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General News

The Long and Winding Road: Tradescantia Biocontrol in New Zealand

A Landcare Research project that began eight years ago with the aim of controlling one of New Zealand's most widespread and problematic weeds, tradescantia (*Tradescantia fluminensis*), has reached a milestone with the release of the first biocontrol agent. Although plenty of natural enemies were identified in the plant's native range in South America, the most promising biocontrol candidates have not been easy to work with.

Tradescantia is one of the world's most popular 'pot' plants. It is a hardy, shade-tolerant plant that has become widespread in frost-free parts of New Zealand's North Island and parts of the South Island. Thriving in shaded areas of gardens and bush, tradescantia grows densely on the ground preventing regeneration of other plants. It is a threat to regeneration, and hence long-term survival, of indigenous forest in northern New Zealand, and is possibly the most widespread and troublesome weed of gardens throughout New Zealand. It is difficult to control as it breaks into many pieces when pulled, with almost every piece of stem capable of resprouting. The plant can also cause canine allergic dermatitis.

The tradescantia leaf beetle (*Neolema ogloblini*) is native to south-eastern Brazil and north-eastern Argentina. Although approval was granted by ERMA (Environmental Risk Management Authority) to release the beetle in New Zealand in 2008, a lengthy delay ensued when it was found that the quarantine culture harboured a gregarine protozoan gut parasite. It was not known whether the parasite was already present in New Zealand, how debilitating it was to the beetles, or whether it could infect other species. The decision was therefore taken not to release the beetles from containment until a parasite-free culture could be obtained. Achieving this proved a challenge, not least because so little was known about gregarines.

Strict hygiene during rearing in the Lincoln quarantine facility did not help eliminate the leaf beetle parasite, so Lindsay Smith and Simon Fowler visited Brazil and collected more leaf beetles. They reared each of the new females in isolation in the hope that some would be free from infection. They used high levels of hygiene for adults and eggs to reduce the likelihood of infection, but low levels for the developing larvae. The rationale for this was that parasites can be difficult to spot at low levels, but keeping the larval culture in not-too-clean conditions gave any parasites that might be present the greatest opportunity to express themselves (as a sick or dying larva or adult). Any sick or dying individuals were culled, along with any eggs/larvae they might have produced by then. A complete record of the process was kept, so a 'family tree' was available for each beetle, which also helped minimize in-breeding. This Herculean effort finally paid off at the end of 2010 when permission was given by MAF (Ministry of Agriculture and Forestry) to release the first gregarine-free line from containment. A shipment was hand-carried to Chris Winks in Auckland for mass rearing at the end of December 2010.

The first release of the leaf beetle in Auckland in March 2011 was understandably greeted with a great sense of satisfaction. Further releases have since been made in Northland, Bay of Plenty, Waikato and Manawatu-Wanganui, and more are planned for next spring. As this is the first time a biocontrol agent has been released against tradescantia, the team are monitoring it carefully. This first season, they are watching to see whether female beetles continue to lay eggs over the cooler months, and will be looking for signs of establishment next spring. Adult feeding damage is quite noticeable as the beetles tend to eat notches in scattered leaves over a wide area. Larvae skeletonize whole leaves sequentially along a stem and if several are feeding in the same area, the damage will be obvious.

While the painstaking work with the leaf beetle was making its slow progress, research on other agents was also advancing: Efforts are now being made to achieve gregarine-free cultures of two more host-specific beetles, the tip feeder *Neolema abbreviata* and the stem borer *Lema basicostata*. The Landcare scientists pursued this trio despite their parasite problems because they attack different parts of the tradescantia plant (leaves, stem, stem-tips) and should make a complementary team. Meanwhile, in Brazil, Robert Barreto (University of Viçosa) is continuing work with a fourth promising agent, the yellow leaf spot fungus *Kordyana brasiliense*. This fungus is host specific and very damaging to New Zealand tradescantia but it proved impossible to experimentally infect plants by standard methods. A novel approach allowed host-specificity testing to be completed, but there is still some way to go before it can be imported into New Zealand.

This project is funded by the Department of Conservation, National Biocontrol Collective (including the Auckland Council) and the Ministry of Science and Innovation under the Beating Weeds programme.

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Source: *What's New in Biological Control of Weeds?* Nos. 50, 55 and 56. Landcare Research New Zealand Ltd 2009 & 2011.
Web: www.landcareresearch.co.nz/publications/newsletters/weeds

New Agent Released against Chromolaena in South Africa

The release of the weevil *Lixus aemulus* onto a dense stand of chromolaena (*Chromolaena odorata*) on the south coast of KwaZulu-Natal (KZN) in March 2011 marks the first introduction of a stem-boring agent against chromolaena in South Africa. It is also the first release worldwide of this agent, which may prove a useful addition to the suite of agents available for control of chromolaena elsewhere.

