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General News

Parasitoids Established for Lily Leaf Beetle in the USA

A paper in *Environmental Entomology* describes a programme leading to the successful establishment of three parasitoids against the introduced lily leaf beetle (*Lilioceris lilii*) in North America, which has the potential to mitigate the impact of the beetle's invasion.[1] The authors discuss how a management strategy could be optimized from what they have learned during the release and monitoring phase of the project.

Lilioceris lilii is found widely in Eurasia and was introduced to North America in 1943. It is now distributed throughout most of the northeastern USA and southeastern Canada, with localized populations further west in both countries. Introduction to new regions and areas has in most cases been via infected bulbs or plants, with ensuing local spread. It is a serious pest of ornamental and native *Lilium* and *Fritillaria* species (family Liliaceae) in North America some of which are of conservation status.

Currently the only other species of *Lilioceris* present in North America, *L. cheni*, was introduced as a biocontrol agent of air potato (*Discorea bulbifera*). Three members of the same subfamily are introduced pests that have been largely controlled by introduced parasitoids. No parasitoids or predators of *L. lilii* had been found in North American populations. Taken together, these factors suggested that classical biological control was a good avenue to explore for *L. lilii*. The area of origin of the lily leaf beetle is thought to be China. It was probably introduced to Europe, where it is not a pest either, several hundred years ago. Published records of natural enemies in Europe led to first surveys being conducted in France, and later in other climatic zones. Beetles on ornamental and especially native lilies were found to be heavily parasitized, usually by several species, although the dominant species varies with region.

Seven parasitoid species were collected during surveys and, after initial screening by CABI in Switzerland, four of them were sent to the University of Rhode Island (URI), USA. Further host-specificity testing in quarantine eliminated one of the species. Proposals for field release of the remaining three species as biocontrol agents for *L. lilii* were approved by USDA-APHIS-PPQ (US Department of Agriculture – Animal and Plant Health Inspection Service – Plant Protection and Quarantine) and relevant US states.

The eulophid *Tetrastichus setifer* and two ichneumonids, *Lemophagus errabundus* and *Diaparsis jucunda*, were released from 1999 and 2003, respectively, in monitored plots in Rhode Island and Massachusetts. Once establishment was documented, the parasitoids were redistributed within the states, and further afield to New Hampshire, Maine and Connecticut, while *T. setifer* was shipped to Canada in 2010 for release near Ottawa. Decisions about where to release the different parasitoids were based on knowledge of the climate of their native ranges in Europe: *T. setifer* in all release areas because it has the greatest likelihood of establishing throughout lily leaf beetle's potential North American range; *L. errabundus* in maritime areas; and *D. jucunda* in northern/inland US locations. Parasitoid establishment and spread was monitored initially by sampling and latterly by enlisting the gardening public to send in larvae for dissection. All three species have established in the USA, and *T. setifer* is established in Canada. They have spread from release sites, with rates varying for the species between 1–2 and 4–5 km/year. Impact in terms of reduced beetle populations and lily damage from *T. setifer* and *L. errabundus* is becoming apparent from monitoring results and anecdotally from gardeners' reports.

The authors use their results to illustrate how horticultural practices could be amended to support biological control. Pesticide use is generally difficult to integrate with biological control, and lily bulbs are frequently treated with systemic pesticides that are not always declared at the point of sale, so organically-produced bulbs are recommended. These are, as the authors note, more expensive and can be difficult to obtain, which would hamper both scientists seeking to establish release plots and gardeners alike. A more-easily integrated change is related to mulching strategies. Mulching lilies is a common practice among North American (and some European) gardeners, but during the first US releases it was found to prevent *T. setifer* over-winter survival and establishment. While lily leaf beetles fly away to seek suitable overwintering sites, the three parasitoids overwinter in host cocoons underneath lily plants, and a layer of mulch may give inadequate protection from low temperatures, desiccation and predation. Equally, autumn disturbance of lily bulbs (moving or lifting in autumn and replanting in spring) can interfere with the parasitoid life cycles.

A larger problem is the slow rate of spread of the parasitoids, attributable at least in part to the patchy distribution of both cultivated and native lilies. As the authors discuss, a programme of laboratory and field-plot rearing and redistribution of three parasitoids was very successful against the related cereal leaf beetle (*Oulema melanopus*) in the 1970s, but *O. melanopus* was recognized as a major threat to agriculture and received substantial funding and staffing. Lily leaf beetle funding will be much more limited. Ensuring that the parasitoids are deployed to best effect as the lily leaf beetle invasion expands will be a real challenge. However, results from releases of the three agents have led the authors to conclude that releases can be quite modest in number, and are most effective on reasonably sized, well-infested lily plots. Parasitoids are also likely to establish more easily on wild lilies (in Europe, parasitism levels are higher on wild lily populations). Wild lilies in the invaded range stand a good chance of harbouring parasitoid populations, which could reduce damage and contain outbreaks better, and this would be good news for North America's threatened and endangered lily species.

