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General News

Biological Control of Air Potato

A chrysomelid leaf-feeding beetle from China is showing promise as a biocontrol agent for air potato (*Dioscorea bulbifera*) in the USA following its first release in Florida in early 2012. Air potato is an herbaceous, perennial twining vine that attains lengths of 20 m or more rendering it capable of climbing over and smothering native vegetation in its introduced range. The vine is found in both Asia and Africa, and although the Florida material was originally thought to have an African provenance, subsequent genetic analysis determined that it was more likely to have originated from China[1]. It was introduced to south Florida in 1905 by a local nurseryman, who later noted its threat. It has since attained a reputation as one of the most aggressive weeds ever introduced. By the 1980s, air potato vines were growing in thickets, waste areas, and hedges or fencerows in many parts of Florida. By 1999, *D. bulbifera* was altering plant communities by displacing native species, changing community structure and disrupting ecological functions.

Vegetative propagation occurs primarily through aerial bulbils (hence the name 'air potato') that form in leaf axils during late summer. These bulbils, which may weigh up to 1 kg, drop to the ground when the vines die back during the cooler months. Vines re-sprout during spring from subterranean tubers or from bulbils. Seed production rarely occurs in Florida with spread mainly through anthropogenic dispersal of the bulbils. Besides Florida, air potato has been reported from most of the US Gulf Coast states, Puerto Rico and Hawaii, while climate matching models suggest it could spread along the Atlantic Coast as far as Charleston, South Carolina.

Mechanical control can be effective in the short term in accessible locations – many infested areas are not – but it relies on the laborious process of cutting the vine and pulling it clear of the underlying vegetation, and then removing all bulbils from the site to prevent re-sprouting. Chemical control is expensive (US$1750/ha/year) and requires several years' treatment. A classical biological control programme was initiated at the USDA-ARS (US Department of Agriculture – Agricultural Research Service) Invasive Plant Research Laboratory (IPRL) in Fort Lauderdale, Florida, with the aim of testing natural enemies from the area of origin to control air potato in the USA.

Lilioceris cheni was first identified on air potato in Nepal in 2002 during surveys for natural enemies of another invasive weed. It was subsequently located in southern China by Gloria Witkus and Allen Dray of IPRL, through collaboration with Matt Purcell from the USDA-ARS Australian Biological Control Laboratory and Ding Jianqing and staff members Wu Kai, Zhang Jialiang and Huang Wei at Wuhan Botanical Garden (an institute of the Chinese Academy of Sciences). It is a fairly large orange-red leaf beetle which has proved to be a host-specific specialist that feeds and develops only on *D. bulbifera* and poses virtually no risk to other plant species[2]. Permission to release the beetle was thus acquired from USDA-APHIS (Animal and Plant Health Inspection Service). IPRL has now begun an ambitious release programme.

Pale white, oblong eggs of *L. cheni* are deposited in loosely aggregated clusters on the undersides of young, expanding leaves of its host plant. The process of oviposition apparently deforms the expanding leaf causing it to curl at the edges becoming cup-like around the eggs. Females deposit, on average, more than 1200 eggs during their lifetime. Larvae feed gregariously and skeletonize the leaves from the underside. Young tender leaves are preferred but larvae also consume older, tougher leaves and are able to feed on the bulbils. They excrete a slimy substance to which they often affix faecal material which provides camouflage and protection from predators. Development of the four larval instars requires about eight days. When fully grown, larvae drop from or crawl off the host plant and enter the soil, where a whitish oral exudate hardens into a foam-like cocoon. Pupation occurs gregariously, with several pupae often clumped together within a matrix of this material. Adults emerge in about 16 days, begin mating in about ten days, and initiate oviposition about five days later. The adults live five months or more and can survive at least a month without food.

Feeding by both adults and larvae skeletonizes the leaves. A single individual can consume approximately 30 square feet [ca. 2.8 m^2] of leaf tissue during its larval and adult stages. Larvae can often be found in aggregations on the growing tips. This damage inhibits vine elongation and may reduce the ability of the plant to climb vertical structures. The host plant drops its leaves during the winter forcing the adult beetles to survive several months without food, presumably in diapause beneath debris, such as leaf litter, on the ground. The overwintered adults emerge during spring and females initially lay about 90 eggs/day during a 13-day period of ovipositional activity.