Two biological control agents are already established on chromolaena in South Africa, the arctiid moth *Pareuchaetes insulata* and the agromyzid fly *Calycomyza eupatorivora*, but both are leaf feeders and are only established in good numbers along the coast where chromolaena does not shed its leaves in winter.

Establishing a stem borer on chromolaena is important, both because the plant has photosynthetic stems and because stem borers are likely to establish in the seasonally drier parts of the plant's invasive range in southern Africa. Another agent that attacks chromolaena stems, the stem-galling tephritid fly *Cecidochares connexa*, is an excellent agent in terms of host range, efficacy and ease of establishment. It is established in Côte d'Ivoire and some countries in Asia and the Pacific, but its narrow host range does not include the southern African biotype of chromolaena.

South African scientists at ARC-PPRI (Agricultural Research Council – Plant Protection Research Institute) focused on *L. aemulus* as an alternative. First collected in Brazil in 1995 by Stefan Neser, laboratory testing indicated that it was damaging to South African chromolaena, with two-thirds of infested stems dying, an almost 50% reduction in the dry mass of stems, and a 94% reduction in seed production. Although host-range testing was completed at ARC-PPRI Cedara in the late 1990s and early 2000s, and permission for the release of *L. aemulus* was obtained from the Department of Agriculture, Forestry and Fisheries in 2006, substantial delays occurred in obtaining the parallel release permit from the Department of Environmental Affairs, and the biocontrol agent remained in quarantine until August 2010.

Following the initial release in March this year, further releases are planned. Scientists will be monitoring the release sites to see whether the weevil is univoltine or multivoltine in the field in South Africa, how quickly populations build up, and how quickly the weevils disperse.

The South African Sugarcane Research Institute received a starter culture of *L. aemulus* in November 2010, and will participate in the mass-rearing of the insect for release. This research has been funded by the 'Working for Water' programme and the KZN Department of Agriculture, Environment and Rural Development.

Sources: ARC-PPRI's *Plant Protection News* No. 87, pp. 20–21 (January–March 2011); and the Chromolaena website (hosted by ARC-PPRI): www.arc.agric.za/home.asp?pid=5229

A list of what agents have been released against chromolaena worldwide, by date and country, has been compiled by Costas Zachariades. A summary appears in the latest issue of the *Chromolaena odorata Newsletter*, No. 18 (May 2011). Bang up to date, it includes the *L. aemulus* release in South Africa. A full version is available on the Chromolaena website (see link above).

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Turfgrass Bioherbicide Finds a New Pathway

A bioherbicide based on *Phoma macrostoma* has received conditional registration from the Pest Management Regulatory Agency in Canada for control of a number of broadleaved weeds in turfgrass. This is an important milestone for a programme in which scientists at the AAFC (Agriculture and Agri-Food Canada) Saskatoon Research Centre have been collaborating with a US commercial partner, The Scotts Company, Marysville, Ohio. It may also have more widespread importance for the bioherbicide sector, for the *P. macrostoma* team believe that central to their success has been the approach of merging a research model (a bioherbicide innovation chain) with a business model (the stage and gate process), and getting input from the commercial partner early in the process "to guide the science behind the technology from discovery to product launch"[1].

Although each year many new prospective bioherbicides are reported, based on isolate screening and biological assessment, very few make it any further. Only five or six bioherbicides have been commercially developed worldwide. Discussing the development of bioherbicides last year in *Biological Control*, Ash[2] argued that, "the future of bioherbicides rests with greater collaboration between a wide variety of scientific disciplines and the early and continued input of industry".

Ironically, the isolate of *P. macrostoma* that has been developed as a bioherbicide did not initially appear promising. Found to be causing 'bleaching' of leaves of Canada thistle (*Cirsium arvense*) during AAFC surveys across Canada in 1996–2002, the damage it caused did not kill plants. But before it was discarded the effects of applying it to soil were examined, and this provided a key discovery: Canada thistle plants that emerged from treated soil were white, root growth was inhibited, and the plants eventually died; serendipitous contamination of this experiment with wind-blown dandelion (*Taraxacum officinalis*) seed revealed that it was similarly affected. So although isolated from leaves, its potential was in soil application.

Recognizing the obstacles to developing apparently promising bioherbicide candidates, a team of bioherbicide researchers at AAFC had devised a bioherbicide innovation chain, comprising a lead researcher who collaborates with a wide range of colleagues with complementary skills and knowledge to guide research through nine stages, from discovery and selection through proof of concept to commercialization and technology adoption. In this process, although issues such as regulation, intellectual property, markets and technology transfer are taken into account, science is the main driver during most stages. In contrast, The Scott Company uses a 'stage and gate' approach to product development, with each stage separated from the next by a management decision (which may be strategic as well as financially based) on whether to proceed. This keeps the focus on the product development chain and moving as quickly as possible to product launch.