Modelling suggests that much of the North American continent is suitable and therefore under threat from the lily leaf beetle. Establishment of a suite of three biocontrol agents while the invasion is still in its early stages could be a key factor in slowing the pest's spread and limiting the impact of the invasion in new areas. This early research will also be invaluable in guiding release strategies as the parasitoids are redistributed in North America to counter the invasion.

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Towards Successful Establishment of Exotic Parasitoids Attacking the Pod Borer *Maruca vitrata* in West Africa

The legume pod borer, *Maruca vitrata* (Lep., Crambidae; syn. *M. testulalis*), remains the single most important insect pest attacking cowpea (*Vigna unguiculata*) and other leguminous crops and wild species in Africa. The damage caused by *M. vitrata* caterpillars feeding on flowers and pods of cowpea is estimated at 20–80%, depending on agro-ecological zone and climatic factors.[1]

For many years, this pest was tacitly categorized as 'indigenous' in Africa, and hence most control approaches were targeting pesticide applications and improving host plant resistance.[1] However, as previously speculated from comparing natural enemy diversity in tropical Asia[2], and recently confirmed by phylogenetic studies comparing worldwide populations of *M. vitrata*[3], it appears now quite clear that this insect originated in Southeast Asia. This hypothesis is also supported by the fact that none of the natural enemies observed in West Africa are specific to *M. vitrata*.[4,5] Earlier biodiversity studies in Asia had identified the parasitic wasp *Apanteles taragamae* (Hym., Braconidae) from Taiwan as a possible biocontrol candidate for testing in West Africa.[6] Although initial results from lab studies were promising, thorough ecological assessment of its real potential in West Africa revealed that it was only marginally adapted to the legume host range present in this region.[7]

In the meantime, more detailed biodiversity studies targeting hymenopteran parasitoids of *M. vitrata* in Southeast Asia revealed two more interesting braconid species, *Phanerotoma syleptae* (an egg–larval parasitoid) and *Therophilus javanus* (a larval parasitoid), with field parasitism rates of up to 60%.[8] Both parasitoids were introduced from the World Vegetable Center (WorldVeg) to the rearing labs of the International Institute of Tropical Agriculture (IITA), Benin Station, for two years' confined testing. An interesting aspect worth mentioning is that, by the time we introduced the parasitoids in our labs, we had just switched from rearing *M. vitrata* larvae on artificial substrate to the use of sprouted cowpea grains as a natural substrate. As we found out later, we would never have been able to establish a rearing colony for one of the parasitoids, *T. javanus*, if we had tried to rear it on *M. vitrata* larvae originating from artificial diet, possibly because of a lack of essential elements, or because of the presence of some anti-nutritional factors affecting the development and survival of the parasitoid.

Once we had obtained release permits from the respective national authorities, a total of 101,600 adult parasitoids – 60,100 in Benin (30,300 *T. javanus* and 29,800 *P. syleptae*) and 41,500 in Burkina Faso (23,000 *T. javanus* and 18,500 *P. syleptae*) – were released, starting in January 2016. Based on ecological observations in their native area in Southeast Asia, our release strategy targeted different agro-ecologies and host plant habitats depending on the parasitoid species. For *P. syleptae*, we released on flowering legume trees and shrubs such as *Pterocarpus santalinoides*, *Lonchocarpus sericeus*, *Philenoptera cyanescens* (syn. *L. cyanescens*) and *Milletia thonningii*, all belonging to the family Leguminosae–Papilionaceae. These plants are major hosts for *Maruca vitrata* populations during the off-season, when no cowpea is planted.[9] In contrast, *T. javanus* was released on cowpea crops and patches of herbaceous legumes including *Sesbania rostrata*, *Tephrosia platycarpa* and *Pueraria phaseoloides*, all Leguminosae–Papilionaceae, as well. Releases were carried out with the active participation of local communities and were preceded by a sensitization campaign explaining in simple terms the concepts of biological control. The two main messages voiced by the campaign were (i) not to apply chemical pesticides where the releases were made, and (ii) to preserve the legume tree species in the environment. In fact, one of these trees, *L. sericeus*, is unfortunately the object of indiscriminate cutting because of its value in artisanal charcoal processing, hence the urgent need for advocating its preservation.

