has less-publicized but serious impacts in natural habitats: Shaw, who has been leading CABI's Japanese knotweed classical biological control project, says that although more famous for its 'concrete-cracking' ability, its impacts on Britain's natural habitats are severe, crowding out native plants and seriously reducing opportunities for native wildlife.

It thrives on disturbance and has been spread by natural means, for instance along waterways, and by human activity such as fly-tipping. It has now colonized almost all regions of the UK; it thrives equally well in towns and the countryside, and is a particular problem in parts of Cornwall and Wales in the south-west of the UK. It has become a pervasive and insidious weed that costs the UK millions in control efforts. A Defra working group estimated that the cost to control it across the UK using traditional methods would be UK£1.56 billion. This is economically and environmentally unsustainable but, according to Shaw, doing nothing is not an option.

What has been frustrating for weed biocontrol scientists like him is that, whereas in countries like the USA, Canada, Australia and New Zealand, research into biological control is the first port of call when a new alien pest species is identified as an apparently unmanageable problem, this is not the case in Europe. Shaw, together with his colleagues working on other weeds in Europe, hopes that the Japanese knotweed application will prove to be a watershed.

The UK is leading the way in Europe in strategic invasive species management, thanks to Defra's non-native species policy, and also in researching alternative weed control measures which can be integrated with traditional methods. Since 2000 CABI has been working to stop the spread of Japanese knotweed with funding from a consortium of sponsors: Defra, the Environment Agency, Network Rail, the South West Regional Development Agency, the Welsh Assembly Government and British Waterways, all coordinated through Cornwall County Council.

The plant has no significant natural enemies in the UK. CABI's Japanese knotweed research project has involved the collection, identification and selection of natural enemies from Japan with potential as control agents. Over 200 species of insects and pathogens have been recorded. Safety has been the priority, and five years of testing has seen the most promising natural enemies tested against 79 related plant species to determine host specificity. These safety tests have led to all but two species being rejected.

The two species identified as potential agents for release in the UK are the psyllid *A. itadori* and a

Mycosphaerella leafspot fungus. So far they are both proving to be highly specific to Japanese knotweed and pose no direct threat to important native species or crops. The fungus' complicated life-cycle presented practical difficulties, while work on the psyllid progressed more quickly to completion, and is the subject of the current application to Defra and its expert review process.

Although permission to release would be a landmark in weed biological control in Europe, CABI does not want to raise expectations about the impact the psyllid would have: it is unlikely to be the end of Japanese knotweeed in the UK. Successful biological control will not eradicate the weed, but it should bring the population to a more acceptable level, where it will become more susceptible to traditional control methods. This view is supported by John Bailey at the University of Leicester, who also cautions against over-hyping the prospects for control. He has been researching the weed since the 1980s and his team was responsible for the molecular work establishing that Japanese knotweed in the UK was a single clone, and identifying where in Japan this had come from and thus where CABI's natural enemy collections were subsequently focused. Pointing out that a biological control agent is rarely a 'silver bullet', he says that although its release would weaken existing plants and slow down or hamper range extension, and may even ultimately reduce the amount of hybrid seed produced, the biocontrol agent should be viewed as "an invaluable aid to levelling the playfield in the fight against this alien plant, rather than as a 'mission achieved'." He suggests that if it is released, this should be as part of a coordinated campaign, involving both public education on the dangers of inadvertently spreading the plant, and a redoubling of the use of more conventional control methods, and that, "to sit back and let [the biocontrol agent] do its work would lead to little reduction in the occurrence of the plant."

Further information:
www.cabi.org/japaneseknotweedalliance

[1]Lawton, J. (1988) Biological control of bracken in Britain: constraints and opportunities. *Philosophical Transactions of the Royal Society of London, Series B* **318**, 335–355.

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Beyond the Cane Toad

A recent flurry of media interest in the UK, brought on by the news of the potential first release of a biocontrol agent against a plant in Europe (see: 'Weed biocontrol in Europe: end of the wilderness years?', this issue), led UK journalists and the general public to develop the dreaded 'cane toad syndrome' once again.

This latest attack occurred on 13 October 2008 when the BBC ran a story, and an interview with Dick Shaw (CABI Europe – UK) (see: http://news.bbc.co.uk/1/hi/sci/tech/7531221.stm) who leads CABI's Japanese knotweed (*Fallopia japonica*) biocontrol programme. Television, radio and local and national newspapers ran stories on the potential release of the sap-sucking psyllid *Aphalara itadori* against the UK's most pernicious and expensive weed. On the whole the publicity was positive: most articles detailed the impacts of Japanese knotweed in the UK, and went some way to explaining the screening methods used to determine the biocontrol agent's host specificity and therefore safety. However, during the media flurry the cane toad reared its very ugly head again with many articles featuring its devastating impact in Australia after its release in the 1930s.

The comments from the public on the BBC website following the story's airing indicate how successful the press has been in educating the public on this dark event in classical biological control (CBC) history. Comments like *"Oh no, not another cane toad"* and "*When will these scientists learn – remember the cane toad*", highlight the need to provide the public with a history of past and present biological control programmes which detail successes as well as failures if weed biological control is going to get the backing it needs at this early stage in Europe.

If approved, the release of *A. itadori* against Japanese knotweed will be the first official release of a biocontrol agent against a weed in Europe. The stakes are high in that, if successful, the knotweed biocontrol programme could be a showcase and platform for further research into weed biocontrol control in Europe. Sheppard *et al.*[1] have shown there is no shortage of European targets, and with climate change and the relaxing of European borders, the numbers of invasive species having a detrimental impact in the UK and mainland Europe will surely increase. European biocontrol practitioners already have their work cut out educating the general public on the concept and principles of biological control and the scientific methodology to determine whether a potential control agent is safe. Having the cane toad cited as the sole example of biological control is unhelpful – there are more appropriate good *and* bad examples to help the public understand the issues.

So why does the media, and general public, have such a fixation on the cane toad? As acknowledged in a previous issue of [*BNI* 27(4), 67N (December 2006), 'The still-controversial cane toad'] the cane toad is "hideously photogenic". What better way of highlighting agents that have 'gone wrong' than by a photo of a toxic warty toad with a large gaping mouth. It was perhaps its starring role in a BBC nature documentary in the 1980s that alerted the media and their audience to the spreading menace and cemented it in our collective consciousness. No one denies the impacts the cane toad has on the biodiversity of Australia, especially the herpetofauna, but when the cane toad was released in Australia in the 1930s, it was not just on a whim of Australian scientists; it was based on evidence that it had achieved a reasonable amount of control of sugar cane pests in Barbados and Jamaica. What is not mentioned in the media is that this introduction was against the advice of some entomologists, and there was little scientific testing on the toad's breadth of diet before it was done. The science and practice of CBC has progressed immeasurably since then, which is what we need to get across to the European public.

What is curious is that the media and the public have continued to focus on the cane toad as the reason for being cautious about – or opposing – the introduction of an exotic agent for biological control of Japanese knotweed, when there is an on-going biological control disaster much closer to home (*at* home in some cases) that could justifiably be cited to greater effect: the harlequin ladybird, *Harmonia axyridis*. With a native range extending through eastern Asia (including Japan), the harlequin ladybird was sold quite legitimately in 1990s as a greenhouse biocontrol agent in European countries for aphids and coccids; such introductions were not subject to regulation because it was assumed that they would not establish outside the protected environment into which they were released. The harlequin's establishment in the wild, its subsequent spread throughout Europe, and arrival and successful establishment in the UK in 2004 has caused particular concern because of the sheer speed of its range expansion and its potential impact on native ladybirds – and because large swarms of harlequins have begun using houses in southern England as overwintering sites. As one of the authors of this article pointed out in a recent issue of *International Pest Control* [50(3) (June 2008), 'What chance classical biocontrol of weeds in Europe?'] the unregulated sale and subsequent escape of the harlequin ladybird could tarnish the concept of biological control in the eyes of the general public. The biological control scientist's argument in both cases, cane toad and harlequin, is the same: they were ill-judged introductions of generalist feeders made with insufficient regard for environmental and non-target effects. Neither of these introductions would be allowed today under current regulation of biological control introductions, and the extensive host-specificity testing this entails. The revision of the ISPM (International Standards for Phytosanitary Measures) No. 3 Code of Conduct and the recent REBECA project (European Union Specific Support Action, 'Regulation of Biological Control Agents') should further ensure that such mistakes do not take place again.

Changes in regulations on host-specificity testing aside, there are other reasons why the cane toad would not be introduced today, and these relate to changes in societal values. Another relevant example for the current debate about CBC is one that has fuelled controversy among conservation and biocontrol scientists for the last decade: the non-target impacts of the European weevil *Rhinocyllus conicus* on native thistles in the USA. Following its introduction into the USA in the late 1960s as a biocontrol agent against the highly invasive Eurasian musk thistle, *Carduus nutans*, *Rhinocyllus* was found feeding and inflicting damage on native *Cirsium* thistles. While the damage inflicted on the native thistles was worrying and its ultimate impact unpredictable, the likelihood that *Rhinocyllus* would attack them had been predicted by the scientists involved in the pre-release host-range testing procedure, yet permission to introduce *Rhinocyllus* was still given – why? At the time of its release, native thistles were believed abundant and their habitat not seriously threatened. However, more significant is the fact that native species or 'biodiversity' was not considered as valuable as it became after the Convention on Biological Diversity (CBD) was drafted in 1995. Biodiversity was certainly not prioritized by the government officials given the task of halting the loss of large swathes of grazing pasture. The economic benefits of releasing *R. conicus* were considered greater than the potential non-target effects on what at the time were considered relatively 'insignificant' native plants, which in any case could be offset against the impact of the expanding musk thistle population on them. Today with societal values shifting to a more ecological conservation perspective, such a release would be unlikely to be allowed, although the cost of 'doing nothing' needs to be taken into account when considering any weed control strategy.

A sense of historical perspective also needs to be applied to the decision to introduce the cactus moth, *Cactoblastis cactorum*, to the Caribbean region for control of *Opuntia* 'prickly pear' species. In the 1920s *Cactoblastis* from Argentina was introduced into Australia to control some 6.5 million hectares of mainly *Opuntia stricta*. The introduction was one of the first success stories for CBC and further introductions were made, with similar success, against introduced *Opuntia* spp. in Hawaii, Mauritius and parts of South Africa. However, deviating from the tried-and-tested method where *Cactoblastis* was released in countries without endemic *Opuntia* spp., in 1957 the moth was released in Nevis in the Caribbean where some of the native *Opuntia* spp. were pasture weeds. From there it spread to other Caribbean islands and eventually to mainland North America in 1989. It now threatens native *Opuntia* of southern USA and Mexico – in the latter case threatening culturally important cactus species [See *BNI* 27(4), 65N–67N (December 2006), 'Biological control agent turned pest insect']. While this example again illustrates how society's perception of the value of biodiversity has changed over the last half-century, it also highlights the necessity of a regional perspective for CBC. In the 1950s, there was less movement of people and goods than today, and onward dispersal of introduced natural enemies to neighbouring countries was little thought about. But by the late 1980s, quarantine authorities in North America knew that the arrival of the cactus moth on the mainland was inevitable. From a European perspective, the example highlights the need for a European-wide approach to host-specificity testing and for including plants endemic to different regions in test lists.

Although the examples above may be relevant to a current debate about the safety of biological control, they do, of course, lend support to the persistent myth, which a large sector of the public believes, that most if not all natural enemy introductions have proved disastrous in the long run. If CBC is to progress, this misperception needs to be addressed and one obvious way of doing this is to look to Australia. Despite continuing to be the victim of the cane toad invasion, the country is one of the most active in biological control programmes against weeds in the world. While Europe has just started to research the potential for biological control as a method of weed management Australia has a long and successful history with biocontrol agents released against over 60 weeds during the last 90 years. So why *are* Australians still practising biological control when they continue to be the victims of the cane toad invasion?