Before engaging with The Scott Company, initial AAFC research concentrated on discovery and proof-of-concept by characterizing the fungus, evaluating fermentation requirements, conducting efficacy and safety testing, elucidating the mode of action, and conducting economic and market analyses. The Scott Company became partners as the project moved into assessing the technology and developing the product, leading to commercialization. *Phoma macrostoma* was a promising candidate as a commercial bioherbicide for a number of reasons: market potential in a number of sectors (turfgrass, agriculture, forestry – although a decision was later taken to focus on the first of these), broad spectrum of activity against important broad-leaved weeds, high efficacy, long shelf life and also low environmental and health risks[3].

In merging the AAFC and The Scott Company development models, the science became more business-led; for example, while biocontrol scientists are used to meeting the requirements of regulatory agencies in terms of specificity and environmental safety data, the AAFC team were also devising tests to provide data that would be needed to support claims that would later be made in marketing the product. Overall, the investment in testing over seven years was considerable, involving 129 efficacy trials and 69 phytotoxicity trials across North America, in eight Canadian provinces and four US states, to ascertain *P. macrostoma*'s impact on individual weed and turfgrass species – and that was in addition to previous specificity/tolerance, environmental safety and toxicology testing to meet regulatory needs.

Scientific research had a key role in informing production decisions: how a bioherbicide is to be produced and formulated is a critical issue. In this case, research that unravelled how *P. macrostoma*'s biology and mode of action affected fermentation and formulation led to the superficially surprising (and closely scrutinized) decision that the first-generation product would be a granular formulation produced by solid substrate fermentation; in contrast, most microbial products in North America are manufactured by liquid fermentation. But for *P. macrostoma*, the chosen method gave the product better viability and stability (i.e. a long shelf life).

Commercialization and launching of the product are now underway, with further trials to ensure that the manufacturing process will deliver product claims in terms of purity, efficacy and shelf life. Meanwhile, team members in sales, marketing, regulatory affairs, supply chain, portfolio management and manufacturing are finalizing details, ensuring that all claims for the product are met, and that the market is prepared; in other words, a very large team with a wide range of expertise, well outside that of a scientific research team, is assuring the move from a product that has fulfilled scientific and regulatory requirements to its commercial launch.

The authors believe that their development of *Phoma macrostoma* through merging research and business models provides a detailed pathway that others, who are about to embark on a bioherbicide project, could follow.

[1] Bailey, K.L. & Falk, S. (2011) Turning research on microbial bioherbicides into commercial products – a *Phoma* story. *Pest Technology* 5 (Special Issue 1).

[2] Ash, G.J. (2010) The science, art and business of successful bioherbicides. *Biological Control* 52, 230–240.

[3] AAFC (2009) AAFC Biopesticide: *Phoma macrostoma*. Control of broadleaved weeds in turf, agriculture, and forestry. AAFC No. 10777.

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ENDURE Speeds Development of Biological Controls

Research conducted under the European Commission-funded ENDURE Network of Excellence (2007–10) has led to the development of a new approach aimed at the fast and cost-effective development of biological control products. Called SelectBioControl, the approach is described as encompassing all the successive steps crucial to the development, production, registration and marketing of such products.

The development of SelectBioControl was led by Jürgen Köhl, from Plant Research International (PRI), part of Wageningen University and Research Centre (the Netherlands), working in cooperation with ENDURE colleagues from France's National Institute for Agricultural Research (INRA), Italy's National Research Council (CNR) and the biocontrol industry body, the International Biocontrol Manufacturers' Association (IBMA).

Kohl explains that under the SelectBioControl approach, they start by testing bacteria and fungi for their effectiveness against pathogens as well as analysing the economically important production and marketing parameters. Only bacteria and fungi that have market potential are taken to the next stage and studied in more detail. SelectBioControl therefore limits overall development costs, and allows better estimates of the total costs and possible risks in advance.

PRI believes it can combine its expertise and work in cooperation with industry partners to translate the SelectBioControl approach into tailor-made and cost-effective product development for any application. It also says it is important that biological and chemical control are complementary and do not exclude each other, which is why SelectBioControl is focused on the development of biological control products that can be used in combination with chemical products.

For more information, contact ENDURE.
Web: www.endure-network.eu/contact

And see: Köhl, J., Postma, J., Nicot, P., Ruocco, M. & Blum, B. (2011) Stepwise screening of microorganisms for commercial use in biological control of plant-pathogenic fungi and bacteria. *Biological Control* 57(1), 1–12.