In Benin, only a few months after the initial releases in early 2016, *Phanerotoma syleptae* was recovered from parasitized pod borer larvae on the target host plants, particularly *L. sericeus*, while *Therophilus javanus* was recovered later in the season, mostly from cowpea and *Tephrosia* spp. Both parasitoids were also recovered from cowpea and from wild host plants in Burkina Faso during the 2016 cropping season. Furthermore, surveys carried out in Benin in February–April 2017 indicate with certitude and unambiguously that both species have successfully survived the long dry season (particularly harsh this year) on alternative host plants in the absence of cowpea, nearly one year after initial experimental releases (first author's unpublished data).

While it is too early to be able to give a proper quantitative assessment of the impact of the released parasitoids on *Maruca vitrata* populations, it is noteworthy that during the recent post-dry season surveys we were able to recover parasitized *M. vitrata* larvae from very low pod borer populations, indicating a good ecological adaptation of both parasitoids, and maybe also an early sign of parasitoid efficacy.

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[9] Arodokoun, D.Y., Tamò, M., Cloutier, C. and Adeoti, R. (2003) The importance of alternative host plants for the annual cycle of the legume pod borer, *Maruca vitrata* Fabricius (Lepidoptera: Pyralidae). *Insect Science and its Application* 23, 103–113.

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Biocontrol Agents Break New Ground in the Cook Islands

International collaboration and funding from New Zealand have facilitated the introduction and release of biocontrol agents against two invasive plants that have not previously been targeted anywhere else. The introductions are part of a larger project to implement biological control of invasive weeds in the Cook Islands.

Seven invasive plant species in the Cook Islands were identified for biological control during consultation in 2009 between Landcare Research New Zealand scientists and experts in agriculture, biodiversity conservation and biosecurity in the Cook Islands. Using a method developed by Landcare Research, the process took into account the importance of each weed and the feasibility and relative cost of implementing biological control. A five-year plan was mapped out for a partnership project between Landcare Research and the Cook Islands Ministry of Agriculture (MoA), funded by the New Zealand Ministry of Foreign Affairs and Trade. Biocontrol agents have so far been released on Rarotonga, the largest island of the Cook Islands archipelago, against five of the invasive plant species, including the two novel targets. In addition, a genetic study is being conducted on peltate morning glory (*Merremia peltata*) because the dominance of this smothering vine over native species had led to its native status in Rarotonga being questioned, with suspicions that it could actually be a Polynesian introduction. If it is a recent introduction, that potentially opens the door to its biological control.

Red passionfruit

Red passionfruit (*Passiflora rubra*) was potentially a difficult target, because it had not been targeted before and because of the need to avoid non-target attack on the related edible passionfruit (*P. edulis*). Traditionally, such a project begins with surveys in the area of origin of the target plant. But evolutionary biologists have long been interested in coevolution between *Passiflora* species and Neotropical *Heliconius* butterflies as a model system. Research on them has been extensive, and has revealed a high degree of host specificity in the butterflies, some of which are known to be specific to *Passiflora* subgenus *Decaloba*, to which *P. rubra* belongs and *P. edulis* does not. Using the published literature[1], a subspecies of the red postman butterfly (*H. erato cyrbia*), which is native to Colombia and Ecuador, was identified as a potential biocontrol agent for *P. rubra*. Another hurdle in a novel project is collecting and developing rearing methods for potential biocontrol agents. But *Heliconius* butterflies are popular exhibits in butterfly houses and available commercially, so procuring *H. erato cyrbia* and establishing a rearing colony were relatively cheap and easy. Host-specificity testing conducted in the Landcare Research Beever Plant Pathogen Containment Facility (BPPCF) in Auckland confirmed that it did not attack edible passionfruit, while the larvae proved destructive on *P. rubra* plants in containment. Permission was obtained to release *H. erato cyrbia*, and first releases on Rarotonga were made in August 2016. Follow-up visits in January 2017 found that it is firmly established and spreading. The hope is that it can be released elsewhere in the Cook Islands; one potential beneficiary is the remnant forest on the makatea (fossilized coral cliffs) that ring Atiu, which is being invaded by red passionfruit.