The scale of, and area covered by, some of Australia's most prolific weeds favours control on a regional or national scale. Such large scale control is often unachievable by traditional (mechanical, chemical) control methods, and when it is, the costs associated are in the A$-millions. The extent of some weed invasions in Australia is almost incomprehensible to Europeans. In the pre-*Cactoblastis* days in the 1920s, *Opuntia* cactus covered an area of some 24 million hectares in Queensland and New South Wales. That is almost exactly the total land area of the whole of the UK. More recently, before the introduction of the rust pathogen *Maravalia cryptostegiae* against invasive rubber vine, *Cryptostegia grandiflora*, this non-native plant occupied some 40,000 km^2 of northern Australia. Other invasive weed targets of current CBC programmes are widespread: *Parkinsonia aculeata* occupies a staggering 12.4% of Australia's landmass, while brambles (*Rubus fruticosus* agg.) and *Lantana camara* occupy some 9% and 5.1%, respectively.

When these figures are considered one can understand why Australians have been quicker to explore alternative approaches but it is perhaps the economics that drive things now. Weed invasions over such large areas have a high impact on Australia's agricultural productivity. The Cooperative Research Centre for Australian Weed Management (Weeds CRC) (www.weedscrc.org.au/publications/factsheets_guidelines.html) estimated that between 1997 and 2002 the economic loss to Australian agriculture from weeds was between A$3444 million and $A4420 million. Environmental losses are much harder to quantify. For the Australians, biological control has proven to be a cost effective method of weed management, although other methods are also used – but at considerable cost because of the vast areas involved. The Weeds CRC estimated the total cost of chemicals for weed control to be between A$820 million and A$974 million per annum. A biological control programme can involve a costly outlay and there is no guarantee of success. However when successful, the control programme has net benefits year on year as the successful control agent will be self-perpetuating and spread throughout the infested area with little to no extra cost. In a study where the Weeds CRC analysed the benefit–cost ratio of CBC programmes in Australia over the past 100 years, they identified 14 giving a positive economic benefit with an average benefit–cost ratio of 23:1. For an average annual investment of A$4.3 million, these weed biocontrol programmes have given an average annual net benefit of A$95.3 million.[2]

One of the biggest success stories for CBC in Australia in recent years has been control of rubber vine following the release of the rust pathogen *M. cryptostegiae* in 1995 [*BNI* 23(2), 37N–38N (June 2002), 'Rubber vine in terminal decline']. Before the release of the rust pathogen, rubber vine was described as the single biggest threat to natural ecosystems in tropical Australia. The plant was threatening the biodiversity of Australia's unique tropical riparian flora, quite literally smothering native *Eucalyptus* forests, and severely degrading pastureland. Interestingly, it invaded areas infested or threatened by the cane toad – such as the Kakadu National Park – but it did not catch Europe's attention in the way the cane toad does. Although this made headlines in Australia, it followed many successes over the years, including water weeds such as salvinia (*Salvinia molesta*), water hyacinth (*Eichhornia crassipes*) and water lettuce (*Pistia*), rangeland weeds such as Paterson's curse (*Echium plantagineum*), giant sensitive plant (*Mimosa invisa*) and ragwort (*Senecio jacobaea*), and weeds of cropping systems including skeleton weed (*Chondrilla juncea*) which invaded wheat growing regions of southeast Australia.

Weeds are not the only invasive group targeted by Australian biocontrol practitioners: successful biocontrol has been achieved against insect pests, crop diseases and vertebrate pests. Introduced mammals have given Australia some of its biggest problems. Although in the public consciousness cane toads are Australia's worst pest, other vertebrates such as rabbits do far more economic and environmental damage. Rabbits have long been the target of a biological control programme, beginning with the introduction of the myxomatosis virus in 1950. In the

1990s, rabbit haemorrhagic disease virus (RHDV) was introduced with great success and rabbit populations were reduced to some 10% of their former levels. Even the cane toad itself could be a target for biological control, with Australian scientists undertaking research on a variety of approaches in recent years, including viruses and other microbial agents found in the toad's native range. If a microbial agent is found, which could cause disease and death, or reduce the toad's resistance to other infectious diseases, the cane toad's days as Australia's most famous invasive could be numbered.

With such a long history in CBC it is then no surprise that Australian biological control practitioners lead the way in most aspects of this approach. The safety testing of the agents, and the test plant selection for the Japanese knotweed project were based on the pioneering work of the late Tony Wapshere (the first officer in charge of the CSIRO biological control unit). The centrifugal phylogenetic method and the adaptions suggested by David Briese and team, underpinned the test plant selection for the Japanese knotweed control programme. CABI scientists have tested some 90 plant species against the psyllid showing this potential agent is host specific to Japanese knotweed.

The message from this is that in Australia CBC is considered as a mainstream option in pest management rather than the preserve of the lunatic fringe and the Australians have a long and growing list of environmental and economic successes to prove the worth of this approach. Europe can learn many lessons from Australia when it comes to the implementation of CBC programmes not to mention quarantine. Many countries have used CBC as a tool for weed management for decades. Lessons have been learnt from past mistakes and huge sums of money have been saved thanks to successful CBC programmes. In time, and with weed biocontrol successes under our belts, the European media might eventually lose its obsession with such an unrepresentative example as the cane toad.

[1]Sheppard, A.W., Shaw, R.H. & Sforza, R. (2006) Top 20 environmental weeds for classical biological control in Europe: a review of opportunities, regulations and other barriers to adoption. *Weed Research* **46**, 1–25.

[2]Page, A.R & Lacey, K.L. (2006) *Economic impact assessment of Australian weed biological control.* CRC for Australian Weed Management Technical Series No 10, 151 pp.

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Diamond Celebrations Mark Sparkling Collaboration

This October, CABI Europe – Switzerland (CABI E-CH) and Canada celebrated 60 years of collaboration, a relationship that has been central to the development of biological control in Canada and of CABI, especially in Switzerland, although Canadian funding has supported CABI's biological control programmes worldwide. A symposium highlighting this collaboration was held on 20 October 2008 in Ottawa at the Joint Annual Meeting of the Entomological Societies of Canada and Ontario.

Nineteenth century North America saw an expansion in planting of crops imported from Europe, some of which subsequently fell prey to insect, disease and weed pests inadvertently imported with them. The first classical biological control introductions against some of these were made in Canada in the 1880s. A small Natural Control Investigations Laboratory was established at the University of New Brunswick in 1915, and after a number of moves reached its long-term home in Belleville, Ontario in 1929. Staff there were involved in most subsequent biological control introductions to Canada, along with other agencies. A key one of these was the Imperial Parasite Service, which was responsible for the greater part of the work overseas. The Imperial Parasite Service was set up at Farnham Royal, UK, in 1927 by the Imperial Bureau of Entomology (itself housed at that time at the British Museum (Natural History) in London). Dr W. R. Thompson became its Director in 1928. Critically, the Imperial Parasite Service was relocated to Belleville in 1940, under Thompson's direction, where it remained for 20 years.

Without the hospitality and assistance of the Government of Canada and its own Entomological Service, the Imperial Parasite Service would not have survived World War II. This was acknowledged during the Imperial Agricultural Bureau Review Conference in 1946, when it was also agreed that it should remain in Canada, initially at Belleville although it transferred to Ottawa at the end of 1948. It became an independent bureau, changing its name to the Commonwealth Bureau of Biological Control (CBBC) in April 1947, and then to the Commonwealth Institute of Biological Control (CIBC) in 1948; from January 1948 the name of the entire organization was changed from Imperial Agricultural Bureau to Commonwealth Agricultural Bureau, or C.A.B. (The name-changing habit thus has a long history.)

The genesis of CABI's European Station in Switzerland soon followed: a substation opened at Feldmeilen close to Zurich in 1948 with Louis Mesnil, a well known authority on parasitic Diptera, as Entomologist-in-Charge; there were already CIBC substations in the West Indies (Trinidad) and the USA (Fontana, California). The station moved to Delémont, at that time in canton Bern, but now in canton Jura, in 1958. The new European Station of

CIBC was purpose-built on land bought by the C.A.B. Executive Council, and the access road was appropriately named 'Chemin des Grillons' by the Conseil Municipal. The building was occupied in 1963. Hubert Pschorn-Walcher succeeded Louis Mesnil as Entomologist-in-Charge of the Station in 1969; he was followed by Klaus Carl until 1996. Dieter Schroeder followed and oversaw an enlargement of the building that increased the facilities by 50%. The current Regional Director, Matthew Cock, took charge in 2000.

Although CIBC prepared and maintained a catalogue of the parasites and predators of the world's insects, its principal activity from its earliest days consisted of the supply of beneficial insects attacking various pests which required field collections and sometimes mass rearing and the development of shipment methods. In some cases, CIBC took complete charge of biological control projects for governments and carried out research and educational work. An early success of research cooperation was the release of the parasitoid *Ascogaster quadridentata* into British Columbia in the late 1930s, which resulted in the control of the pea moth, *Laspeyresia nigricana.* Another example of successful control of an agricultural pest was the release of the egg parasitoid *Ageniaspis fuscicollis* against the apple ermine moth, *Yponomeuta malinellus,* in the late 1980s, which caused the widespread collapse of populations of the introduced pest.

Funding from Canada for survey work by CIBC in India and Pakistan led to the establishment of CIBC stations in these countries. Later, Canada through Colombo Plan funding and subsequently the Canadian International Development Agency (CIDA) funded totally or partly the establishment of station buildings, starting with Pakistan in 1957, followed by India, Trinidad and Kenya. The headquarters of CIBC moved from Ottawa to Trinidad in 1959. Subsequently, Canada's International Development Research Centre (IDRC) and CIDA funded CABI to carry out a series of research and implementation programmes against a range of pests in tropical countries, notably cassava mealybug, cassava green mite, tsetse flies, conifer aphids and locusts in Africa.

The Review Conference in September 1985 saw the member countries of C.A.B. agree to seek full international status and adopt a new title for the organization – CAB International (CABI). CIBC was renamed the CAB International Institute of Biological Control but the acronym CIBC was retained. CIBC headquarters moved from Trinidad to Silwood Park, Ascot, UK. In 1990 the four scientific institutes of CAB International again changed their names and CIBC became the International Institute of Biological Control, with the acronym IIBC. In 1998, the four scientific institutes of CABI were integrated into CABI Bioscience, which merged CABI's worldwide scientific activities in the characterization and utilization of biodiversity for pest and disease management, and environmental conservation. In 2006, CABI restructured and the different divisions of CABI were reunited under a single logo, reflecting the synergies across all our activities. As a result CABI Bioscience Switzerland Centre became CABI Europe – Switzerland, or CABI E-CH.

Meanwhile, back in Canada, the Belleville laboratory morphed through several name changes: variously Dominion Parasite Laboratory, Entomology Research Institute for Biological Control, and Belleville Research Institute at different points during its life. In 1936 a 40-room insectary with quarantine capability was built and in 1955 a modern office-laboratory building replaced the original structure. In 1972, when the Research Branch of Agriculture Canada was reorganized, the laboratory was closed and staff were relocated to regional Research Centres across Canada.

The Insect Pathology Laboratory, later the Insect Pathology Research Institute of the Canada Department of Forestry (now the Canadian Forest Service of Natural Resources Canada – NRCan, CFS), opened in 1950 at Sault Ste. Marie in Ontario. The work conducted at this facility focused on insect pathogens, building on the work begun in 1940 on viral diseases of the European spruce sawfly, *Diprion hercyniae.*

After 1972, the Biocontrol Unit was formed in Ottawa to coordinate importations and operate what is now called the National Arthropod Containment Facility located on the Central Experimental Farm. Focal points for biocontrol research were shifted to Simon Fraser University (Burnaby, British Columbia), Macdonald College (Montreal, Quebec), Forest Pest Management Institute of the Department of the Environment (Sault Ste. Marie), University of Guelph (Guelph, Ontario), and Regina Research Station of Agriculture Canada (Regina, Saskatchewan). Today, biocontrol research is conducted at various Agriculture and Agri-Food Canada (AAFC) and CFS locations, and at several universities. Furthermore, two Biocontrol Research Chairs have been created, one at Simon Fraser University and another at the Université de Montréal.