Source: *ENDURE News*, No. 13, June 2011.
Web: www.endure-network.eu

Managing Weaver Ant Colonies

The weaver ant *Oecophylla smaragdina* is a useful biocontrol agent in a number of tree crops and timber trees in Australia, South-east Asia and the Pacific, where it acts as a predator and repeller of insect pests. It has become a major component of integrated pest management programmes in cashew, mango and African mahogany in several countries in the region. Scientists at Charles Darwin University in Darwin (Northern Territory, Australia) have published several booklets giving step-by-step instructions on how to use weaver ants at the colony level in various crops and countries. A new paper in the *Journal of Applied Entomology*[1] was stimulated by three questions frequently asked by extension officers and farmers. These concern the best time of day to (i) identify ant colonies, (ii) transplant colonies and (iii) measure ant abundance. The common thread to the questions is the ants' diurnal activity pattern at the colony level, about which very little has been published.

The authors studied three types of ant trails (trails in trees leading directly to ant nests; trails on overlapping branches linking trees; and trails on the ground between trees) in three weaver ant colonies on the campus of Charles Darwin University in dry and wet seasons over a two-year period. They found that ants were least active in the hours 10:30–14:00, while peak activity was during the hours 16:00–21:00, with a smaller peak of activity at 08:00–09:00. Although patterns of activity were similar in wet and dry seasons, the ants were some eight times more active in the wet season than in the dry season. Their findings allow them to recommend that the best time to identify colonies and measure ant abundance is late afternoon to dusk (16:00 to 21:00), while the optimum time for moving colonies is around the middle of the day (10:30–14:00). The senior author of the paper, Renkang Peng, says that the results can be widely applied in the geographical distribution areas of *O. smaragdina*.

In Africa, the related species *O. longinoda* is also an efficient biocontrol agent. Its use was pioneered in coconut by the late Prof. Michael Way, and it is recognized as useful in other tree crops such as cocoa, mango and cashew. From published research, it seems likely that its diurnal (and seasonal) patterns of activity at the colony level are similar to those of *O. smaragdina*. Peng says that the results from *O. smaragdina* may be applicable to *O. longinoda*, as the two species have very similar foraging ecology and behaviour, although their morphs differ. He suggests, however, that it would be beneficial for a similar study to be conducted with the African species, and that the *Journal of Applied Entomology* paper gives detailed methods on how to assess weaver ant activity at the colony level.

[1]Peng, R., Christian, K. & Gibb, K. (2011) The best time of day to monitor and manipulate weaver ant colonies in biological control. *Journal of Applied Entomology* Online.
doi: 10.1111/j.1439-0418.2011.01651.x.

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Krishna Kumar is NBAII's New Director

Dr N.K. Krishna Kumar assumed charge as the second director of the National Bureau of Agriculturally Important Insects (NBAII; formerly Project Directorate of Biological Control), Indian Council of Agricultural Research (ICAR), Bangalore, India, on 30 June 2011. He was the Head of the Division of Entomology and Nematology for eight years, and acting Director during 2006–07 at the Indian Institute of Horticultural Research (IIHR). Dr Kumar, an entomologist of repute, has over 30 years of research experience on insect pests of many crops, chiefly vegetables and fruits of the tropics. He holds a doctoral degree from the University of Hawaii (1989–93) and was a post-doctoral fellow at the University of California, Davis (2002–03). Even as a student in the USA, he had won appreciation in the form of the East–West Center award, a best paper award from the Entomological Society of America as well as an award of merit from Gamma Sigma Delta (Pacific Branch).

Dr Kumar has developed integrated methods for the management of important insect pests affecting crops such as tomato, brinjal (aubergine), chilli, bell pepper, okra, cabbage, cauliflower and French bean by rational combination of host plant resistance, use of trap crops, cultural practices and plant products, and minimum use of chemicals. His other notable contributions include: development of a database on serpentine leafminer (SLM-INFO); locating the source of resistance to chilli thrips, brinjal leafhopper and fruit borer; tracing the resistance to thrips in chilli, paprika and bell peppers in relation to the introduction and domestication of peppers in Europe and Asia; and identification of the mechanism of resistance to thrips in chilli and bell peppers. In addition, he has proficiency and interest in the field of virus–vector relationships. He one of the rare entomologists who have specialized in insect vectors, especially on the thrips–tospovirus relationship.