In Florida, beetles were first released in two cages (75 beetles/cage) at Long Key Park, Broward Co. during early November 2011 to ascertain their ability to overwinter. About 10% survived when the cages were removed on 1 March 2012. These 16 beetles, which were released in the surrounding area, constituted the first open release. Additional releases were made during the ensuing months.

Extensive damage became apparent at most sites within three months with little apparent dispersal of the beetles even to adjacent areas. By autumn, however, most of the vines in release areas had been stripped of foliage, which seems to have induced local dispersal. Initial observations suggest that bulbil production has been reduced where defoliation has been prolonged and intense. Although it is a bit early to declare the beetles established, at least four sites, ranging from Miami in the south to Gainesville in the north, now seem to have persistent populations. It remains to be seen if they will again survive the winter period when foliage is unavailable for sustenance, especially in colder, more northern areas.

Meanwhile, a second agent may be in the offing. The collecting trip for *L. cheni* in southern China also found another promising natural enemy, *L. egena*, which feeds on the bulbils, in contrast to the predominantly foliage-feeding *L. cheni*. This species is now undergoing host-specificity tests at IPRL. The two species are potentially a very effective combination since in Florida the plant reproduces mainly vegetatively via the bulbils and seed production is rare.

[1]Croxton, M.D., Andreu, M.A., Williams, D.A., Overholt, W.A. and Smith, J.A. (2011) Geographic origins and genetic diversity of air-potato (*Dioscorea bulbifera*) in Florida. *Invasive Plant Science and Management* 4, 22–30.

[2]Pemberton, R.W. and Witkus, G.L. (2010) Laboratory host range testing of *Lilioceris* sp. near *impressa* (Coleoptera: Chrysomelidae) – a potential biological control agent of air potato, *Dioscorea bulbifera* (Dioscoreaceae). *Biocontrol Science and Technology* 20(6), 567–587.

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Progress in Biocontrol of Mile-a-Minute

Working on the US *Persicaria perfoliata* (mile-a-minute) biological control programme, which began in 1996, has demanded patience. However, as a paper in *BioControl* indicates[1], an introduced weevil is now making headway, which is a relief not only because the road to release it was long, but also because it has been described by scientists involved in the programme as the only likely insect candidate against the weed[2] although more than 100 species were found attacking it in its native range.

Persicaria perfoliata is an aggressive annual vine native to Asia. It was accidentally introduced into Pennsylvania in the 1930s and has since expanded northwards to Massachusetts, southwards to North Carolina, and westwards to Ohio – and it is continuing to spread. Although characteristic of stream banks in its native range, it invades forest edges, light gaps, open fields and riparian borders in North America. As indicated by its common name, *P. perfoliata* grows rapidly, reaching lengths of up to 6 m. The vines can overgrow other plants, producing masses of intertwining foliage, and flowering prolifically. A single plant can produce thousands of seeds a year, which can survive up to six years in the soil.

A survey conducted in China by the US Department of Agriculture (USDA) Forest Service and scientists from Wuhan Botanical Garden (an institute of the Chinese Academy of Sciences) found more than 100 insect species feeding on *P. perfoliata*[2], including foliar feeders, stem borers, and seed and fruit feeders. Yet of these only one, the weevil *Rhinoncomimus latipes*, proved sufficiently host specific to meet current regulatory requirements in the USA. There are many plant species in the family Polygonaceae in North America including crop species (such as buckwheat) and some native congenerics, two of which are found growing with *P. perfoliata* in its introduced range. *Rhinoncomimus latipes* is closely associated with its host plant at all stages, which probably contributes to its host specificity. Tests conducted in China and in quarantine in the USA found only minor adult feeding on a few Polygonaceae and no feeding on plant species outside this family. The weevil occurs widely in China and populations from three provinces were tested; those from the southern province of Hunan were found to be most effective against North American *P. perfoliata*. The biocontrol agent, reared at the New Jersey Department of Agriculture Phillip Alampi Beneficial Rearing Laboratory, was first released in 2004, and since then weevils reared at the same laboratory have been released in ten states. Thanks to continual improvements increasing numbers have been reared over the years, with more than 76,000 insects released in 2009 and 2010.