Collaboration between Canada and what is now CABI E-CH has strengthened during the last 60 years and is essential to fulfill Canada's needs for foreign exploration, research on the target pests and their natural enemies, and for developing new methods for ensuring the safety of candidate agents. Throughout the history of classical biological control in Canada a close link has existed between CABI in Switzerland and AAFC and CFS. Despite declining funding over the last two decades this close collaboration continues, particularly with AAFC. Emphasis has shifted from a focus on mainly forest pests in the early years to almost exclusive emphasis on weeds and agricultural pests. For example, releases of the weed biological control agents *Mecinus janthinus* against Dalmatian toadflax, *Linaria dalmatica*, and *Mogulones cruciger* against houndstongue, *Cynoglossum officinale,* resulted in successful control of these weeds in British Columbia. Biological control research collaborations with Canada are now conducted primarily with AAFC centres in Saint John, Newfoundland; St. Jean sur Richlieu, Quebec; Ottawa and London, Ontario; Saskatoon, Saskatchewan; Lethbridge and Beaverlodge, Alberta; and Agassiz and Summerland, British Columbia. Agriculture Canada and CFS set up working groups in 1990 in order to set priorities for the collaborative projects. This role is now held exclusively by AAFC who meet annually to discuss all aspects of invasive species control including what collaborative projects CABI should focus on.

Currently, joint research is focused on biological control options for the agricultural pests cabbage seedpod weevil, *Ceutorhynchus obstrictus*, root maggots, *Delia radicum*, swede midge, *Contarinia nasturtii*, leek moth, *Acrolepiopsis assectella*, and the invasive weeds common tansy, *Tanacetum vulgare*, tansy ragwort, *Jacobaea vulgaris*, hawkweeds, *Hieracium* spp., swallow-worts, *Vincetoxicum* spp., Japanese knotweed, *Fallopia japonica*, and oxeye daisy, *Leucanthemum vulgare*.

Collaboration with CABI on publishing projects has seen the publication of the *Biological Control Programmes in Canada* series. Furthermore, Canadian and CABI scientists made a significant contribution to the CABI book *Environmental impact of invertebrates for biological control of arthropods*.

The last decade has seen a new initiative: training of Canadian undergraduate and graduate students has become an important part of Canada–CABI collaboration. Each year, CABI E-CH offers placements to allow undergraduate students of biology and agriculture and post-graduate researchers to assist CABI E-CH staff with high impact practical projects and receive hands-on training in practical aspects of applied biological control research. This has led to excellent relationships being developed with many Canadian universities, a total of 90 student placements, and many research papers. A number of the students have subsequently won prizes and prestigious scholarships on the basis of work undertaken in collaboration with CABI.

Canadian–CABI collaboration came under the spotlight in 2007 when the current Chairman of CABI's Executive Council, Dr Gary Whitfield (Science Director with AAFC), visited Delémont in late June. He met with scientists of the Agricultural Pest Research and Weed Biological Control Research Sections working on projects funded or co-funded by AAFC, in order to review the results achieved. Their work, as when the Station was first founded, includes exploration for natural enemies of designated targets, followed by characterization of their identity, life history parameters, ecology and behaviour. Gary was particular interested to meet Canadian students involved in international student placements at CABI E-CH during the summer field season. At the end of his visit Gary said he felt morale and motivation at the Centre were good, excellent science was being conducted and the Canadian students were really enjoying their time at CABI as well as benefiting academically. Overall his view was that Canada was getting superb value for money from the work it contracts to CABI.

Compiled by Ulli Kuhlmann, Peter G. Mason, Tim Haye & Matthew J.W. Cock

For further information on CABI-Canadian collaboration, see the CABI E-CH webpage: www.cabi.org/Switzerland

Boneseed Biocontrol Proving a Tough Nut to Crack

Boneseed (*Chrysanthemoides monilifera* ssp. *monilifera*), a woody evergreen shrub that forms a dense canopy, is invasive in southeastern Australia. Improving the effectiveness of the biological control programme against this weed is a high research priority, as none of the six insect agents released in previous years has established in the field, and it is too early to know if the recently released leaf buckle mite (*Aceria* sp.) will establish.

The systemic South African rust fungus, *Endophyllum osteospermi*, is a promising biological control agent for boneseed because it reduces growth and reproduction of plants by causing extensive deformation of infected branches (witches' brooms). However, the rust develops visible symptoms, in the form of witches' brooms, only 1–3 years after infection of its host, which has made host specificity testing a challenge, and presents challenges in terms of a release strategy should it be approved for introduction.

A recent two-year project led by Dr Louise Morin (CSIRO Entomology), in collaboration with Dr Alan Wood (Agricultural Research Council – Plant Protection Research Institute, Stellenbosch, South Africa), has built on research conducted in South Africa in the mid 1990s to progress work on this candidate agent. Its aim was to complete the testing phase for the rust fungus, which would provide data to assess risks and, if these proved acceptable, support an application for its release in Australia. The project has reached some stalemates but also seen some breakthroughs.

Because of the slow appearance of symptoms, a novel approach based on a three-tier system was developed back in the 1990s to test the host specificity of the rust against a test plant list that includes the target weeds (boneseed and the closely related bitou bush, *C. monilifera* spp. *rotundata*, which is invasive in coastal habitats of eastern Australia), 29 taxa related to the target species, and five species of ecological importance where *Chrysanthemoides* are found in Australia.

- *Tier 1: Detached-leaf test.* Can the fungus penetrate leaves? Tests were performed on all species on the test list in South Africa in the late 1990s, using microscopy techniques to determine whether the rust had penetrated leaves. Results indicated the rust penetrated its known hosts, boneseed and bitou bush, and six non-target species: *Osteospermum* spp., *Dimorphotheca jucundum*, *Gazania rigens*, *Gerbera jamesonii*, *Eucalyptus cladocalyx* and *Bedfordia arborescens*[1]. However, penetration of epidermal cells does not necessarily imply that the infection process will be successful, hence the progression of testing to Tier 2.

- *Tier 2: Attached-leaf test.* Can the fungus colonize leaves? Frustratingly, trials performed on the target and six non-target species in South Africa and in the CSIRO Black Mountain Containment Facility in Canberra under the recent project failed to find signs of leaf colonization by the rust in any species, including boneseed. Germination tests indicated that the spores used were highly viable, so their failure to penetrate even the known host may relate to slightly suboptimal conditions during testing preventing infection, or clearing and staining techniques at the microscopy stage being not sensitive enough to detect early colonization. The results underline the extreme variability and technical complexity associated with this host–pathogen system.

- *Tier 3: Whole-plant test.* Can the fungus develop witches' brooms? Given the failure of the Tier 2 test, which it was hoped would further reduce the number of plant species needing to be tested, Tier 3 tests have to include all six non-target plant species that were successfully penetrated by the rust fungus in the Tier 1 tests, together with boneseed and bitou bush. These tests were established in spring 2008 in South Africa, and involved repeatedly inoculating plants with at least three different batches of field-collected spores over several weeks. It is anticipated that plants will have to be maintained for up to three years to allow time for witches' brooms to develop. The difficulty is that annual plant species are likely not to survive for that long.

Even if the rust passes the host specificity tests, a further obstacle to its release in Australia was foreseen. Because of the rust's long generation time, it was anticipated that it would not be possible to maintain infected plants in quarantine until F1 spores were produced for release. The release of spores from a F1 generation is favoured by the Australian authorities when an introduced pathogen is approved for weed biological control to ensure that unwanted exotic microorganisms are not inadvertently introduced. Against expectations, small witches' brooms with developing fruiting bodies were recently found on five of the 42 boneseed plants that were inoculated with the rust in December 2007 and since maintained under quarantine conditions. It has yet to be seen whether the fruiting bodies on these witches' brooms will mature and produce viable spores, but the prospects of being able to one day release this fungus in Australia are slowly brightening.

If the rust passes Tier 3 testing and is eventually approved for release, the project scientists will not want to wait for visible disease symptoms to appear, which can take more than a year, to know whether their release strategy is effective for the rust to establish. A PCR (polymerase chain reaction) based diagnostic tool has thus been developed by the project, to enable them to detect the presence of the rust in symptomless leaf tissue. Unfortunately this tool is not appropriate to speed up the testing regime because of possibilities of false negatives.

[1]Wood, A.R. (2006) Preliminary host specificity testing of *Endophyllum osteospermi* (Uredinales, Pucciniaceae), a biological control agent against *Chrysanthemoides monilifera* ssp. *monilifera*. *Biocontrol Science and Technology* **16**, 495–507.

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Climbing Fern Presents Few Biocontrol Options

A description of the impacts of Old World climbing fern (*Lygodium microphyllum*) in the US state of Florida leaves little doubt that this invasive weed needs controlling, and that classical biological control is the best option. But the USDA-ARS (US Department of Agriculture – Agricultural Research Service) biocontrol programme against it has not found this easy going, as a paper in the October 2008 issue of *Biological Control* describes[1].

First recorded naturalized on Florida's southeastern coast in 1968, *L. microphyllum* is now found throughout south and central Florida. Its rapid vine-like growth habit allows it to grow over shrubs and trees and smother native understorey vegetation. It alters fire ecology because old rachis mats, a legacy of its tree-climbing habit, provide a route for brush fires to reach the canopy and kill trees that would normally survive. The weed has proven difficult to control, with burning and mechanical measures arguably providing further opportunities for it to outcompete the native flora. Herbicides, although effective, are environmentally and economically unsustainable in the long term.

Climbing fern thus seemed an ideal candidate for biological control. The catch was that as part of an ancient lineage of ferns it proved to have few natural enemies, and even fewer suitable for introduction as classical biological control agents. Despite the USDA-ARS team from Florida and collaborators overseas (including the USDA-ARS Australian Biological Control Laboratory in Indooroopilly, Queensland) surveying some 320 sites in 16 countries on three continents over ten years, only 23 species were identified feeding on it, and only eight of these were deemed suitable for further consideration as potential biocontrol agents.

A crambid leaf-feeding moth, *Austromusotima camptozonale* (formerly the pyralid *Cataclysta camptozonale*) was selected as the first agent for release under the biocontrol programme based at the USDA-ARS Invasive Plant Research Laboratory (IPRL) in Fort Lauderdale, Florida. Releases were made at *L. microphyllum*-infested sites in cypress swamps, pine flatwoods and Everglades tree islands, representing the most commonly invaded habitats in southern Florida. Yet despite a protracted release programme of first adult moths (some 10,500 individuals at eight sites in 2004–05, including almost 3000 in field cages), and then larvae (16,000 at 13 sites in 2006, and 14,000 at eight sites in 2007), *A. camptozonale* has never been found established in southern Florida. The best result was for larvae released in cypress swamps where they were recovered for three months after release at 71% and 83% of sites in 2006 and 2007, corresponding to survival into the second field generation.

Efforts to understand this failure to establish took two directions: the team looked at predation and parasitism in the field, and analysed the results of other natural enemy releases against weeds, with particular reference to Pyralidae *sensu lato* (including Crambidae).

Field studies were conducted in cypress swamps and pine flatwoods. *Austromusotima camptozonale* eggs and larvae were set out at and subsequently retrieved from sites under conditions that either allowed all parasitoids and predators access, or protected *A. camptozonale* from crawling/walking predators by 'Tangle-Trap®', or prevented all predation and parasitism through cage sleeving. Eggs appeared to suffer neither parasitism nor predation, although 20% mortality was recorded in pine flatwoods which was attributed to the eggs being exposed to high temperatures in these relatively open environments. Clues did emerge from the results for larvae, however, because fewer were recovered from treatments in which walking predators had access, and trapped ants were found in Tangle-Trap treatments. This tied in with casual observations of ants preying on *A. camptozonale* larvae during releases and strongly suggested a role for ant predation.

The authors then conducted an analysis of past weed biological control programmes, using Julien & Griffiths[2], to see how Lepidoptera in general and pyralids in particular have fared as classical biological control agents. They found that Lepidoptera are the second most common order of introduced insects, after Coleoptera and ahead of Diptera and Hemiptera, but had the lowest establishment rate of the top four (calculated by agent, programme or total number of releases). Within the Lepidoptera, pyralids were the most commonly introduced species against weeds (25% of agents) but had the second lowest rate of establishment (50% of agents) of the 'top four' families, after Gracillariidae and Tortricidae and above Sesiidae. Although pyralids outperformed noctuids by all measures of establishment (agent, programme or total number of releases), this was due to the many successful establishments in many countries of just one species: the cactus moth *Cactoblastis cactorum*. Other published analyses have also identified Pyralidae as one of the top 'poor establishers'.

A previous analysis by Crawley[3] identified attributes that increase or decrease likelihood of successful establishment. While high rates of increase, high voltinism, long-lived adults, and low per capita feedings rates associated with small individual size increased the probability of an agent establishing, high powers of dispersal, low frequency of occurrence in the native habitat and external feeding (with associated risk of predation) decreased it. Conversely (and against expectations), analysis of Julien & Griffiths[2] by life habit indicated that 75% of externally feeding introduced pyralid weed biological control agents established (a higher figure than for internally feeding pyralids), and they established in 75% of programmes where such introductions were attempted. The discrepancy may reflect differential investments of effort in the execution of release programmes and subsequent monitoring.