Two of his most recent projects, viz. 'Outreach Programme on Management of Sucking Pests of Horticultural Pests' and 'Potential of RNAi in management of *Helicoverpa armigera* Hübner' have received all-round appreciation. His excellent expertise in molecular systematics is evident in his developing the DNA barcode for 50 different species of insect pests in the orders Thysanoptera, Hemiptera, Coleoptera, Lepidoptera and Diptera, as well as designing species-specific markers for major insect pests of horticultural crops.

He has published more than 100 research papers and several book chapters. He has also edited a book on *Advances in IPM for Horticultural Crops* which has been recognized as the first comprehensive account on the subject in India.

During his tenure at IIHR, he organized several group meetings and brainstorming sessions on topics as varied as thrips and tospoviruses, sucking pests, and bioinformatics, among others. He has served on several important committees both as a chairman and a member. He is also the president of the Association for Pest Management in Horticultural Ecosystems, and vice- president of the Society for Promotion of Horticulture. He is a founder member of the Entomological Foundation of India. As chairman of the Institute Technology Management Unit at IIHR, Dr Kumar initiated the process of successful commercialization of more than 25 horticultural technologies.

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Award for Canadian Biocontrol Scientist

In June 2011, Dave Gillespie was presented with the Agriculture and Agri-Food Canada (AAFC) Gold Harvest Award for Career Achievement. Over his 30-year career as a research scientist with AAFC's Research Branch, Dr Gillespie's research on the natural enemies of insects and mites has contributed directly to the discovery and widespread use of many of these species for biological control in domestic and international greenhouse operations.

For the first 20 years of his career, he worked with the Canadian greenhouse vegetable industry to find biological control agents to manage pest insects, thus substantially reducing the use of pesticides in greenhouse vegetable production. His early research on the responses of greenhouse insects to colour led to use of colour traps for monitoring greenhouse pests. Dr Gillespie's unique way of offering his research findings to the greenhouse industry at large, such as beneficial insect production companies and greenhouse crop managers, has resulted in his contributions being used around the world. He is currently the principal investigator for a national AAFC peer-reviewed project on the biological control of the cabbage seedpod weevil in Canada. Under Dr Gillespie's leadership, this collaborative project advances the interests of canola producers to find biological control solutions to major pest problems.

Source: AAFC.

CABI Launches Open-Access Invasive Species Compendium

Developed by CABI, with support from a consortium of partners, the Invasive Species Compendium (ISC) is an online, open-access, comprehensive reference work covering recognition, biology, distribution, impact and management of the world's invasive plants and animals. It aims to be the most extensive and authoritative compilation on the subject in the world. Content is derived from thousands of peer-reviewed expert contributors, backed up by existing compilations of knowledge and research on invasive species. It offers extensive global coverage of all invasive species, from every taxonomic group (excluding human pathogens), with fast and easy navigation between text, images, maps and databases.

The ISC is a constantly developing resource, thanks to a brand new technical platform which enables CABI's experts to update the datasheets and bibliographical data on a weekly basis. As of July 2011, the ISC covers some 8500 species with almost 6900 basic summary datasheets and 1500 detailed datasheets. It provides access to more than 900 full text articles (in pdf format) and over 70,000 abstract summaries, with plans to reach 75,000 abstracts by the end of 2011.

Web: http://www.cabi.org/isc/

CABI Annual Reports 2010

The annual report for CABI Europe UK[1] covers all work carried out by its staff in 2010, including biological control projects. Most of these projects involve classical biological control of invasive weeds (under CABI's Invasives theme) for and with partners around the world, notably North America, Australia and New Zealand. A new feature in recent years has been work for Europe and the UK, and the report includes news of the release of Europe's first weed biological control agent, against Japanese knotweed (*Fallopia japonica*) in the UK. News of projects concerning microbials and biopesticides for commodity crops (under the Commodities theme) is also reported.

As this issue goes to press, the 2010 annual report for CABI Africa[2] is also almost ready. As well as coverage of its projects working with and for farmers, it includes news of projects on invasive alien species management, principally in Africa but also in the Caribbean and South-east Asia.

[1] CABI (2011) *CABI Annual Report, Europe UK 2010*. CABI, Egham, UK, 72 pp.
Web: www.cabi.org/uk

[2] CABI (2011) *CABI Annual Report, Africa 2010*. CABI, Nairobi, Kenya, 44 pp.
Web: www.cabi.org/africa

Biocontrol is Part of Integrated Project against African Witchweeds

A new collaborative four-year project aims to generate much higher yields for farmers in Kenya and Nigeria by targeting control of the parasitic weeds *Striga*, known as witchweed, and also the lesser known problem, *Alectra*. *Striga* is estimated to cause up to US$1.2 billion in damage every year to the maize and cowpea crops of tens of millions of smallholder farmers in sub-Saharan Africa. Crop plants have more difficulty competing with witchweeds in poor soils, thus intensive farming and the expansion of farming into marginal soils have encouraged the weeds' spread in recent decades. Difficulties of controlling them are compounded by their prolific seed production and the longevity of the seed bank.