Eggs are laid on leaves, stems and buds, and larvae bore into the stems at internodes and feed internally in the stems. When mature, they drop to the ground and pupate in the soil under the plant, while emerging adults crawl back up plants to feed on foliage, mate and lay eggs. This life cycle takes about 26 days in the laboratory, which translates into 3–4 overlapping generations per year in south-eastern Pennsylvania.

Weevils overwintered after release and have established at 54 of 56 sites where they were released between 2004 and 2007; both May and October releases led to successful establishment. They have proved resilient in their introduced environment, surviving at sites that were flooded, mowed, and subject to tidal flooding. Large populations of weevils have been recorded at release sites the year after release. The biocontrol agents are having a measurable and at times rapid impact on the target weed. At a site in New Jersey where some 7000 weevils were released in 2005, spring seedling counts and percentage cover were dramatically reduced in a single year; in contrast both remained high at a control site for three years – until weevils dispersed into this site after which seedling counts and percentage cover fell. It is a similar story in Delaware where a massive *P. perfoliata* infestation was greatly reduced in a season, apparently through a combination of weevil feeding and late summer drought.

The average dispersal rate of the weevil after the first year is estimated at over 4 km/year. Given the extensive North American distribution of *P. perfoliata*, it would take more than a century to reach the edge of the current distribution. It has therefore been given a help with additional releases, mostly of weevils reared at the New Jersey facility: *R. latipes* was released in Delaware, Maryland, New Jersey, Pennsylvania and West Virginia between 2004 and 2008, and also in Connecticut, New York, Rhode Island and Virginia in 2009; weevils were then released in Massachusetts in 2010 and North Carolina in 2011. There has been no evidence of non-target feeding or oviposition, even in field experiments that assessed closely related non-targets and other species that had been fed on in quarantine by releasing weevils at the base of each plant; these weevils moved rapidly to nearby *P. perfoliata* plants.

Interest now is also focusing on restoration. Although *R. latipes* populations can increase quickly and have a rapid impact on the target weed, in the US Mid-Atlantic region competing plants may be largely other non-native invasives. Current research is therefore looking at integrated weed management, and how combining biological control, herbicide application and restoration planting of native competitors can assure the establishment of a diverse predominantly native plant community following control of *P. perfoliata*.

[1]Hough-Goldstein, J., Lake, E. and Reardon, R. (2012) Status of an ongoing biological control program for the invasive vine, *Persicaria perfoliata* in eastern North America. *BioControl* 57(2), 181–189.

[2]Ding J.Q., Fu W.D., Reardon, R., Wu Y. and Zhang G.L. (2004) Exploratory survey in China for potential insect biocontrol agents of mile-a-minute weed, *Polygonum perfoliatum* L., in eastern USA. *Biological Control* 30, 487–495.

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Prospects for Biological Control of Red Palm Mite

The red palm mite (*Raoiella indica*; RPM) was until recently reported as a minor seasonal pest of coconut, date and areca palms in Old World countries such as India, Mauritius and Reunion. It was first reported on coconut in Coimbatore in India in 1924 and later in Egypt on date palm in 1942, and subsequently in other Old World countries. In 2004, it was reported for the first time in the New World on the island of Martinique, from where it has spread rapidly throughout the Caribbean archipelago into southern Florida, Mexico and South America (Colombia, Brazil, Venezuela). A study by Peña *et al.* in 2009[1] examined the densities of RPM in Puerto Rico, Trinidad and Florida. They reported populations reaching up to 4000 per leaflet on coconut palms at peak densities compared to a maximum of 750 per leaflet on coconut in Kerala in India[2]. RPM forms colonies which are often found along the midrib on the underside of host plant leaflets/leaves. Ochoa *et al.*[3] showed that members of the *Raoiella* genus exploit their host plants by feeding through the stomata which may lead to inefficiencies in host transpiration during heavy infestations. RPM colonies in the invasive range take over the underside of the leaflets/leaves turning them yellow and causing a drop in plant productivity. In addition, the mite has proven to be capable of spreading rapidly between plants. Although the mechanism of dispersal has not been confirmed, it is thought that at high population densities the mites drop off leaves onto understorey vegetation and may also be transferred on wind currents. All reported hosts (91 plant species) of RPM are monocots from the orders Arecales (Arecaceae) and Zingiberales (Heliconiaceae, Musaceae, Strelitziaceae, Zingiberaceae). Most are palms that originated in areas of the Eastern Hemisphere; about a quarter of the hosts are native to the New World and could be considered new host associations of RPM. The mite has been reported widely on *Musa* species (bananas and plantains) and other ornamentals in the New World whereas these host plants were absent from the literature pertaining to its Old World range prior to 2004.