The feeding niche issue aside, the authors of the climbing fern study acknowledge that the poor record of Pyralidae *sensu lato* overall, together with other characteristics of *A. camptozonale*, made it a less than ideal choice for introducing: it is large, its adults are short-lived, it has high powers of dispersal and it occurs at low densities in its native habitat. Nevertheless, they argue, given the limited choice they had, *A. camptozonale* was a reasonable first choice: a mite and a sawfly also being studied were both presenting problems that delayed host-range testing, so *A. camptozonale* and another crambid, *Neomusotima conspurcatalis*, by necessity became first and second choice. While substantial progress has since been made with the non-lepidopteran species, *N. conspurcatalis* remains next in line to be released, but the lessons learnt regarding temperature-related egg mortality and ant predation with *A. camptozonale* will be taken into account in designing the release programme for *N. conspurcatalis*. Lepidopteran agents can and do establish.

[1]Boughton, A.J. & Pemberton, R.W. (2008) Efforts to establish a foliage-feeding moth, *Austromusotima camptozonale*, against *Lygodium microphyllum* in

Florida, considered in the light of a retrospective review of establishment success of weed biocontrol agents belonging to different arthropod taxa. *Biological Control* **47**(1), 28–36.

[2]Julien, M.H. & Griffiths, M.W. (eds) (1998) *Biological control of weeds, a world catalogue of agents and their target weeds*. CABI Publishing, Wallingford, UK.

[3]Crawley, M.J. (1989) The successes and failures of weed biocontrol using insects. *Biocontrol News and Information* **10**, 213–223.

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Seeking Biocontrol Agents for Casuarinas

Casuarinas are attractive and superficially desirable trees for coastal environments. They were introduced into the USA in the early 1900s as ornamental shade trees. Now three species, *Casuarina equisetifolia*, *C. glauca* and *C. cunninghamiana*, have become serious invasive weeds of coastal areas in the USA especially southern Florida, the Virgin Islands, Puerto Rico and Hawaii. In Florida they are a problem in the Everglades National Park and surrounding areas. Their rapid growth, dense coverage, and thick litter accumulation mean they inhibit growth of native plants. The shallow and wide-spreading roots make them prone to being toppled in strong winds – an additional problem in hurricane-prone Florida and the Caribbean. The trees are also very salt tolerant, which allows them to grow on coastal dunes, increasing beach erosion and interfering with nesting by endangered crocodiles and sea turtles.

Gary Taylor from the University of Adelaide, Australia has been conducting Australian surveys for insect herbivores on the Casuarinaceae since mid 2004 in collaboration with Matthew Purcell, Bradley Brown and John Goolsby from the US Department of Agriculture's Australian Biological Control Laboratory (USDA-ABCL) in Brisbane, Queensland. They have been joined on expeditions by Greg Wheeler and Ted Center from the Invasive Plant Research Laboratory (IPRL) in Fort Lauderdale, Florida, USA. In all, the expeditions covered more than 5000 miles in northern and eastern Australia, encompassing much of the Northern Territory and the states of Queensland, New South Wales and Western Australia. Given the attractive features of the trees, one of the main thrusts behind the survey work has been finding seed, flower, or fruit feeders to decrease casuarina reproduction and spread without destroying parent trees, thus diminishing sources of conflicts of interest.

Taylor, Purcell and Brown, and John Gaskin, research leader of USDA-ARS's Pest Management Research Unit in Sidney, Montana, currently comprise the casuarina research team. Wheeler is the lead scientist for the project, coordinating the funding, surveys, and plant DNA testing (see below).

From some 300 insects including wasps, weevils, stem borers, sap suckers and seed eaters recovered during these surveys, the field of potential control agents has been narrowed to about 12 candidates that attack not just *C. equisetifolia,* but also *C. glauca* and *C. cunninghamiana*. Among the top finds were the seed eating wasp *Bootanelleus orientalis,* which is host specific to *C. equisetifolia*, and a defoliating moth, *Zauclophora pelodes*. Many more of the collected insects are still to be classified, and some are as yet undescribed taxa. Most of the identifications are being made by taxonomists at various participating institutions, with the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Australian National Insect Collection in Canberra taking the lead.

The prioritized insects are currently being tested by Purcell and colleagues in Australia to determine their suitability for biological control in the USA.

Sorting Out Confusing Casuarinas

While the identity of some of the insects collected from *Casuarina* spp. in Australia has still to be resolved, the identity of some of the target trees in the USA is also unclear. It is often difficult to tell the various *Casuarina* species and subspecies apart, and there is one particularly taxing *Casuarina* – long suspected of being a hybrid – which has no name, and no one knows for certain what its parents were. In this case morphological differences – leaf shape, flower characteristics – are unable to provide clear answers. Yet it is critical to sort out the taxonomy of the target species in order to select best-matching biological control agents and thus maximize chances of successful control. Fortunately, John Gaskin and his team at Sidney, Montana, have encountered and solved similar puzzles in the past (for example, *Tamarix*).

The technique is to compare samples of DNA from known species in the area of origin of the weed (in this case *Casuarina* spp. in Australia) with DNA of the invasive plants in its introduced area (*Casuarina* taxa in south Florida). The study is the first to use DNA to definitively identify the Florida *Casuarina* spp. Gaskin expects to have final results late this year.

The South Florida Water Management District, the Florida Department of Environmental Protection, and the National Park Service have all helped in funding research into casuarina biological control. This research is part of Crop Protection and Quarantine, an ARS national programme (#304).

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Marcia Wood (2008) In search of – biological control agents for the invasive Australian pine. *Agricultural Research* **58**(8), September 2008.
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Web: www.csiro.au/science/ps334.html

Can Flowers Improve Biological Control of the Diamondback Moth?

South African biocontrol scientists in the Insect Ecology Division, ARC-PPRI (Agricultural Research Council – Plant Protection Research Institute), have done a great deal of work on the importance of parasitoids in suppressing populations of the diamondback moth (DBM), *Plutella xylostella*, in *Brassica* crops. However, the fact that these crops are largely grown in monocultures poses the challenge to foraging parasitoids of balancing reproductive and nutritional requirements. Because parasitoid fecundity is generally linked to longevity, laboratory studies have shown that parasitoids provided with honey and water lived significantly longer and were more fecund than individuals with no access to these resources. In monocrop habitats, parasitoids have to leave the crop habitat frequently to search for food sources such as nectar and pollen.

The provisioning of appropriate floral resources has been shown to improve parasitism levels of various insect pests through attraction and retention of parasitoids in the crop habitat, a practice referred to as conservation biological control. Moreover, studies have shown that the additional labour costs of sowing annual flowering plants in the crop environment can be offset where planting a particular flowering plant enhances biological control of target insect pests.

During visits to cabbage growers in various parts of the country, Morake Mosiane and Robert Nofemela collected many individuals of the three major parasitic wasps of DBM, the braconids *Cotesia plutellae* and *Apanteles halfordi* and the ichneumonid *Diadromus collaris*, on two indigenous species, *Lepidium transvaalense* and *Lepidium africanum* ssp. *africanum,* and the Mediterranean and Macaronesian native *Lobularia maritime*, all members of the Brassicaceae. The relative value of these plants in improving longevity, fecundity and searching efficiency of DBM parasitoids has never been studied, and they are also embarking on a study which aims to establish the appropriate density of these floral resources within cabbage plots. Further, they plan to discover whether DBM larvae and/or moths feeding on these plants derive benefits from having them in the crop environment.

Source: Mosiane, M.S. & Nofemela, R.S. (2008) Habitat management to improve biological control of the diamondback moth in South Africa. *Plant Protection News* No. 76, p. 7. (Newsletter of PPRI, an institute within the Natural Resources and Engineering Business Division of ARC, South Africa.)

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IPM CRSP Helps Contain New Papaya Mealybug Invasions

Thanks to efforts by scientists in IPM CRSP (Integrated Pest Management Collaborative Research Support Program) led by Virginia Tech in the USA, the latest countries to be invaded by papaya mealybug (*Paracoccus marginatus*) – Indonesia and India – have been able to implement biological control swiftly, and the threat is being contained.

In May, 2008, a team from IPM CRSP identified papaya mealybug at the Bogor Botanical Gardens in West Java, Indonesia. Identification was confirmed by the California Department of Food and Agriculture. This was the first reported occurrence of papaya mealybug in Indonesia and Southeast Asia. Two months later, on a trip to Tamil Nadu Agricultural University in Coimbatore, India, Muni Muniappan, Director of IPM CRSP at Virginia Tech, recognized telltale sticky residue on papayas as papaya mealybug. In each case, government authorities were alerted and advised on appropriate actions to take; the sooner authorities can arrest the spread of the papaya mealybug, the better their chances of saving this lucrative tropical crop.

Papaya is perhaps best known as an exotic fruit, but it is also the source of papain, which is used in the production of chewing gum and shampoo, toothpaste and tooth whiteners, as a meat tenderizer, and in the brewing and textile industries. In many tropical countries, papaya is an important commercial crop and a key component of the daily diet. For this reason, papaya mealybug is a serious threat. In Indonesia, India, countries in the Caribbean and South America, and the US states of Hawaii and Florida, papaya is worth millions of dollars for farmers, middlemen and processors. In West Java, it has wiped out most of the papaya plantations.

It is a particularly devastating pest because it is polyphagous, with a host range of over 60 species of plants including important horticultural crops and ornamental species. On papaya plants, the mealybug infests all parts of the young leaves and fruits, mostly along the veins and midrib of the older leaves. Young leaves become crinkly, and older leaves turn yellow and dry up. Terminal shoots become bunchy and distorted. Affected trees drop flowers and fruits. In addition, the mealybug's honeydew promotes sooty mould growth, making the fruit inedible and also unusable for the production of papain.

Papaya mealybug originates from Mexico, where it was first identified in 1992. In 1995, it was discovered on the Caribbean island of St Martin. By 2000, it had spread to 13 countries in the Caribbean, to Florida in the USA, and to three countries each in Central and South America. As the result of a classical biological programme developed between the Inter-American Institute for Cooperation (IICA) and USDA-APHIS (US Department of Agriculture – Animal and Plant Health Inspection Service), natural enemies in the form of three species of encyrtid parasitoid wasps were released, first in the Caribbean, and later elsewhere as the pest spread to new countries, and have been widely successful in containing pest populations – and therefore decreasing the likelihood of their onward spread. A rearing facility is maintained in Puerto Rico and the biocontrol agents are offered free of charge to countries that need them.

While the challenge of reclaiming the papaya plantations from the papaya mealybug seems daunting, Muniappan is optimistic, because the use of parasitoids has been very effective in Caribbean and Latin American countries and in Florida, Guam and Palau. But he stresses the need for vigilance.

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Main source: Rich, M. (2008) Invasive papaya pest discovered by IPM CRSP in Asia. IPM CRSP Success Story.
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Landcare Research Eyes Dung Beetles for New Zealand

New Zealand lacks native pastoral dung-burying beetles. To put it another way, it has mountains of dung contaminating forage and only mainly introduced pastoral earthworms active during autumn–spring to remove it as part of a natural nutrient cycle process. It lacks the sort of process found in environments where the ungulates we bred our domesticated varieties from originated, and coevolved with dung-burying beetles. A tropical species, *Copris insertus*, was deliberately introduced to New Zealand between 1955 and 1958 but only established at Whangarei in the North, probably due to poor climate matching. Two accidentally introduced Australian onthophagines (*Onthophagus granulatus* and *O. posticus*) are widespread but have little impact, presumably because of their small body size (5–7 mm) and low population densities, and the fact that they are faced with an estimated 113 million tonnes of cattle dung dumped on pastures each year.