The US$9 million project is supported by a $6.75 million grant from the Bill and Melinda Gates Foundation to IITA (International Institute of Tropical Agriculture), the project coordinator; partners include CIMMYT (International Maize and Wheat Improvement Center), AATF (African Agricultural Technology Foundation), ICIPE (International Centre of Insect Physiology and Ecology) and BASF Crop Protection.

The project goal is to help 200,000 maize farmers and 50,000 cowpea farmers in areas with high rates of *Striga* infestation in Kenya and Nigeria to achieve up to 50% higher maize yields and 100% higher cowpea yields. The project will evaluate and implement four approaches: using *Striga*-resistant crop varieties; using a 'push-pull' technology that involves intercropping with specific forage legumes that inhibit the germination of *Striga*; using herbicide-coated seeds; and deploying biocontrol of *Striga*. After a two-year evaluation period, the project will scale up the most effective approaches. In addition, the project will provide lessons and strategies for scaling up in other areas of sub-Saharan Africa, where witchweed is a major problem for maize and cowpea production, and generate data on the biology of witchweed, including the plant's relationship with different hosts and methods for rapid screening for resistance to the weed in maize and other crops.

Source: www.iita.org

Risks of Biocontrol in Conservation

Classical biological control is increasingly used for ecological or conservation purposes, in some cases to great benefit. However, there are also cases of biocontrol agents introduced against agricultural and rangeland pests inflicting non-target impacts on native biodiversity – in some cases decades later and (though not always) of a nature not anticipated when the introduction was made. This has led to a common view among the conservation sector that, for natural areas, the benefits of biological control are outweighed by unknown and unquantifiable risks.

In a review in *BioControl*[1], Daniel Simberloff asks how conservation managers tasked with managing invasive species are to evaluate the potential of classical biological control and separate potential successes from potential disasters. He indentifies four types of risk from an introduced biocontrol agent, which he evaluates in turn: (i) direct attack on non-targets, (ii) indirect effects on non-targets including apparent and exploitative competition, trophic cascades, and effects on ecosystems, (iii) dispersal of the biocontrol agent to a new area by a variety of natural and human-mediated means, and (iv) changed relationships between a biocontrol agent and a native species; he includes, for (iii) and (iv) in particular, changes potentially generated by global climate change. He also notes that the concept of risk–benefit, on which the process of evaluating a biocontrol programme or introduction is based, was developed along financial lines while the value of biodiversity is hard to quantify, which can make conservationists feel side-lined by the process.

Simberloff identifies a number of key areas where improvements are need for predicting how an agent will behave in a new environment. Although the continued development of the centrifugal phylogeny method for host-specificity testing means that an accurate picture may be gained for a weed biocontrol agent, the same is not true for an agent intended for arthropod pest control where more attention needs to be paid to effective testing. For both kinds of agents, he stresses the importance of choice tests in helping to predict indirect effects. Next, although rearing a range of test plants is generally a feasible operation, rearing all the insects on an arthropod test list presents a far greater challenge which needs addressing. In addition, Simberloff asks for more emphasis to be placed on the possibility of dispersal, though acknowledging that this can be difficult to quantify or predict. He also emphasizes the importance of considering possible changes in species distribution and overlap using climate change models. Overall, given the need for conservationists to consider the implications of management measures on a complex natural ecosystem, Simberloff calls for better methods to be developed for predicting and assessing population impact of introduced biocontrol agents, instead of focusing on simpler measures such as attack rate.

Although this summary may have painted a picture of the conservationist as a die-hard refusenik, it is only a snapshot of Simberloff's review in which, using numerous well-chosen examples, he covers all manner of pest problems that conservation managers face. Simberloff says that there are occasions when a keystone species is under threat and the stakes so high that land managers might overcome reservations and "be inclined to allow a greater risk of attack on non-targets." It is important for all cases where classical biological control is under consideration to have the best-possible predictions for the overall impact of releasing a biocontrol agent into that system.

[1] Simberloff, D. (2011) Risks of biological control for conservation purposes. *BioControl* Online First. doi: 10.1007/s10526-011-9392-4

Meta-Analysis Indicates Study Method Matters

Aquatic and wetland weeds include some of the iconic success stories in classical biological control, yet control can be variable even with them. For the various weeds targeted around the world, a good many studies have tried to assess how well control has worked and, especially where control is inadequate, what affects it. Is it possible to draw some general conclusions from them? Meta-analysis is a useful tool for understanding patterns across multiple studies, and allows the results of independent experiments to be quantitatively synthesized and general conclusions drawn. A meta-analysis in *BioControl*[1] by Reeves and Lorch included data from three decades of experimental studies (1980 – September 2009) on biological control of aquatic and wetland weeds, and sought to determine whether (i) differences exist in how well diverse biocontrol agents perform, and (ii) experimental design can affect study results. A useful feature of this paper is the detailed methods, which include literature search methods, data inclusion methods, and measures to avoid non-independence of data.