The expansion of RPM onto a widened apparent host range and the difference in densities between the native and invasive ranges indicate that RPM is not being wholly controlled by native natural enemies in the New World. This broad host range makes RPM a difficult pest to control using chemicals as many different hosts need to be targeted. Indeed, the height of coconut palms is a barrier to the application of sprayable chemicals. Classical biological control has therefore been considered the stand-out option for the control of RPM. Several authors[4,5,6] have undertaken surveys within the past few years for natural enemies of RPM in the Old World and the most commonly found predator in association with RPM was *Amblyseius largoensis.* Carrillo *et al.*[7,8] have carried out several studies investigating the associations and feeding habits of the New World *A. largoensis* on RPM, and it seems the predator preferentially feeds on RPM compared to the other phytophagous native mites they tested; however, the preferred stage to prey on appears to be the RPM egg. No such studies have been carried out in the Old World, therefore further studies to elucidate whether *A. largoensis* from these areas is able to handle the RPM adult stage more readily need to be conducted, indeed Carrillo et al.[8] found evidence that experience of handling RPM larvae increased the likelihood that this stage would be attacked by the predator and that there may be an underlying genetic basis for this. Bowman and Hoy[9] have undertaken a molecular analysis of *A. largoensis* collected in the New World (Florida, USA) and the Old World (Mauritius) and have shown that the two populations are genetically different, although it is unclear whether these indicate the existence of biotypes or cryptic species. Hoy[4] pointed out the difficulties associated with obtaining a release permit for the phytoseiid in Florida, due to these differences and evidence that the two populations interbreed on a laboratory scale. It will be important to determine which populations of *A. largoensis* are more efficient in preying on RPM. Due to the marked preference that *A. largoensis* exhibits for RPM eggs, it would be desirable to find other natural enemies that could prey on or parasitize other stages of the pest. Acaropathogenic fungi found attacking RPM in Puerto Rico could prove very useful. But it is likely that other mortality factors will be required to effectively suppress the pest. The search for effective natural enemies should be intensified and ways to improve the levels of control by the existing natural enemies should be further investigated[10].

One thing for sure is that the solution to the RPM problem is not going to be simple and it is unlikely that it will be solved by one golden bullet; however, with researchers investigating all avenues for control including predators and pathogens, there are likely to be more options available to growers and governments in the near future.

[1]Peña, J.E., Rodrigues, J.C.V., Roda, A., Carrillo, D. and Osborne, L.S. (2009) Predator-prey dynamics and strategies for control of the red palm mite (*Raoiella indica*) (Acari: Tenuipalpidae) in areas of invasion in the neotropics. In: *Integrated control of plant feeding mites. IOBC/WPRS Bulletin* 50, pp. 69–79.

[2]Taylor, B., Rahman, P.M., Murphy, S.T. and Sudheendrakumar, V.V. (2011) Exploring the host range of the red palm mite (*Raoiella indica*) in Kerala, India. In: de Moraes, G.J. and Proctor, H. (eds) *Acarology XIII: Proceedings of the International Congress. Zoosymposia* 6, 86–92.

[3]Ochoa, R., Beard, J.J., Bauchan, G.R., Kane, E.C., Dowling, A.P.G. and Erbe, E.F. (2011) Herbivore exploits chink in armor of host. *American Entomologist* 57, 26–29.

[4]Hoy, M.A. (2012) Overview of a classical biological control project directed against the red palm mite in Florida. *Experimental and Applied Acarology* 57, 381–393.

[5]de Moraes G.J., de Castro T.M.M.G., Kreiter, S., Quilici, S., Gondim, M.G.C. Jr., de Sa, L.A.N. (2012) Search for natural enemies of *Raoiella indica* Hirst in La Réunion Island (Indian Ocean). *Acarologia* 52, 129–134.