Losey and Vaughan[1] formulated *conservative* estimates that services provided by dung beetles alone are worth approximately US$380 million annually to the US economy (to put that in context, the USA has almost 100 million head of cattle in production per year, while New Zealand has some ten million). Faced with these figures, Landcare Research scientist Shaun Forgie has been casting calculating looks across the Tasman Sea to Australia, where CSIRO (Commonwealth Scientific and Industrial Research Organisation) undertook a successful Dung Beetle Project to establish breeding populations of exotic dung beetles, mainly from southern Africa, that bury ungulate dung rapidly in order to reduce dung-breeding pest flies, minimize forage fouling and thus increase pasture productivity (amongst other things). Many countries have had similar success with establishing exotic fast-burying dung beetles because their native beetles are often not adapted to either man-made pastoral environments or dung from exotic pastoral livestock.

Potential environmental and economic benefits of introducing a multitude of exotic fast dung-burying beetles are far wider than just removing dung. They would include:

• *Improved soil health and reduced runoff.* Increased aeration and water penetration into the soil, through beetle tunnels (in addition to earthworm burrows), reduces urine and liquid dung runoff, reducing microbial contamination, leachate pollution, and eutrophication of waterways.

- *Reduced nitrous oxide emissions.* Herbivore excreta account for 50% of New Zealand's anthropogenic N_2O emissions and 80% of the nitrogen content of dung is lost by volatilization when dung remains on the pasture surface, compared to only 10% following burial by dung beetles.
- *Greater pasture productivity.* Stock will not graze around dung pats, increasing forage foul and reducing pasture productivity. Dung burial by dung beetles reduces forage foul and enhances grass growth, reducing reliance on fertilizer inputs. Fertilizer is the biggest single item of working expenses on most sheep, beef and dairy farms.
- *Reduced fly pests and human disease.* Nuisance flies breed in dung. New Zealand has a very high rate of seasonal, sporadic campylobacteriosis compared to other OECD (Organisation of Economic Co-operation and Development) countries, with up to 14,000 cases reported each year. Cattle dung and flies are believed to be the main source and vector of this disease. In Hawai'i, introduced dung beetles reduced fly emergence from dung by 95%.
- *Reduced infection by parasitic worms of livestock.* Dung burial removes the infective stages of parasitic worms of livestock.

Together with Landcare Research's Hugh Gourlay, Dr Forgie, who says he completed an MSc and PhD on dung beetle research with the express aim of cleaning up New Zealand's pastures one day, is preparing an application for start-up funding for a New Zealand dung beetle project. The aim is to draw together a team with diverse expertise in dung beetle ecology, eco-climatic modelling, risk assessment, nematode epidemiology and soil processes to determine which exotic dung beetles might be appropriate for introduction into New Zealand and to collect quantitative pre-release data so that the impact of dung beetles on ecosystem processes can be assessed after their release. An additional feature would include assessing the impact of introduced dung beetles on the native dung beetles and introduced pastoral earthworms.

A sheep, beef and dairy farmer community collective will apply for the importation and full release of a suite of exotic dung-burying beetles through the Environmental Risk Management Authority (ERMA) which will include full tribal Maori consultation. The collective will seek financial support from the Sustainable Farming Fund for Landcare Research, as science providers, to advise on the application and, if the application is successful, species selection, and conduct mass-rearing and distribution of dung beetles. If all goes well and ERMA permission is obtained, Dr Forgie could begin to fulfil his dream and import breeding stocks of the first few species and begin quarantine, mass rearing, and monitored release at selected sites.

Dr Forgie envisages that the project will take 10–15 years. From small beginnings, via funding initiatives from an end-user committee to start the project, he believes that once the project is in the mass rearing phase it will expand to a full nationwide release programme with additional funding sources from farming groups and agricultural organizations.

[1]Losey, J. & Vaughan, M. (2006) The economic value of ecological services provided by insects. *BioScience* **56**(4), 311–323.

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IPM Systems

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

Glyphosate Could Help Water Hyacinth Biocontrol

Despite extensive research into the biological control of water hyacinth (*Eichhornia crassipes*) in South Africa, attempts to use biological control against the weed remains inadequate in some circumstances. The worst problems are encountered in:

- 'Highveld' areas, where low winter temperatures slow the development of *Neochetina eichhorniae* and *N. bruchi* weevils, the main biocontrol agents in South Africa.
- Excessively eutrophic waters, in which water hyacinth plants proliferate and grow at rates that the biocontrol agents cannot match.

In both circumstances, when water hyacinth escapes from biocontrol those charged with controlling the weed turn to herbicides. These kill the weed efficiently, but this causes weevil populations to crash, which means that when new water hyacinth plants sprout from seed, there are no weevils to exert control, so herbicide has to be used again. To counter this problem, researchers recommend leaving substantial areas of untreated weed as refuges for the weevils. This requires planning and management at levels not always possible in South Africa.

Interest has therefore focused on whether sub-lethal or retardant doses of herbicide can suppress weed in these situations while allowing biocontrol agents to survive. Previous published work has shown that the glyphosate formulation Roundup® is neither lethal nor a growth retardant for *Neochetina* weevils. A new study reported in the November 2008 issue of *Biological Control*[1] describes how a 0.8% dose of the broad-spectrum herbicide glyphosate retards vegetative growth but allows weevil populations to be maintained.

Outdoor container experiments conducted at Witswatersrand University, Johannesburg, indicated that 0.8% glyphosate retarded water hyacinth ramet production and suppressed leaf growth, while lower concentration had no significant effect and higher concentrations (1.0% or more) killed the plants. Subsequent experiments demonstrated that weevils on plants sprayed with 0.8% glyphosate not only had similar numbers of larvae to control (unsprayed) plants at the end of eight weeks, but their impact on the plants, in terms of feeding scars and petiole mining, was actually greater than on the unsprayed plants at day 60.

Drawing on other published work, the authors suggest the increased feeding observed on the sprayed plants could be related to glyphosate-related plant changes such as inhibition of feeding deterrent production, increased sugar content, or decreased leaf and petiole hardness. They note that the presence of early instar larvae mining the petioles indicates that the weevils' reproductive capacity was not compromised by herbicide treatment, while the palatability and suitability of the sprayed plants allowed the weevils to persist despite fewer oviposition sites (i.e. fewer leaves owing to the herbicide's retardant effect).

The authors say that South African ecosystems are characterized by 'boom and bust' water hyacinth populations in which biocontrol agents are unable to build up damaging numbers. They argue that the integration of a retardant dose of glyphosate with biological control offers a potential tool for sustainable control of water hyacinth at sites where neither biological control nor chemical control have so far achieved this. Low-dose herbicide treatment of a water body would suppress water hyacinth plant growth while allowing the water hyacinth mat to persist as a habitat for immature and immobile stages of the weevils. Adult populations could thus build up to levels where they could inflict damage, and particularly as the water hyacinth plant growth would have been retarded by the low-dose herbicide treatment. The next step, they say, is to try their integrated approach under natural field conditions.

[1]Jadhav, A., Hill, M. & Byrne, M. (2008) Identification of a retardant dose of glyphosate with potential for integrated control of water hyacinth, *Eichhornia crassipes* (Mart.) Solms-Laubach. *Biological Control* **47**(2), 154–158.

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Breakthrough in *Metarhizium* Formulation

Scientists with the US Department of Agriculture – Agricultural Research Service (USDA-ARS) have developed a method that triggers microsclerotia production in the entomopathogenic fungus, *Metarhizium anisopliae*. Sclerotia – compact mycelial aggregations – are produced by many plant-pathogenic fungi as overwintering propagules but this is the first time they have been reported in *Metarhizium*. The advantage, from the point of view of the biopesticide manufacturer, is that this form of the fungus can survive drying and storage.

For more than a decade, *Metarhizium*-based biopesticides (such as BioCane™ for control of sugarcane grub in Australia, Destruxin™ for controlling a variety of insects in South America, or Meta52™ for control of Coleoptera in managed turf and horticulture in the USA) have been formulated using spores, such as conidia, produced by solid-substrate fermentation of the fungus. The abundant conidia produced by this method are collected and dried before being formulated (e.g. coated onto corn-grit granules), or mixed directly into the soil. The mass-production system is time-consuming and labour-intensive. Alternatively, spent solid substrate can be saved after removal of the conidia and used directly as a granular carrier. However, it is often inappropriate in size and shape for use in general agriculture. Other mycopesticides based on the fungal mycelium or blastospores (hyphal bodies formed during liquid media) have suffered from poor shelf life and high costs.

Microbiologist Mark Jackson (USDA-ARS National Center for Agricultural Utilization Research, Peoria, Illinois) and entomologist Stefan Jaronski (USDA-ARS Northern Plains Agricultural Research Laboratory, Sidney, Montana) discovered that *Metarhizium* could form microsclerotia in 2004 (although they were unable to achieve this with other entomopathogenic fungi including *Beauveria bassiana* and *Paecilomyces fumosoroseus*). Since then they have developed a patent-pending method of mass-producing billions of *M. anisopliae* microsclerotia in liquid fermentation, inside giant vats, or 'fermentors'. They have also shown that using microsclerotia instead of conidia can cut the costs and time involved in preparing granules of the fungus for use against soil dwelling insects and can significantly improve its shelf life and efficacy.

The mode of action on the target insect remains the same, because once in the soil the microsclerotia readily produce conidia. An insect crawling through soil seeded with the microsclerotia will bump into one or more concentrations of conidia. The conidia attach to the insect's cuticle and germinate soon after. The germinating fungi use a combination of mechanical pressure and a cocktail of enzymes to breach the cuticle and invade the insect's circulatory system within 24 hours. The insect usually succumbs to the fungus with a few days.

Discovery of the fungus' capacity to produce microsclerotia came from Jaronski's work aimed at developing a *Metarhizium*-based biopesticide for control of soil-dwelling insect pests. Joint research in Peoria and Sidney indicated that three US isolates and one Canadian isolate of *M. anisopliae* all produced microsclerotia in liquid culture under certain conditions, with strain F52 producing highest concentrations. *Metarhizium* strain F52 is the chief active ingredient in four US-registered mycoinsecticide products for controlling soft-bodied ticks and certain beetles/weevils.

Experiments using the sugarbeet root maggot (*Tetanops myopaeformis*) as a model system revealed clear superiority of the microsclerotial granules over conventional granules (conidia on a nutritive carrier such as corn grits or spent solid substrate). The microsclerotia have several advantages. Commercial quantities of microsclerotia can be produced in about four days, while it takes at least two weeks to produce equivalent quantities of conidia plus time to formulate them as granules. The microsclerotia can be simply air dried; expensive processes such as freeze drying are not required. *Metarhizium* on nutritive granules or spent solid substrate from conidia production typically takes 7–10 days to grow and resporulate after being applied to soil, while air-dried granular microsclerotia-based formulations germinated within four days and produced greater numbers of spores. In addition microsclerotia can hydrate and produce conidia at lower soil moistures than the other two formulations. Another factor may be the large numbers of microsclerotia that can be produced and applied to the soil.

A big advantage of microsclerotia formulations over conidia-based formulations is that they can be formulated into granules sized to be readily compatible with farmers' seed planters and pesticide granule applicators (spent substrate granules, for example, are the wrong size and shape and must be pulverized before most farmers' use; this process often severely damages the fungus). Microsclerotial granules also qualify more readily for the organic crop market, whereas many binders used with conventional granular carriers disqualify them or cause short shelf life. The microsclerotial preparation retained viability for at least one year at 20–25°C when stored dry and *in vacuo*.

Jaronski has been working with North Dakota State University scientists in Fargo since 2004 to assess the field efficacy of conidia-coated corn-grit granules of *M. anisopliae* strain F52 against the sugarbeet root maggot, which is the biggest pest of this crop in the USA. Results have been encouraging. At low pest pressure, the biopesticide was able to control maggot pests as effectively as the synthetic insecticide terbufos. At higher pest pressure it was effective when used as part of an IPM strategy in combination with oat or rye cover crops.

In 2006, Jaronski began comparing the conidia-on-corn-grit granules with microsclerotia-based ones derived from the liquid-culture method, for which USDA-ARS filed a patent in September 2007. In laboratory assays, some 25% of sugarbeet root maggots exposed to the spores produced on corn-grit granules in non-sterile clay soils routinely die by the third week. In soil treated with a like weight of microsclerotia, 100% were dead in the first week. These observations reflect the faster and greater conidia production by microsclerotia in soil. During 2007 and 2008 field trials, sugarbeets in microsclerotia-treated plots also suffered fewer scars from maggot feeding.

The development of a liquid culture method for producing high concentrations of microsclerotia provides a novel approach for the control of soil-dwelling insects using microsclerotial preparations of *M. anisopliae*. The technique is applicable not just to sugarbeet root maggots, but to any soil-dwelling pest attacked by *M. anisopliae,* so has great potential for this sector of the biopesticide market.