The authors found no significant differences between agent groups and that most the agents included in the analysis were significantly damaging, underlining that biological control of aquatic and wetland weeds has indeed been widely successful. However, experimental design had a significant effect on results of studies, leading the authors to suggest field studies with controls (rather than observational studies) be performed using subsamples of an area (i.e. quadrats, transects – rather than individual plants or artificial arenas), with biomass or density being the plant variable measured (in preference to e.g. weed cover or leaf area damaged). They also suggest that more long-term and non-target effect studies would be beneficial.

[1] Reeves, J.L. & Lorch, P.D. (2011) Biological control of invasive aquatic and wetland plants by arthropods: a meta-analysis of data from the last three decades. *BioControl* Online First. doi: 10.1007/s10526-011-9393-3.

Bodyguards: Making the Most of a Host

Two recently published papers report new findings about host manipulation by natural enemies. In *Biology Letters*[1], Maure *et al.* provide evidence for a fitness-related cost of host manipulation by a ladybird parasitoid. As the authors say, "Host manipulation by parasites not only captures the imagination but has important epidemiological implications." The accepted but until now untested hypothesis is that parasitoids engaging in such behaviour must trade the benefits of host manipulation with their costs to fitness-related traits, such as longevity and fecundity. The solitary braconid parasitoid *Dinocampus coccinellae* develops in the haemocoel of its host, the coccinellid *Coleomegilla maculata*. It emerges at the prepupal stage through the host's abdominal segments and spins a cocoon between its legs – but unusually, does not kill its host. Instead, it survives in a semi-paralysed state, displaying grasping behaviour and twitching at irregular intervals, especially when disturbed, which allowed some potential trade-off effects of the 'behaviour' to be evaluated.

In laboratory experiments, the authors demonstrated that, as predicted by the hypothesis, parasitoid cocoons attended by a living ladybird (naturally attached by cocoon silk) were preyed on by lacewings less than unattended cocoons (ladybirds removed), or cocoons under dead ladybirds (ladybirds experimentally killed but maintained in position). They also showed that although the length of the time the cocoon is attended does not affect the emerging adult parasitoid's longevity, it is negatively correlated with its fecundity.

In *Animal Behaviour*[2], Harvey *et al.* report, "the first experimental evidence that a solitary parasitoid usurps the behaviour of its host over several days as a 'bodyguard' against hyperparasitoids". Previously support for the bodyguard hypothesis has been found only for predation (as above). The authors looked at a solitary braconid parasitoid (*Microplitis* sp.) and an ichneumonid hyperparasitoid (*Gelis agilis*) of the armyworm *Mythimna separata*. When the mature *Microplitis* sp. larvae emerge from the host, they spin a cocoon which is attached to the posterior paralysed host segments, while the anterior segments can still move. The authors describe how these still-active segments act as an 'attending larva', exhibiting aggressive behaviour that repeatedly drives off approaching hyperparasitoids. Using choice and no-choice tests to compare *Microplitis* sp. survival and successful parasitism by *G. agilis* in cocoons in the presence and absence of an attending larva, Harvey *et al.* showed that the hyperparasitoid was rarely able to parasitize cocoons with attending larvae, but successfully parasitized unattended cocoons.

[1] Maure, F., Brodeur, J., Ponlet, N., Doyon, J., Firlej, A., Elguero, E. & Thomas, F. (2011) The cost of a bodyguard. *Biology Letters* FirstCite 22 June 2011. doi: 10.1098/rsbl.2011.0415.

[2] Harvey, J.A., Tanaka, T., Kruidhof, M., Vet, L.E.M. & Gols, R. (2011) The 'usurpation hypothesis' revisited: dying caterpillar repels attack from a hyperparasitoid wasp. *Animal Behaviour* 81(5), 1281–1287.

Reviews with an Eye to the Future

A clutch of recent reviews look at biological control programmes against significant target pests with the aim of identifying the best approaches to pursue now.