African tulip tree

African tulip tree (*Spathodea campanulata*) is native to Central and West Africa. Introduced widely, it has naturalized in other parts of Africa and the Caribbean and Pacific regions, and has become a serious invader of natural forest and agriculture in some countries. Biological control developed for the Cook Islands could potentially be implemented more widely. Surveys in Ghana led to three agents being prioritized for further investigation by researchers at Rhodes University in South Africa. The gall-forming eriophyid mite *Colomerus spathodeae*, widely distributed from Ghana through to Uganda, proved sufficiently host-specific.[2] It was approved as the first biocontrol agent for African tulip tree in the Cook Islands after an environmental impact assessment for Rarotonga demonstrated that it was suitable for release. A shade-house culture was established at the MoA in early 2017 and preliminary field releases were made around the island, where signs of mite damage were becoming apparent just a week later. Testing of a second agent at Rhodes University, the chrysomelid leaf-mining beetle *Paradibolia coerulea*, is at an advanced stage and, if this is successfully concluded, the beetle could also be released.[3]

Other targets

One invasive plant has been suspended as a target: reports of giant reed (*Arundo donax*) as a widespread invasive on Rarotonga proved to be inaccurate owing to confusion with elephant grass (*Pennisetum purpureum*). Giant reed is actually highly localized on Rarotonga and could conceivably be eradicated and does not warrant biological control.

Progress on the remaining four target plants is being made. Biocontrol agents that have proven successful elsewhere have been released on Rarotonga against three of the plants prioritized in 2009. Extensive research in Hawaii underpinned approval to release the scale *Tectococcus ovatus* against strawberry guava (*Psidium cattleianum*). Galls on plants were observed in early 2017, suggesting it has established. *Puccinia xanthi*, a rust fungus that keeps cockleburr (*Xanthium pungens*; part of the *X. strumarium* complex and commonly known as Noogoora burr in Australia) under control in Australia was released in 2015 and found established in 2017. This plant is widely distributed in the Pacific, so success in the Cook Islands would encourage wider biological control efforts. Another rust fungus has been more difficult to work with in the Cook Islands: *Puccinia spegazzinii* failed to establish first time against *Mikania micrantha*. A renewed attempt using plants inoculated multiple times in New Zealand and imported for field release is extending the period of sporulation in the field post-release to give a wider window for suitable conditions for establishment. A third rust fungus, *Puccinia arechavaletae*, has been prioritized for grand balloon vine (*Cardiospermum grandiflorum*), and a culture has been imported into New Zealand, where it is currently undergoing host-range testing in the BPPCF against three plant species of importance in the Cook Islands, prior to approval for release there being sought. The Cook Islands project is drawing on host-specificity testing by PPRI in South Africa, where *C. grandiflorum* is also a major weed.

Merremia peltata

The most recent genetic analysis indicates that samples from the northern and western Pacific (e.g. Australia, Micronesia, New Guinea) are genetically distinct, indicating that they have probably been isolated from one another for a long time. By contrast, South Pacific samples (e.g. American Samoa, Fiji, New Caledonia, Niue, Rarotonga, Samoa) are genetically similar to one another and also to some samples from Micronesia. Thus *M. peltata* may have recently colonized the South Pacific from Micronesia. The team working on the genetics study are hoping to obtain more samples to confirm their findings.

The vision for this ambitious project is being realized: 'off the shelf' biocontrol agents and previous research on them is facilitating biological control against some priority invasive plants in the Cook Islands, while new biocontrol agents are being successfully developed for novel invasive plant targets, which may in the future become 'off the shelf' agents for other countries, which is particularly appropriate for the Pacific. A recent review by Day and Winston[4] (see *BNI* 37(4) – December 2016) highlights difficulties faced by the small and geographically dispersed countries and territories in this region in implementing classical biological control, but how they can share experiences with each other, as well as benefit from research and programmes in countries further afield, to tackle common invasive weed problems.

Main source: Landcare Research New Zealand.
Web: www.landcareresearch.co.nz/publications/newsletters/biological-control-of-weeds/issue-79

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Gary R. Buckingham: 1942–2017

One of the world's great weed biological control experts, Gary R. Buckingham, passed away on 16 January 2017 at Richmond, California. Gary was born to Richard and Ione Buckingham in Rapid City, South Dakota, and completed high school in La Porte, Indiana. He received a Bachelor of Science in Agriculture (BSA) with distinction in Entomology from Purdue University in 1964. Gary then moved to the San Francisco Bay Area where he earned his PhD in Entomology from the University of California (UC) Division of Biological Control, Berkeley, in 1975, with research carried out at the university's Gill Tract-Albany Lab. His PhD dissertation was titled "The parasites of walnut husk flies (Diptera: Tephritidae: Rhagoletis) including comparative studies on the biology of *Biosteres juglandis* Mues. (Hymenoptera: Braconidae) and on the male tergal glands of Braconidae (Hymenoptera)". While at Berkeley Gary met and married May (Narasaki) Buckingham, his beloved wife of 46 years.