This research is part of the ARS national programmes Crop Protection and Quarantine (#304) and Quality and Utilization of Agricultural Products (#306).

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Main source: Suszkiw, J. (2008) Multiplying *Metarhizium. Agricultural Research* **58**(8), September 2008.
Web: www.ars.usda.gov/is/AR/

Also see:
www.ars.usda.gov/Research/docs.htm?docid=10525

Invasive Mosquito Targeted by IPM Project

A new project in the USA is targeting the Asian tiger mosquito (*Aedes albopictus*), an invasive pest and potential health risk. The project is funded by the Northeastern IPM Center, which is jointly administered by Pennsylvania State University (lead institution) and Cornell University.

The Asian tiger mosquito first appeared in the USA in Texas in 1985 on a shipment of tyres from Japan. Within a decade, it had spread to 30 states and across the northeast of the country. Easily identifiable by its black body with distinctive white stripes, the invasive species differs from most/other nuisance mosquitoes in the USA in being a day-biting mosquito, which puts limitations on control measures that target the adult (effectively ruling out synthetic insecticides). Its spread is causing particular alarm because it has the potential to spread human diseases such as West Nile virus, dengue fever and chikungunya fever, and heartworm in dogs.

The IPM project will include low volume (LV), or area-wide spraying of *Bti* (*Bacillus thuringiensis* var.

israelensis) against larval stages of the mosquito. Although *Bti* has been widely deployed against mosquitoes, it is applied directly to water bodies where larvae are/may be found in a liquid, briquette or granular formulation, by hand or via aerial drop/spray over large areas. However, it is difficult if not impossible to identify and treat all *A. albopictus*' breeding sites. The Asian tiger mosquito will develop in almost any container that holds standing water: piles of tyres and discarded household items such as cans, as well as permanent urban/home features such as storm drains and catch basins, ponds, water butts, bird baths, flowerpots, gutters – and even cemetery urns. George Hamilton, Professor of Entomology at Rutgers University (New Jersey) and project coordinator, says they are hoping LV delivery will allow the *Bti* to drift and settle into sites where larvae reside, providing a quick, efficient and cost effective control

Hamilton and his colleagues plan to use truck-mounted ULV equipment typically used by mosquito control programmes to apply synthetic insecticides in urban residential settings against adult mosquitoes. This approach, he says, should reduce the abundance of the Asian tiger mosquito, the dependence on broad-spectrum pesticides, non-target impacts, and pesticide resistance. They are currently testing *Bti*'s effectiveness in both field trials and 'real world' conditions. First trials have given excellent results and they are now tweaking the equipment to maximize the area they can cover.

Hamilton says they will also prepare workshops and print and web-based materials to train mosquito control personnel throughout the region and beyond in the use of the technology. All training materials will be made available on the Rutgers Center for Vector Biology's website (see below).

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Role for Biopesticides in Promoting Healthy Eating

With increasing consumer pressure on both farmers and supermarkets to minimize the use of chemical pesticides in fruit and vegetables, a newly published study funded by the UK Economic and Social Research Council (ESRC) explains some reasons why there is currently little use of biological alternatives in the UK. It also points out how biopesticides, by improving consumer confidence in food, could promote healthy eating.

The three-year study 'Biological alternatives to chemical pesticide inputs on the food chain: an assessment of sustainability' was conducted by Professor Wyn Grant, Dr David Chandler, Professor Mark Tatchell, Dr Justin Greaves and Gillian Davidson at the University of Warwick, Department of Politics and International Studies, as part of the Rural Economy and Land Use (RELU) programme.

The researchers interviewed regulators, biopesticide manufacturers, farmers, retailers, European Union (EU) officials and environmental groups, while soil samples were collected from eight English counties to assess the biological diversity and biogeography of natural populations of insect pathogens in the soil. The study brought together team members from different disciplines. Attendees at two one-day conferences included an American biopesticides manufacturer, an environmental group, a leading UK food retailer and the Pesticides Safety Directorate (PSD).

The study found that biopesticides can play a significant role in a more sustainable food chain at a time when chemical pesticides are being withdrawn owing to resistance problems or because they are no longer commercially viable. Chemicals also endanger workers' health and can contaminate groundwater. The bar for chemical pesticide registration looks likely to be raised further within the EU with revisions to Directive 91/414 threatening to severely limit agrochemicals permitted for use in EU countries, and with Regulation EC/396/2005 and its annexes coming into force in September 2008, which places strict limits on maximum residue levels for pesticides in food for human or animal consumption.

Lead researcher Professor Wyn Grant described the potentially important contribution biopesticides could make to a competitive agriculture industry. He pointed out that they have the potential to increase consumer confidence in fruit and vegetables whilst moving away from a polarized and over-simplified choice between conventional and organic modes of production. The research suggests that consumer concerns about toxic residues could undermine the recommended 'five a day' target for the consumption of fresh fruit and vegetables. Supermarkets have responded to consumer pressure by banning some approved pesticides, but have been slow to embrace biopesticides.

Biopesticides are applied in much the same way as chemical pesticides to fight insect pests, but have advantages over them: they have few non-target impacts, are compatible with other natural enemies, do not leave toxic residues and are relatively cheap to develop. As these benefits outweigh their disadvantages – lower effectiveness and a shorter shelf life – why has there been poor uptake of biopesticides in Britain?

Because the regulatory system in the UK was developed with chemical pesticides in mind, which does not encourage the development of biopesticides, the regulator – the PSD – lowered registration fees and created a Biopesticides Champion in 2006. The study found that this has led to a modest increase in the number of biological products being registered, with others in the pipeline.

The researchers pinpointed a lack of mutual recognition between EU member states as a key reason why the USA has a much higher rate of biopesticide use. This makes it hard for the small companies – often start-ups – that usually develop biopesticides to obtain economies of scale. These issues were addressed by the EU Policy Support Action REBECA (Regulation of Biological Control Agents), which reported earlier this year with proposals for improvements in the registration process for biological control agents in Europe (see: www.rebeca-net.de).

New chemical formulations could be used to solve problems with biopesticide storage and efficacy and this might lead to greater interest from large businesses, the study says. Biopesticides need to be fitted into current environmental stewardship schemes to provide incentives for their use. Moreover, consumers need to be educated about biopesticides – and they should be given a different name with less negative connotations; 'Natural Controls' is one suggestion. The researchers also suggested providing an ethical marque for products.

Importantly, risks, costs and benefits need to be shared out between the manufacturer, regulator, government and consumers. The researchers also propose a framework to promote innovation within the regulator, including pressure from central government, the appointment of key individuals to drive through change, the need for regulators to develop their expertise, and commercial or financial pressure.

The researchers noted that the absence of a Europe-wide market for biopesticides is a significant obstacle to their wider commercial availability, though moves are underway to remedy this. They also pointed to 'patchy' interaction between the regulator and retailers, and a lack of involvement of environmental groups, which they put down to indifference rather than hostility.

At European level, the project was presented to a steering group of the European Commission. The findings will be published as a book by CABI.

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Biopesticide from Knotweed Launched

While research is making progress on the classical biological control of Japanese knotweed (see 'Weed biocontrol in Europe: end of the wilderness years?', this issue), another knotweed, *Fallopia sachalinensis* (formerly *Reynoutria sachalinensis*) or giant knotweed, is the source of a biopesticide for crop diseases recently launched by Marrone Organic Innovations (MOI; California, USA). *Reynoutria sachalinensis* is native to eastern Asia, and was introduced into Europe and North America in the nineteenth century for growing as cattle fodder.

The origins of the new product lie in an initiative launched by the German company BASF in the early 1990s, under which large numbers of plant extracts were screened for fungicidal properties. The most promising was a dried extract of *R. sachalinensis*, which was developed in the USA by North Carolina-based KHH Biosci Inc. as Milsana®. The product was approved by the US Environmental Protection Agency (EPA) for use on ornamental plants grown in greenhouses.

In early 2008, MOI bought the assets of KHH, including patents, trademarks, EPA registrations, formulation and manufacturing technology, and field trial data. This allowed it to develop a new *R. sachalinensis* product, which it is marketing as Regalia® SC and was launched at the annual convention of the Florida Fruit and Vegetable Association in September. MOI say that the new biopesticide is a powerful control tool for both fungal and bacterial disease in a wide range of fruit, ornamental and vegetable crops. In developing the new product, they have made it more flexible for tank mixes and added more crops to the label, particularly for California (pepper, tomato, grape *Botrytis*) and Florida (citrus). MOI also have an organic formulation pending with EPA.

The mode of action involves induced resistance: Regalia elicits activation of the sprayed plant's internal defence system, inducing the following responses: (a) an increase in the production of reactive oxygen species, (b) an increase in the production of enzymes of the phenolic pathway, (c) promotion of lignification of cell walls (strengthening/hardening), (d) inhibition of papilla formation, and (e) an increase in the production of phytoalexins. Together these inhibit development of fungal and bacterial disease-causing organisms.

According to MOI, Regalia's unique mode of action provides the same level of control expected from conventional fungicides and fits well into disease management strategies. The company cites the results of more than 100 trials that have shown its efficacy against crop diseases such as powdery mildew, bacterial diseases, rusts, grey mould and other crop diseases. Initially, Regalia is available for use on vegetables and ornamentals, but for 2009 MOI are focusing on introducing it for grapes, tree fruits and other crops.

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Training News

In this section we welcome articles about 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.

Farmer Attitudes to Biocontrol in Strawberry IPM

Although the importance of knowing the target market is a critical element in new product design, this has not, in general, been recognized by scientists developing pest management programmes centered on the use of biological control agents (BCAs). Yet, as a study published in the November 2008 issue of *Biological Control* indicates, consideration of the socioeconomic environment and understanding farmer attitudes can help identify problems and needs to be addressed – and perhaps predict in which systems adoption of BCAs is likely to be most successful[1].

The team, from Italy and Israel, used a semi-structured questionnaire, with closed- and open-ended questions (translated into local languages) to investigate farmer perceptions and experiences about BCAs in strawberry IPM programmes in three regions:

- *Trentino Province, Italy (in autumn 2004)*: Farmers have the longest experience of using IPM in strawberry among the groups in this study. Farms tend to be small (50% are <0.5 ha) but few are devoted solely to strawberries, and most farmers are organized in cooperatives. Almost all strawberries are grown in soil-less substrate in high polyethylene-tunnels in April–October for the domestic market. The most important pest/disease problems are powdery mildew (*Podosphaera aphanis*), *Phytophthora* and mites (*Tetranychus* spp.).
- *Sharon area, Israel (in spring 2006)*: Farmers have experience of strawberry production but IPM has been introduced relatively recently. Farms are larger than in Italy (67% are 2–5 ha) and farmers tend to be affiliated with growers' associations and through them with marketing companies. Most strawberries are grown in low polyethylene-tunnels and harvested in late winter for the export market. The most important pest/disease problems are powdery mildew, then *Colletotrichum* and mites.
- *North Rhine-Westphalia, Germany (in spring 2007)*: Farmers have long experience of IPM in other crops but are relatively new to strawberry growing. Farmers are not organized into cooperatives but sell direct to consumers/wholesalers. Strawberries are almost all grown in open fields in spring and summer, and for the domestic market. The most important pest/disease problems are *Botrytis cinerea*, *Phytophthora* and mites.

Strawberry was an interesting crop to investigate for at least two reasons: it has the highest value per hectare of any outdoor horticultural crop, and it has also been rated as one of the six crops most tainted by pesticides. Strawberry is indeed attacked by a long list of pests and pathogens, and two dozen BCAs have been commercialized for use on the crop.

The survey investigated the level of knowledge of BCAs and factors influencing growers' confidence in them, their use in current IPM programmes and problems encountered, and strategies that could increase the adoption of BCAs in IPM programmes.