In *Biological Control*[1], Michael Cripps and co-authors provide a comprehensive review of the classical biological control programmes against Canada thistle (*Cirsium arvense*), covering both deliberate and accidental introductions, in North America (NA) and New Zealand (NZ). Nearly 50 years after the first agents were released, there is no evidence for successful control in either NA or NZ. Although the same five agents were released in both NA and NZ, the native floras might have dictated a different path: there are no related thistles in NZ, but Cardueae in NA include species of conservation concern and some biocontrol agents released against thistles in NA later became the subject of safety concerns. In a retrospective evaluation of the selection of the five agents, the authors recognize contemporary justifications for the agents released in NA but conclude that they would not meet today's host-specificity requirements, while the release of the same five agents in NZ meant that other more promising agents may have been overlooked. Turning to the failure of biocontrol, they conclude that in NA this is a result of compromised safety and lack of impact, while in NZ it is attributed to non-establishment or lack of impact. They say that a new more NZ-specific initiative has led to the identification of agents with better prospects for contributing to the successful control of *C. arvense* in New Zealand.

In *Biocontrol, Science and Technology*[2], Peter Harris explains the mutualistic association between diffuse and spotted knapweed (*Centaurea diffusa* and *C. stoebe micranthos*) and arbuscular mycorrhizal fungae (AMF) phylotypes, and the effects of this on knapweed-feeding insects. Knapweed AMF maintain hyphal links to adjacent plants, and there is a nutrient flux to the strongest sink, usually knapweed. Harris describes the how AMF affect knapweed shoot/nutrient allocation, and how this in turn affects knapweed biology and phenology, and thus knapweed-feeding insects. The aim of this review is to explain enough about AMF–knapweed–insect relationships to understand how they impact on biological control and so avoid the mistakes of the past. On the basis of this review, the author argues that two further biocontrol agents will be needed if biological control in North America is to be effective, in addition to the four currently approved species.

In the same journal[3], Kim Hoelmer and co-authors look at the potential for classical biological control of olive fruit fly (*Bactrocera oleae*) in California, where it is a recent introduction, and in the Mediterranean, where it has long been recognized as a serious threat to olive production. They identify Africa and Asia as the most promising regions for exploration based on several factors including current understanding of *Bactrocera* phylogenetics and the paucity of the natural enemy fauna of *B. oleae* in the Mediterranean compared with Africa.

[1] Cripps, M.G., Gassmann, A., Fowler, S.V., Bourdôt, G.W., McClay, A.S. & Edwards, G.R. (2011) Classical biological control of *Cirsium arvense*: lessons from the past. *Biological Control* 57(3), 165–174.

[2] Harris, P. (2011) A knapweed biological control perspective. *Biocontrol, Science and Technology* 21(5), 573–586.

[3] Hoelmer, K.A., Kirk, A., Pickett, C.H., Daane, K.M. & Johnson, M.W. (2011) Prospects for improving biological control of olive fruit fly, *Bactrocera oleae* (Diptera: Tephritidae), with introduced parasitoids (Hymenoptera). *Biocontrol, Science and Technology* iFirst. doi: 10.1080/09583157.2011.594951.

Cold Storage of Insect Parasitoids

A comprehensive review in *Biological Control*[1] focuses on this valuable method for increasing the shelf life of biocontrol agents. Tolerance to cold storage varies not only between species and higher taxonomic groups, but between individuals. Moreover, reduction in fitness traits may become apparent immediately post-chilling, during later development, or even in the subsequent generation. The authors therefore examine a wide range of factors, including genotype and other biotic and abiotic factors, that affect a parasitoid's ability to withstand cold storage. They also survey the range of fitness traits in parasitoids that are affected by cold storage. The authors note that the review therefore provides "a comprehensive list of documented factors that must be taken into account when designing cold storage protocols."

[1] Colinet, H. & Boivin, G. (2011) Insect parasitoids cold storage: a comprehensive review of factors of variability and consequences. *Biological Control* 58(2), 83–95.

Arthropod Symbioses: Special Issue

The study of arthropod symbiosis has been moving from a theoretical discipline to one that has applications in pest control. A special issue of the *Journal of Applied Entomology*[1] is based on a meeting held at Kolymbari in Crete, Greece, in September 2010 (sponsored by the European Union COST Action FA0701 'Arthropod symbioses: from fundamental studies to pest and disease management'). The meeting dealt with 'Applied arthropod symbiosis: from the development of novel technologies to commercial, legal and ethical considerations'. Articles in this special issue deal with the potential of transgenic manipulation of symbionts (such as *Wolbachia*) in controlling a range of pest groups, including olive and Mediterranean fruit flies (*Bactrocera oleae* and *Ceratitis capitata* – medfly), mites and mosquitoes, for improving health of honeybees and sterile medflies, and also regulatory issues regarding the use of symbionts in this way.

[1] Bourtzis, K. & Yuval, B. (2011) *Journal of Applied Entomology* 135(7).