In 1970, Gary was sent to the USDA-ARS lab at Rome in Italy by the UC Division of Biological Control to study biological control of field bindweed, *Convolvulus arvensis,* and yellow starthistle, *Centaurea solstitialis.* In 1972, he was hired by the ARS as Research Entomologist and Leader at the Rome lab. His studies included insects attacking thistles, Dalmatian toadflax (*Linaria dalmatica*) and opium poppy, *Papaver somniferum.*

In 1977, Gary was transferred to Gainesville, Florida where he and May spent the next 25 years. Gary was a member of the ARS, Invasive Plants Research Laboratory (formerly Aquatic Plant Control Research Unit), Ft. Lauderdale, Florida, but worked at the quarantine facility of the Florida Biological Control Laboratory at the Division of Plant Industry (DPI), Gainesville. He was also a Courtesy Assistant Professor in the University of Florida Department of Entomology and Nematology in Gainesville.

Gary's research included studies of the biology and host range of foreign insects with potential for biological control of the Australian weeds, melaleuca, *Melaleuca quinquenervia,* and old-world climbing fern, *Lygodium microphyllum,* both of which threaten the Everglades and the South Florida ecosystems. He had extensive foreign experience, having conducted explorations and field collections in 20 countries for insects to control weeds as well as insect pests and having travelled to 19 additional countries for meetings and visits. Gary also made highly significant research contributions to the ARS efforts to control alligatorweed, *Alternanthera philoxeroides,* Eurasian watermilfoil, *Myriophyllum spicatum*, hydrilla, *Hydrilla verticillata,* and water hyacinth, *Eichhornia crassipes*, with insects. Upon retiring from the ARS in 2004, Gary and May moved to and settled in Sacramento, California.

Through his career, Gary published numerous research papers and other publications highlighting his studies and gave numerous talks at national and international scientific meetings. His research took him abroad to several countries and the travel fitted well with Gary's interests in collecting not only insects but also antiques and experiencing foreign cultures and food, especially desserts. Gary was an avid photographer and usually had his camera ready to capture interesting shots of 'bugs', nature, antiques, and people. He was also a good, keen tennis player.

By: Lloyd Andres, Al Cofrancesco, Susan Wright and Raghavan Charudattan.

Eucalyptus Gall Wasp Biological Control

A paper in *Biological Control* evaluates classical biological control of the eucalyptus gall wasps *Leptocybe invasa* and *Ophelimus maskelli* in Israel, with results also given for *O. maskelli* in Portugal.[1] The authors analyse the results of a detailed post-release monitoring study to assess the impact of the biological control programme in Israel, and the contribution of the various biocontrol agents. The conclusion is that the biological control programme has led to effective control of the gall wasps, with steep decline recorded for both pests. Control of *L. invasa* is better, possibly because of the richer and more diverse guild of biocontrol agents that was established. Two of three *O. maskelli* parasitoids and all four *L. invasa* parasitoids that were introduced in 2003 and 2005, respectively, were recovered during the study. Most *O. maskelli* parasitism was from one species (*Closterocerus chamaeleon*), while two species (*Quadrastichus mendeli* and *Megastigmus zvimendeli*) provided the majority of *L. invasa* parasitism.

Pre- and post-release monitoring of the impact of *C. chamaeleon* against *O. maskelli* in Portugal also indicates successful biological control. The paper notes biocontrol agent introductions in other countries (Turkey, India and South Africa for *L. invasa*, and Italy for *O. maskelli*), as well as their natural spread and impact in various countries. The authors conclude that, largely by natural spread, the exotic parasitoids are providing effective control of the invasive eucalyptus gall wasps through much of the Mediterranean region.

[1]Mendel, Z., Protasov, A., La Salle, J., Blumberg, D., Brand, D. and Branco, M. (2017) Classical biological control of two *Eucalyptus* gall wasps; main outcome and conclusions. *Biological Control* 105, 66–78.

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Invertebrate Biological Control Agents: New Publications

Three publications to note, the first a book by Esther Gerber and Urs Schaffner[1], which collates information on 176 taxa of exotic (non-European) invertebrate biological control agents (IBCAs) introduced into Europe against 58 target pests since 1897. The book has its origins in earlier publications (D.J. Greathead's 1976 *A Review of Biological Control in Western and Southern Europe* and the BIOCAT database). It provides an updated representative picture of the history of IBCA releases into the environment in Europe.