Level of Knowledge

Growers in all three regions identified some common features of BCAs in strawberry IPM: less environmental impact, but also higher crop monitoring costs, greater sensitivity to weather conditions, and slower and weaker impacts than synthetic pesticides. Both Israeli and Italian growers thought BCAs were safer for growers to apply and gave a healthier product, but were more costly, either in direct costs, or indirectly in terms of labour for monitoring and/or release. However, even though the Italians recognized positive health aspects of BCAs for growers, they did not correlate these with absence of pesticide residues. Conversely, German growers recognized the absence of chemical residues but did not recognize the product as healthier as a consequence; in fact, the Germans did not equate BCAs with any impacts on their own health, possibly because the safety regulations applied in Germany are strict enough that farmers do not consider pesticides to be linked with human harm. Israeli growers, on the other hand, did link absence of pesticide residues with a healthier product, probably because their production is exported to the UK and detection of chemical residues can result in product rejection. Of the three groups, Italian growers were most risk averse, and were alone in expressing concern about a shorter product shelf-life.

The main sources of information identified were other growers, extension agents and agricultural journals, followed by the popular media. In Italy and Germany, predators and nematodes were the best known BCAs (along with pheromones), while predators and bioinsecticides were best known in Israel.

Confidence in BCAs

Confidence was higher in Israeli growers than in either of the other groups, and more Germans than Italians mistrusted BCAs. Nonetheless, many sceptical growers used them in all three countries. In Italy and Israel, growers' own experience and suggestions from cooperatives/growers' associations had most influence on confidence in BCAs, while in Germany word-of-mouth and advertising had most impact.

The high confidence in Israeli growers was linked to positive efforts by extension services and the growers' association to involve growers via demonstration projects, sharing positive experiences, etc. Relative lack of confidence in Germany was linked to lack of experience and fear of losses related to low efficacy; other minor factors included belief that chemicals are better, limited promotion of BCAs, and negative personal experiences.

A statistical analysis of responses regarding growers' confidence suggested that this was significantly influenced by media as an information source, years of farming experience (which showed a modest negative effect in decreasing the probability of trust in BCAs: experienced IPM growers were less likely to trust an 'experimental' approach than an alternative tried-and-tested IPM technology), and, most importantly, the recognition of the positive characteristics of BCAs regardless of the negative characteristics. The authors suggest this latter feature is perhaps because growers perceive that social and environmental benefits outweigh such negative aspects as higher costs and risk of yield loss, but say it needs more investigation.

The authors argue that lack of confidence, where it existed, stemmed at least partly from limited promotion of BCAs by research centres and biocontrol companies, which is itself a reflection of the fact that most companies producing BCAs are small-to medium-sized enterprises not in a position to fund market development.

Current Use of BCAs

Growers used BCAs to control similar problems in all three countries although the relative usage varied. In Italy, weevils (*Otiorhynchus*) were the commonest target with mites and thrips second; in Germany mites and thrips were the main targets, with weevils second (but BCAs were used only in protected cultivation, which is a minor part of the overall production); and in Israel all surveyed farmers used BCAs for mites, and a very high proportion used them for aphids and thrips. Satisfaction, however, was different in the three regions, with significant differences between Israel (positive) and Italy (less so), with Germany intermediate between them.

Problems Encountered

Practical problems with the use of BCAs included failure to achieve total control, their sensitivity to weather conditions, the need to apply them at a specific time and to monitor pest and crop, and higher costs. While these problems were common to all regions, their relative importance varied. Italians complained most about time for monitoring, which they consider as "wasted" (attributed to the fact that they work only part-time on their farms); Israelis complained about lack of total control of problems, and also effects of weather on efficacy; and Germans gave equal weight to effects of weather, incomplete control, higher costs, and absence of product warranty.

Strategies to Increase Use

Strategies aimed at increasing adoption varied between the three countries as a result of socioeconomic conditions, farm management and organizational structures, and the presence/absence of cooperatives. Israel has introduced IPM in strawberries most recently, and has had marked success with use of BCAs increasing on an area basis from <1% in 1997 to 67% in 2003, coupled with a 30% reduction in insecticide applications over this period, and increased fruit consumption and farmer incomes. Several strategies were used, but ones perceived as most important by growers were advertising that highlighted differences in the BCA-treated product to consumers, and government intervention in the form of a subsidy that helped reduce costs and risks to growers from changing pest control methods, together with free technical support (which the government later began to charge for); these allowed an increase in the price of strawberries and guaranteed a fair profit.

In Italy strawberries were already produced under IPM so introduction of additional BCAs did not produce any perceivable difference for consumers. So Italian growers felt subsidies to cover additional costs was by far the most important strategy for promoting expansion, with free technical support coming next. In Germany, lack of a growers' association may explain low uptake of BCAs. German growers felt an increase in product price would most help adoption, followed by subsidies and free technical support.

Conclusions

The authors conclude that the agricultural system had a marked effect on attitudes, with a strong infrastructure in the form of growers' organizations and expert advisers, a well-planned pest control programme and a network for disseminating trial results all likely to increase growers' knowledge of BCAs and facilitate their use in IPM programmes. They argue that better results in terms of spreading the use of sustainable practices are obtained when government actively promotes adoption of BCAs by providing and disseminating information and expert advice rather than providing subsidies.

Notwithstanding the generally good levels of satisfaction encountered during the study, the authors end the paper by identifying areas for improvement if BCAs are to be better integrated into IPM programmes in strawberries, including increasing the efficacy of the BCAs, and improving dissemination of information among growers and consumers.

[1]Moser, R., Pertot, I., Elad Y. & Raffaelli, R. (2008) Farmers' attitudes toward the use of biocontrol agents in IPM strawberry production in three countries. *Biological Control* **47**(2), 125–132.

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Announcements

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

Montpellier ISBCW Proceedings

The Proceedings of the XII International Symposium on Biological Control of Weeds have been published. The volume contains over 250 papers and abstracts presented at the symposium, under the following themes: 'Ecology and modelling in biocontrol of weeds', 'Benefit/risk and cost analyses', 'Target and agent selection', 'Pre-release specificity and efficacy testing', 'Regulations and public awareness', 'Evolutionary processes', 'Opportunities and constraints for the biological control of weeds in Europe', Release activities and post-release evaluations', and 'Management specifics, integration, restoration and implementation'.

Julien, M.H., Sforza, R., Bon, M.C., *et al. Proceedings of the XII International Symposium on Biological Control of Weeds.* CABI, Wallingford, UK, 768 pp. Price: UK£75/US$150/€100. ISBN: 978 1 84593 506 1

Codling Moth Granulovirus Review

Codling moth, *Cydia pomonella*, is regarded as the most serious insect pest of apple worldwide. A review of a biopesticide widely used against it has been published in *Biocontrol Science and Technology*.

Most growers use broad-spectrum insecticides to control codling moth, but alternatives are being developed as part of the drive to reduce synthetic pesticide use. One of the most effective non-chemical means of control is a virus that is specific for codling moth and closely related pest species, codling moth granulovirus (CpGV). The virus was first isolated in Mexico and subsequently studied and evaluated in Europe and North America. Commercial products of CpGV are now produced in Europe and North America and used by growers worldwide. The authors of this paper reviewed world literature on research and use of the virus to produce an organized and extensive source of information on CpGV and its role in integrated pest management.

Lacey, L.A., Thomson, D., Vincent, C. & Arthurs, S.P. (2008) Codling moth granulovirus: a comprehensive review. *Biocontrol Science and Technology* **18**(7), 639–663.

Microbials in Temperature Orchard IPM

The note above gives us a belated opportunity to highlight the excellent review of the potential for microbial control agents (MCAs) in temperate orchard IPM, which appeared in this year's *Annual Review of Entomology*. The authors review briefly the groups (viruses, bacteria, fungi and entomopathogenic nematodes) and the main taxa within them that are used in orchard IPM, and then tackle the topic on a crop and target pest basis.

They summarize the use of the granulovirus against codling moth, referred to above, in organic apple and pear orchards and note that interest in the technology is growing amongst conventional growers. However, they say that *Bacillus thuringiensis* is the most extensively used MCA for control of lepidopteran orchard pests. Among other groups, they point to the significant use of nematodes in citrus for control of root weevils. Nonetheless, they find that despite these successes, in most orchard systems MCAs account for a relatively small proportion of the pest control tactics employed, and in some systems they are not used at all. They identify two important factors for improving use of MCAs: (a) selecting the most effective MCA for a given pest and habitat relies on thorough understanding of the biology and ecology of pest and pathogen and the orchard agroecosystem into which it will be applied, and (b) MCA efficacy is likely to be enhanced through formulation and optimum timing of applications, but orchard redesign to improve activity and persistence of MCAs may also increase efficacy.

Lacey, L.A. & Shapiro-Ilan, D.I. (2008) Microbial control of insect pests in temperate orchard systems: potential for incorporation into IPM. *Annual Review of Entomology* **53**, 121–44.

ISBCA 2009 Approaches

Hard to believe, the time has flown, but the Third International Symposium on Biological Control of Arthropods is almost upon us. It is being held in Christchurch, New Zealand on 8–13 February 2009 with the theme 'Maximising success while minimising risk'. Sessions will cover: 'New and emerging successes in biological control: has theory improved practice?', 'Biocontrol and environmental/climate change', 'Exploring biological control to manage new or potential invasive alien pests', 'Molecular tools in biological control of arthropods', GMOs and biological control', 'Impact of landscape composition and structure on natural enemies', 'Recent advances in conservation biological control', 'Omnivory in biocontrol', 'The role of theory in greenhouse control', 'Biological control of phytophagous mites – theory and practice', 'Attributes of exotic biological control agents: good and bad', 'Inducible plant responses and their impact on biological control of plant pests', 'Food web interactions and impact on biocontrol', 'Progress and prospects to assess predation', and lastly 'Capacity building through action learning in region-wide biological control'.

The symposium will host a closing debate on the last day, Friday 13 February entitled, 'Genetically modified organisms should have no role in biological control'. The debate leaders will be Prof. Miguel Altieri, University of California, Berkeley, USA and Prof. Tony Shelton, Cornell University, USA. (And this leads neatly to the next announcement.)

However, before moving on, a mention for a post-conference workshop on vinecology (16–17 February) at Lincoln University near Christchurch, led by Steve Wratten of Lincoln University, New Zealand and Miguel Altieri. Worldwide, vineyards occur largely in Mediterranean biomes, which are biodiversity-rich. Vineyards are traditionally monocultures and destroy most original diversity, especially that associated with the ecosystem service which is biocontrol. There is a current trend for many vineyards to extend onto hillsides, increasing biodiversity loss. This workshop will explore how ecosystem services can be restored to and integrated into working viticultural landscapes.

Further details on the conference website:
Web: www.isbca09.com

Ecological Impact of Genetically Modified Organisms

The Fourth Meeting of the IOBC/WPRS (International Organization for Biological Control – West Palaearctic Regional Section) Working Group, 'GMOs in Integrated Plant Production' takes place in Rostock, Germany on 14–15 May 2008, organized by BTL Bio-Test Laboratory (Sagerheide), BioOK (Rostock) and institutes of the University of Rostock.

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International Bioherbicide Workshop 2009

You can now register online for the 2009 Weed Science Society of America (WSSA) annual meeting and the International Bioherbicide Group (IBG) workshop. The WSSA meeting is in Orlando, Florida, USA, on 9–13 February 2009, and the IBG workshop is being held just before it, on 8 February. One-day registration for the IBG workshop is available for those who cannot participate in the full conference (US$100) with a biocontrol field trip at an extra cost ($25).

The meeting brochure contains a condensed programme plus meeting information:
http://wssa.net/Meetings/WSSAAnnual/2009/WSSABrochure.pdf

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Integrated Control of Plant-feeding Mites

The IOBC/WPRS (International Organization for Biological Control – Western Palaearctic Regional Section) Working Group 'Integrated Control of Plant-feeding Mites', is holding its next meeting at the Experimental Institute for Agricultural Zoology (ISZA) in the Italian city of Florence on 12–13 March 2009.

Invited speakers and topics for presentations include: Carlo Duso and colleagues (University of Padua, Italy) speaking on 'Mite-fungi relationships in vineyards: implications for IPM'; Jim McMurtry (University of California, Riverside, USA), on 'The Phytoseiidae in biological control: relevance of taxonomic classification and life style categorization'; Jorge E. Peña (University of Florida, USA) on 'Predator–prey dynamics and strategies for control of the red palm mite (*Raoiella indica*) in areas of invasion in the Neotropics'; and Maurice W. Sabelis (Institute for Biodiversity and Ecosystem Dynamics (IBED) Amsterdam, The Netherlands) on 'Intraguild predation, displacement and biological control'.