[6]Taylor, B., Rahman, P.M., Murphy, S.T. and Sudheendrakumar, V.V. (2012) Within-season dynamics of red palm mite (*Raoiella indica*) and phytoseiid predators on two host palm species in south-west India. *Experimental and Applied Acarology* 57, 331–345.

[7]Carrillo, D., Peña, J.E., Hoy, M.A. and Frank, H.J. (2010) Development and reproduction of *Amblyseius largoensis* (Acari: Phytoseiidae) feeding on pollen, *Raoiella indica* (Acari: Tenuipalpidae), and other microarthropods inhabiting coconuts in Florida, USA. *Experimental and Applied Acarology* 52, 119–129.

[8]Carrillo, D., de Coss, M.E., Hoy, M.A., Peña, J.E. (2012) Variability in response of four populations of *Amblyseius largoensis* (Acari: Phytoseiidae) to *Raoiella indica* (Acari: Tenuipalpidae) and *Tetranychus gloveri* (Acari: Tetranychidae) eggs and larvae. *Biological Control* 60, 39–45.

[9]Bowman, H.M. and Hoy, M.A. (2012) Molecular discrimination of phytoseiids associated with the red palm mite *Raoiella indica* (Acari: Tenuipalpidae) from Mauritius and South Florida. *Experimental and Applied Acarology* 57, 395–407.

[10]Carrillo, D., Frank, J.H., Rodrigues, J.C. and Peña, J.E. (2012) A review of the natural enemies of the red palm mite, *Raoiella indica* (Acari: Tenuipalpidae). *Experimental and Applied Acarology* 57, 347–360.

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Hybridization: Assessing an Unintended Consequence of Biocontrol

A study reported in *Biological Control* highlights the importance of determining whether biocontrol agents could hybridize with closely related native taxa and, if so, evaluating the impact on biological control and native biodiversity[1].

The hemlock woolly adelgid (*Adelges tsugae*) from Japan is a serious introduced pest of hemlock species (*Tsuga canadensis* and *T. caroliniana*) in the eastern USA. A native lineage of *A. tsugae* in western North America, where it is not a pest, made the suite of predators there a promising source of biocontrol agents. One of these, *Laricobius nigrinus*, has been introduced throughout the introduced range of *A. tsugae* in the eastern USA since 2003. *Laricobius* species are known to feed only on Adelgidae. One member of the genus, *L. rubidus*, is endemic to the eastern USA; although most commonly associated with *Pineus strobi* on *Pinus strobus*, it has been reported from three non-native adelgids including *A. tsugae* on *T. canadensis*. A study of genetic diversity using the cytochrome c oxidase subunit I (COI) mitochondrial gene indicated low sequence divergence between the species, while another study that reconstructed the phylogeny of the genus *Laricobius* confirmed that *L. nigrinus* and *L. rubidus* are recently diverged sister species. Together with observations of *L. nigrinus* and *L. rubidus* mating, these studies drew attention to the possibility of hybridization between the two *Laricobius* species.

This new study[1] looked at predicting the impact of species hybridization on biological control of *A. tsugae* and on native biodiversity in eastern North America. The authors assessed and used six microsatellite markers to distinguish species and hybrids and to test for population structure within species, while morphology was examined to determine characters distinguishing parent species from hybrids. Next, they used variation in microsatellites and mitochondrial COI DNA to demonstrate widespread presence of fertile hybrids on *T. canadensis* infested with *A. tsugae* at sites in eastern USA where *L. nigrinus* was released, and found a strong asymmetric introgression towards *L. nigrinus*. They suggest that both species could persist within a patchwork of species and hybrids in the eastern USA.

The authors discuss the impact this outcome could have on biological control of *A. tsugae*, indicating that the effects could be positive and negative. They argue that the study underlines the importance of evaluating the potential for introduced biocontrol agents to hybridize with native close relatives. The authors found just three previously reported examples of hybridization between a classical biocontrol agent and a native species. They suggest the *Laricobius* system could provide an opportunity to improve understanding of emerging hybrid zones by tracking progress of hybridization over time.