A paper by Peter Mason and co-authors in *EPPO Bulletin*[2] is based on a presentation given at the Joint EPPO/COST SMARTER Workshop on the Evaluation and Regulation of the Use of Biological Control Agents in the EPPO Region in Budapest in November 2015. It reviews regulatory oversight in the EPPO (European and Mediterranean Plant Protection Organization) region in terms of history, country examples and extent (or rather lack) of harmonization. It reviews North America in similar terms, highlighting the role of the North American Plant Protection Organization (NAPPO) in harmonizing information requirements and guidelines for certification of movement for IBCAs, and discusses how the North America model could be adapted for the EPPO region.

The third paper, from the International Organisation for Biological Control (IOBC) Global Commission on Biological Control and Access and Benefit Sharing, has a global perspective.[3] It comprises a best practices guide for the use and exchange of invertebrate biological control genetic resources, in line with the requirements of the Nagoya Protocol to the Convention on Biological Diversity. The authors say that following best practices will demonstrate due diligence in responding to access and benefit sharing (ABS) requirements, and also provide reassurance to the international community that biological control is both very successful and an environmentally safe pest management method based on the use of biological diversity.

The Commission has included as components of best practice: collaboration to facilitate information exchange on what IBCAs are available and where from; knowledge sharing via freely available databases documenting successes and failures; cooperative research to develop capacity in source countries; and transfer of production technology to provide opportunities for small-scale economic activity. The guide also provides two model concept agreements: (i) for scientific research and non-commercial release into nature where ABS regulations are in place, and (ii) for provision of IBCAs where ABS regulations are either not restrictive or absent.

[1] Gerber, E. and Schaffner, U. (2016) *Review of Invertebrate Biological Control Agents Introduced into Europe*. CABI, Wallingford, UK, 194 pp.

[2] Mason, P.G., Everatt, M.J., Loomans, A.J.M. and Collatz, J. (2017) Harmonizing the regulation of invertebrate biological control agents in the EPPO region: using the NAPPO region as a model. *EPPO Bulletin* 47, 79–90. DOI: 10.1111/epp.12355.

[3] Mason, P.G., Cock, M.J.W., Barratt, B.I.P., Klapwijk, J.N., Lenteren, J.C. van, Brodeur, J., Hoelmer, K.A. and Heimpel, G.E. (2017) Best practices for the use and exchange of invertebrate biological control genetic resources relevant for food and agriculture. *BioControl*. DOI:10.1007/s10526-017-9810-3.

Commercializing Entomopathogenic Nematodes

Two recent papers in biological control journals tackle important issues in making entomopathogenic nematodes (EPNs) a commercial success: regulation and cost. Abate and co-authors[1] review global distribution of EPNs, including those released commercially, in light of import regulations and issues that influence them. They assess whether current policies deal adequately with risks of global EPN movement, and suggest considerations for future use of EPNs in biological control. Testa and Shields[2] describe the development of a labour-saving, 'low-tech', and thus low-cost mass-rearing method for EPNs that has been used to supply over 100 billion EPN infective juveniles for an area-wide biological control programme over an eight-year period in the USA.

[1] Abate, B.A., Wingfield, M.J., Slippers, B. and Hurley, B.P. (2017) Commercialisation of entomopathogenic nematodes: should import regulations be revised? *Biocontrol Science and Technology* 27, 149–168.

[2] Testa, A.M. and Shields, E.J. (2017) Low labor "in vivo" mass rearing method for entomopathogenic nematodes. *Biological Control* 106, 77–82.

Conference Proceedings

Interest in Biocontrol Research is Growing in India as Evidenced by Increased Turnout at National Biocontrol Conference

That biological control is more relevant today than it has ever been was amply proven going by the increased turnout at the Fifth National Conference on Biological Control: Integrating Recent Advances in Pest and Disease Management (5ncbc2017) held in Bengaluru, India, on 9–11 February 2017. Standalone biocontrol agents and products are now available for myriad insect pests, phytophagous mites, plant parasitic nematodes, plant diseases and weeds around the world. Wherever there is an established integrated pest management (IPM) system, there is an opportunity to add in or integrate one or more biocontrol agents so as to devise a robust, biointensive IPM. The 2017 conference was aimed to create a platform for national researchers to project their results, ideas and concepts on how to integrate more and more biocontrol methods, technologies and products into existing pest and disease management programmes. The Society for Biocontrol Advancement (SBA) partnered the ICAR–National Bureau of Agricultural Insect Resources (NBAIR) in organizing this national meeting. The Indian Council of Agricultural Research (ICAR), State Bank of India and several private firms sponsored the event.