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Induced Resistance in Plants

The IOBC/WPRS Working Group, 'Induced Resistance in Plants against Insects and Diseases', focusing on 'Induced resistance – chances and limits' will hold its next meeting on 12–16 May 2009 in Granada, Spain. The meeting will focus on 'chances and limits', particularly in multitrophic interactions, model systems and crop protection.

Contact: María José Pozo and Victor Flors.
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IPM and Food Safety Training Course

A course on 'Integrated Pest Management (IPM) and Food Safety' is being organized in Wageningen, the Netherlands on 18 May – 12 June 2009. The course includes two modules: 'Pesticides and food safety in IPM', and 'IPM policy and institutional innovations'.

Web: www.cdic.wur.nl/UK/newsagenda/agenda/Integrated_Pest_Management_and_food_safety.htm

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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 here.

SIP in Warwick

The 41st Annual Meeting of the Society for Invertebrate Pathology (SIP) and the Ninth International Conference on *Bacillus thuringiensis* were held at the University of Warwick, UK, on 3–7 August 2008.

This conference follows a pretty fixed pattern. After the opening ceremony a Founders Lecture honours a pioneer in the discipline of invertebrate pathology. This year it was André Paillot (1885–1944), with the lecture delivered by Johannes Jehle. Paillot was a scientist with broad interests, working with a range of pathogenic agents. He wrote various books, such as *L'Abeille – anatomie-maladies-ennemis* (very appropriate for this conference which focussed significantly on bee diseases), *'L'Infection – immunité et symbiose* and *Les insectes nuisibles – des vergers & de la vigne'*. This was followed by a Plenary Session on 'Honey Bee Colony Collapse Disorder'.

Subsequently the conference had a dozen symposia sessions covering topics as diverse as 'Microsporidia of Aquatic Arthropods' to 'Comparative Genomics of DNA Viruses'. There were the (usually) 15 minute contributed papers on fungi, microsporidia, nematodes, bacteria, viruses and microbial control, workshops, poster sessions and a student workshop – 'Spreading the Word: Skills for Communicating Science and Getting it Funded'. Sadly the last bit did not cover how to change the mindset of donors set against agricultural research. This was a useful workshop and included an excellent presentation on, appropriately, 'Delivering oral presentations'. This should not have been restricted to a Student Workshop as many experienced scientists would have benefited greatly from the advice given. Possibly conference organizers should restrict the number of slides per presentation.

However, there were many good presentations, even if they suggested little movement within the practical discipline and, perhaps, a feeling that biopesticides are not living up to their potential and should sink further back into niche use. This seemed to reflect a failure to learn from previous experience. With mycoinsecticides for example, many presentations were similar to those of 20 years ago, without benefiting from the advances in recent years.

There was an excellent symposium on 'Regulatory and Market Barriers for Approval of Microbial Control Products', unfortunately in the graveyard shift just before the banquet. This innovative session had stimulating presentations on 'Regulatory innovation and biopesticide commercialisation', 'Microbial control products: the regulatory challenge', 'Commercialisation of microbial control products: the industry perspective' and 'Understanding the adoption of alternative pest management strategies: an economist's view'. Mixing presentations from academics, regulators, the industry and an economist viewing from outside the discipline made, for me, the best symposium of the conference. It made up for what should have been a valuable symposium on 'Biological Solutions to Pest Control' which promised insights into commercialization from the industry. Biocontrol practitioners want their work adopted and company presentations should show the avenues to collaboration; this did not happen.

There were many good things to this conference; as always there was great support and encouragement for young scientists. It is small enough to keep track of people and there were many opportunities to meet with the famous names. It was also surprisingly expensive; three weeks later I stayed in a luxury hotel in Kyoto for significantly less per night than student accommodation at the University of Warwick. I am not quite at the stage of feeling exploited, but not too far off so I hope SIP is careful in the future. That slightly sour note aside, it was a good conference and hopefully will have stimulated further interest amongst the many young scientists attending for the first time.

By: Dave Moore, CABI

New Books

The US *Bemisia tabaci* Biocontrol Programme

When the B-biotype of *Bemisia tabaci* became a major pest in the USA in the 1980s and early 1990s, estimates of financial losses to various crops ran to billions of dollars. In Arizona, California, Texas and Florida losses during 1991 and 1992 ranged from $200 million to $500 million. The introduction to this book contains many other such staggering figures highlighting the impact of one of the worst insect pests in the history of agriculture. Among the reasons for the massive impact of *B. tabaci*, in particular the B-biotype, is its ability to transmit more than 100 plant viruses that cause devastating losses to many crops, including cotton, tobacco, soybean, vegetable crops and ornamentals. The immediate impact of *B. tabaci* on US agriculture prompted a concerted and well-funded campaign to search for effective, sustainable control measures for the pest, including classical biological control. This volume effectively summarizes the history and progress of that campaign, while saying disappointingly little about its outcome.

The book is divided into 18 chapters by 30 authors from various research institutes, mostly in the USA, and spanning 11 states. The states that were most badly affected by *B. tabaci*, Arizona, California, Florida and Texas, are particularly well-represented in the authorship.

Following the excellent introduction, which contains detailed summaries of financial losses, the foreign exploration programme for natural enemies of *B. tabaci* is described. Alan Kirk (one of the main protagonists of this episode and a remarkably effective field biologist), Lerry Lacey and John Goolsby describe how more than 235 collections from around the world were sent in 130 shipments to what was effectively 'Mission Control' for the campaign – the Mission Biological Control Laboratory (MBCL) in Texas. During this foreign exploration field parasitism, almost exclusively by *Encarsia* and *Eretmocerus* species, reached 44% and 67% in Spain and Thailand, respectively. At this point, 13 parasitoids and several predators were evaluated against *B. tabaci*. The authors recount how delays in shipping a sample of *Bemisia* from the cotton-growing area of Multan in Pakistan meant that by the time it reached Texas three weeks later the sample consisted of a bag of green slime –the decomposed leaf matter. With laudable persistence and determination, the MBCL staff salvaged from it 20 late-instar whiteflies from which a new species of *Eretmocerus*, *E. hayati* Zolnerowich & Rose, eventually emerged in sufficient numbers for it to be cultured and later successfully released.

An account of research on entomopathogenic fungi associated with *B. tabaci* (Lacey, Wraight & Kirk) is followed by two summaries on the most important parasitoid genera affecting *Bemisia* and other whiteflies. *Encarsia* (Heraty, Polaszek & Schauff) is a megadiverse genus of parasitoids, displaying a variety of complex biologies and morphologies and has attracted considerable attention from biologists in recent decades. This chapter presents a state-of-the-art overview of the genus. The following chapter, by Greg Zolnerowich and the late Mike Rose, deals similarly with *Eretmocerus*. Mike, to whom this volume is dedicated, was involved in the campaign from its outset. He was a greatly respected expert on biological control using parasitoids, and pioneered many laboratory techniques for rearing and maintaining cultures of natural enemies. He was also the world's leading expert on the genus *Eretmocerus*.

The subsequent chapter (Vacek, Ruiz, Ciomperlik & Goolsby) describes how the emergence and increased availability of polymerase chain reaction (PCR) technology in the 1990s coincided fortuitously with the characterization of parasitoid populations and species that were otherwise difficult or impossible to characterize using morphology. PCR and gene sequencing are now used almost routinely by systematists to describe and diagnose *Encarsia* and *Eretmocerus* species.

The following three chapters deal with parasitoid evaluation: in quarantine (Goolsby, Legaspi & Legaspi), in field cages in California (Hoelmer & Roltsch) and in the field in Texas (Ciomperlik & Goolsby). In summary, the most successful species to emerge from these trials were *Encarsia bimaculata* Heraty & Polaszek, *Encarsia sophia* (Girault & Dodd), the above-mentioned *Eretmocerus hayati* and *Eretmocerus mundus* Mercet. Mass-rearing of these and other parasitoids is dealt with in the next chapter (Simmons, Pickett, Goolsby, Brown, Gould, Hoelmer & Chavarria). The next four chapters cover releases and recovery of parasitoids in Texas (Goolsby & Ciomperlik), Arizona (Gould, Waldner, Colletto & Merten) and California (Roltsch, Hoelmer, Simmonds & Andress; Pickett, Simmonds & Goolsby). The final three chapters provide accounts of integration of classical biological control with traditional control (Simmons, Hoelmer & Natwick); multivariate analysis for measuring the impact of imported parasitoids (Andress, Quinn & Gould) and indigenous parasitoids and non-target effects of exotics (Hoelmer, Schuster & Ciomperlik).

The book concludes with an epilogue extolling the general virtues of classical biological control, and citing in detail the success of the importation of *Eretmocerus hayati* – the species that almost didn't make it – into Queensland, Australia. The summary that follows emphasizes the success of the project in terms of effective interagency collaboration, but is inconclusive with regard to the overall success of the programme. The final statement calls for detailed, quantitative evaluation of the impact of parasitoids of *B. tabaci* in all the release areas of the USA.

The editors are to be congratulated on compiling this highly instructive and comprehensive overview of one of the most extensive pest control programmes ever undertaken. The command and coordination of an army of 30 *Bemisia* specialists is a great achievement. The target, *B. tabaci*, was particularly complicated – literally a complex of species and populations with a large network of both indigenous and exotic natural enemies. Indeed the abundance of indigenous natural enemies of *B. tabaci* in the USA might have suggested that classical biological control may not have been the best strategy for this particular pest. However, the campaign appears to have met with some success, despite requiring further evaluation. Certainly *Encarsia* and *Eretmocerus* species have been highly effective in more straightforward classical biological control campaigns, such as those against *Siphoninus phillyreae* (ash whitefly) in the USA and *Aleurocanthus woglumi* (citrus blackfly) in the Caribbean. The importance of sound taxonomy, both morphological and molecular, as an indispensable aspect of such programmes, is emphasized in the present volume. At US$179 the book is expensive, but a very useful addition to the series and essential for those working in biological control or interested in other aspects of insect natural enemies.

*Gould, J., Hoelmer, K. & Goolsby, J. (2008) *Classical biological control of* Bemisia tabaci *in the United States. A review of interagency research and implementation.* Progress in Biological Control, Vol. 4. Springer, Dordrecht, The Netherlands, 343 pp. Hbk. Price: US$179.00/UK£95.00/€119.95.
ISBN: 978 1 4020 6739 6

By: Andrew Polaszek

Weeds CRC Publications on Classical Biocontrol

The Cooperative Research Centre for Australian Weed Management (Weeds CRC) has produced two new Best Practice Guides and four new Factsheets, to explain the core aspects of classical biological control against invasive plants.

The new publications outline and summarize results from several years of research undertaken by scientists within the Weeds CRC. These results have been published in numerous scientific papers over the years, including a special issue of the *Australian Journal of Entomology*. However the new publications summarize the main issues and findings for a non-specialist audience. They are intended for people with a general interest and involvement in the management of alien invasive plants, who may be aware of classical biological control as a possible management technique, but who lack specialist knowledge and may not have the time to read standard textbooks or scientific papers.

The four Factsheets respectively deal with *Agent selection*, *Host specificity testing*, *Agent release and establishment*, and *Impact evaluation*. Each briefly explains the particular issue, highlights core points and illustrates these with an Australian case study. Recent key references are listed for further reading, and a contact email address included for more information on each case study.

The two Best Practice Guides further develop the themes of *Release and establishment of weed biological control agents* and *Impact evaluation of weed biological control agents*.

The *Release and establishment* guide outlines ways to enhance agent establishment in order to increase overall efficiency of weed biocontrol programmes. The *Impact evaluation* guide highlights principles and approaches to measure the impacts of agents on target weed populations and to quantify the benefits for associated plant communities, ecosystems, the economy and society in general. Both guides give information on the main issues and difficulties encountered, with examples and a case study from recent Australian biocontrol programmes. There is a short list of references for further reading.

These new publications are available as pdfs from the Weeds CRC website: www.weedscrc.org.au/publications/weed_man_guides.html#bpgbio
and
www.weedscrc.org.au/publications/factsheets_guidelines.html

The policy of the Weeds CRC is to make the results of its research widely available to the community. Users are therefore welcome to translate or adapt these publications for their own education or training materials, so long as the Weeds CRC is adequately acknowledged as the source. The Weeds CRC was funded from 1995 to 2008 under the Australian Government Cooperative Research Centres Programme, with additional funding from several core partner organizations (see www.weedscrc.org.au for full list).

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