Professor H.A. Ranganath, an insect geneticist of international repute and former Vice-Chancellor of Bangalore University, was the Chief Guest. T.M. Manjunath, a legendary figure in biocontrol research and development in India, was the Guest of Honour. P. Sreerama Kumar, Chief Organizing Secretary, delivered the Welcome Address and Chandish R. Ballal, President, SBA & Director, NBAIR, presented the Presidential Address. The inaugural programme included release of new publications, praising senior biocontrol workers, distribution of SBA Awards and honouring biocontrol farmers. On the first day, various donor-sponsored awards instituted by SBA were given away. There were also a cultural programme and the conference dinner on that day. On day three, a short tour was arranged to Bannerghatta National Park on the outskirts of Bengaluru city.

The meeting heard from ten invited lead speakers, while there were 55 other oral presentations and 134 posters. There were six technical sessions and two poster sessions, the latter attracting a significant number of posters from students and young researchers.

Technical Session I (Biological Control: Macrobials & Microbials): Chandish R. Ballal (NBAIR) presented a lead paper on "Biocontrol success in India and abroad – drawing parallels". She narrated the global history and success stories of various biocontrol programmes, and compared and contrasted the import regulations in vogue in various countries regarding natural enemies for invasive pests, procedures and constraints. P.S. Vimala Devi (ICAR–Indian Institute of Oilseeds Research) presented another lead paper on "Perspectives on the use of *Bacillus thuringiensis* for effective management of insect pests". Highlighting the various recent developments, she indicated that increased *Bt* efficiency can be possible through development of nanosuspensions and nanoemulsions. Also, reducing the particle size of *Bt* to sub-micron size would not only lower the effective dose but also improve the consistency of formulations.

The oral presentations included a paper on the impact of *Bm*NPV (*Bombyx mori* nucleopolyhedrovirus) on silkworm rearing and techniques for its early diagnosis (Mudasir Gani *et al.*), indicating that horizontal transmission of the virus is best prevented through use of antibody-based biosensors which have high specificity, sensitivity and the option of "on-site" pathogen detection. Another interesting paper was on rhamnolipids from *Pseudomonas aeruginosa* DR1 for biological control of *Fusarium* wilt (M. Yahya Khan *et al.*). Other papers during the session covered: efficacy of *Neoseiulus longispinosus* in the management of *Tetranychus urticae* on cucumber; rhizoplane fungi of grasses and *in vitro* biological management of *Colletotrichum* diseases in forest nurseries in Kerala; recent trends in biological control of scale insects on fruit crops; the effects of soil moisture and host stage on suppression of *Leucopholis lepidophora* by entomopathogenic nematodes; endophytic entomopathogenic fungi as biocontrol agents for insect pest management; on-farm impact of *Trichogramma* spp. against lepidopteran pests in organic rice in Punjab; development of *Trichoderma* formulations to obtain more colony-forming units and longer shelf-life; a first record of *Encarsia formosa*, an aphelinid parasitoid of greenhouse whitefly in India; screening and identification of antagonistic microbes against *Fusarium ambrosium*, a symbiont of tea shot-hole borer; interactions of soil-applied, non-native *Trichoderma harzianum* with resident microflora in the tomato rhizosphere; morphometry and biology of a geocorid predator of soft-bodied insects; and the bioefficacy of entomopathogenic fungi in suppression of termites in sugarcane.

Technical Session II (Biointensive IPM): In their lead paper on *Trichoderma* formulations, S.C. Dubey (ICAR–National Bureau of Plant Genetic Resources) and Aradhika Tripathi (ICAR–Indian Agricultural Research Institute) showed how their products 'Pusa 5SD' (seed application) and 'Pusa Biopellet' (soil application) exhibited longer shelf-life and were effective against several diseases of pulse crops, including dry and wet root rot of mungbean and chickpea, wilt of chickpea and root rot and damping-off complex in French bean. A lead talk on the current scenario and future prospects of biological control of weeds was presented by A.N. Shylesha (NBAIR) on behalf of Sushilkumar (ICAR–Directorate of Weed Research) and P. Sreerama Kumar (NBAIR). He advocated the introduction of known bioagents into India, which have been proven successful against common weeds in other parts of the world, and stressed the need to integrate biological methods with chemical and mechanical methods to hasten the process of weed management. The oral presentations included a paper on biointensive options for the management of *Tuta absoluta*, an invasive pest introduced to India in 2014 (M. Mohan *et al.*); a concept-introducing paper on ecological engineering for enhancing biocontrol of hoppers in rice (Chitra Shanker *et al.*); and another on the impact of biointensive IPM practices on insect pests and grain yield in basmati rice (Sudhendu Sharma *et al.*).

Technical Session III (Biorational Approaches & Biocontrol-Compatible Molecules): In his lead talk on "Pheromones in pest management", A.R. Prasad (Indian Institute of Chemical Technology, Council of Scientific and Industrial Research), highlighted how his group could successfully demonstrate the utility of pheromones based on indigenously synthesized pheromone components in field crops such as rice, cotton, groundnut, sugarcane, eggplant, cabbage and okra through a farmer participatory approach. In another related lead talk, N. Bakthavatsalam and K. Subaharan (NBAIR) explained how infochemicals help in identifying the presence of cryptic insects like mealybugs, and how aggregation pheromones help in mass-trapping pests like coffee white stem borer (*Xylotrechus quadripes*), coconut rhinoceros beetle (*Oryctes rhinoceros*) and red palm weevil (*Rhynchophorus ferrugineus*).

One of the advanced papers presented was on the utility of nanosensors in agricultural pest management (Deepa Bhagat *et al.*). Pheromone nanosensors allow users to detect pests early, to measure the concentration of pheromones in the field and to release pheromones from devices in appropriate quantity and time. Other papers of interest covered: Z-10 dodecenal, a kairomone for the attraction of *Exorista bombycis*, the uzifly parasitoid of *Bombyx mori*; biosurfactants produced by endophytic actinomycetes and their application as biocontrol agents; and physiological and behavioural response of coconut red weevil to host volatiles.

Technical Session IV (Biodiversity & Conservation): S.K. Gupta (Medicinal Plants Research & Extension Centre, R.K. Mission) gave a lead presentation on the efficiency and potential of the predatory mites of India, highlighting some of the important species and discussing how best the promising predators could be utilized in pest management. In the second lead paper of the session, Abraham Verghese (GPS Institute of Agricultural Management) and co-authors presented a case study on bird insectivory decline and pest boom in Bengaluru. They used archived notes of the last four decades to extrapolate the biodiversity trends over this period, arguing a need to conserve insectivorous birds in agro-horti ecosystems as part of conservation biological control. The oral presentations were mostly taxonomy-related, with topics ranging from solitary bees to semi-aquatic bugs that feed on mosquito immature stages, fruit flies, parasitic hymenopterans, thrips and pentatomid bugs.

Technical Session V (Molecular Biology & Bioinformatics in Biological Control): The lead talk on "Multipartite interaction of introduced biocontrol agents in the rhizosphere" by M. Anandaraj and P. Umadevi (ICAR–Indian Institute of Spices Research) highlighted the importance of recent technological platforms, viz. metagenomics and proteomics, in understanding microbial interactions in soil, because the field performance of any biocontrol organism depends on its rhizosphere competence: its ability to grow on the roots of the plants within a stipulated time while competing with numerous native microbes. Giving the final lead talk on entomopathogenic nematodes, M. Nagesh (NBAIR) underlined the importance of molecular and gene manipulation techniques as they offer enormous opportunity for *in vivo* production, formulation and storage, which are extremely important for their utilization. Papers on transcriptome analysis of *Trichogramma chilonis*; comparative genomic sequence analysis of *Ha*NPV (*Helicoverpa armigera* NPV); and diversity of *cry* genes occurring in north-eastern India, had direct relevance to biological control.

The high point of 5ncbc2017 turned out to be the final session, *Technical Session VI*, during which a *Bioresources–Biocontrol Interface: Panel Discussion* was organized. In the afternoon on day two, the nine experts on the panel discussed various issues related to bioresources vis-à-vis biological control. Among the various recommendations, it was generally agreed that import regulations should be relaxed at least for importation of natural enemies, but that due care should be taken during bulk import of natural enemies to avoid problems of accidental introduction of unwanted organisms. A committee should be constituted with representatives from ICAR, NBAIR, the National Biodiversity Authority, the Directorate of Plant Protection, Quarantine & Storage, the Department of Agricultural Research and Education, and private organizations to debate on all the issues regarding import, export and exchange of natural enemies, and to resolve issues related to exporting dead/preserved specimens for taxonomic studies. It was also felt that a core group of entomologists should be formed to list and resolve problems related to import/export/exchange of dead insects and import/export of live insects for research/biocontrol. Further, procedures for registration of biopesticides should be made less stringent than for chemical insecticides. The panel discussion was followed by the Valedictory Ceremony and later by the Annual General Meeting of SBA.

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