[1]Havill, N.P., Davis, G., Mausel, D.L., Klein, J., McDonald, R., Jones, C., Fischer, M., Salom, S. and Caccone, A. (2012) Hybridization between a native and introduced predator of Adelgidae: an unintended result of classical biological control. *Biological Control*, online 17 August 2012. DOI: 10.1016/j.biocontrol.2012.08.001

Second Biocontrol Weevil Threatens an Endangered Thistle

A second biocontrol agent has been implicated in the threatened extinction of a US federally threatened thistle species, *Cirsium pitcheri*. Fifteen years ago, the introduced seed-feeding weevil *Rhinocyllus conicus* was identified by Svata Louda and colleagues as a potential threat to US native thistle species including *C. pitcheri*. In 2005 *R. conicus* was found on *C. pitcheri* in Chicago Botanic Garden although it has still not been found on a natural population of this species. However, a second seed-feeding weevil, *Larinus planus*, has been recorded on *C. pitcheri* in nature and a study reported in *Biological Conservation* describes how the weevil, in the presence of other threats to the thistle, could push this already threatened species towards extinction[1]. *Cirsium pitcheri,* which grows on the shorelines of Lakes Huron, Michigan and Superior in the USA and Canada, is a short-lived perennial that flowers only once and does not reproduce vegetatively. It is thus particularly vulnerable to threats to seed production and seedling recruitment. Besides insects, other threats include habitat destruction, human disturbance, non-native plant species, native mammals and birds, and climate change. The reported study assessed ecological and genetic factors responsible for changes in population growth rates in thistle populations throughout its range and how these factors might impact population viability.

Larinus planus is an Old World seed-feeding weevil that, unlike *R. conicus*, was introduced to the USA inadvertently. It was first discovered in Maryland in 1971 and subsequently re-distributed in the USA and Canada as a biocontrol agent particularly for Canada thistle, *Cirsium arvense*. It has been found on at least three species of native thistles in western US states. In one natural stand of *C. pitcheri* in Wisconsin, which was apparently free of the weevil as recently as 2007, the authors first recorded the weevil in 2010 infesting one-third of inspected seedheads. A more extensive survey at the same site in 2011 found the weevil to be present in over half the seedheads with virtually no viable seed in infested heads; thus the weevil had reduced fecundity by about 50%. Long-term data from two other sites, in Wisconsin and Michigan, indicate that *C. pitcheri* population growth rates vary widely between years but support the view that most populations of the thistle hover near or below replacement – in other words on the brink of extinction. Modelling data from these two sites, including what the authors describe as conservative data on the impact of *L. planus* herbivory, indicates that although other threats (finch seed predation and inbreeding) have greater impacts on seed production and seedling replacement, the addition of *L. planus*, which reduced population growth by an estimated 11.5%, could be a crucial additional threat. The authors say that the impact they estimate for *L. planus* is similar to projections given for *R. conicus* by Svata Louda and co-authors in earlier publications.

[1]Havens, K., Jolls, C.L., Marik, J.E., Vitt, P., McEachern, A.K. and Kind, D. (2012) Effects of a non-native biocontrol weevil, *Larinus planus*, and other emerging threats on populations of the federally threatened Pitcher's thistle, *Cirsium pitcheri*. *Biological Conservation* 155, 202–211.

Fungal Endophytes: Potential for Cereal Disease Biocontrol

A review in *Biological Control* proposes that the role of fungal endophytes in cereals needs to be explored for a potential new control strategy for fungal diseases. The demand for cereals to feed the growing world population is constrained by declining yields which are due in part to substantial losses attributable to fungal diseases, and there are practical and regulatory constraints to controlling them using existing measures[1].

The authors briefly review knowledge of all classes of endophytes, but argue that for biocontrol it is desirable for an endophyte to (i) persist throughout the host life cycle, (ii) remain in an endophytic and asymptomatic state, and (iii) be seed transmissible. They focus on clavicipitaceous endophytes as currently holding most promise for cereals (they are used commercially in turfgrass). In reviewing what is known about these species in cereals the authors note the importance of both seeking novel species and investigating the role of known cereal endophytes. Drawing on research in pasture grasses they point to the potential for finding endophytes that are active against fungal diseases while producing few or no toxic alkaloids such as ergot alkaloids. The authors say little attention has been paid to endophyte-mediated pathogen suppression in cereals and review what literature there is for wheat, barley and maize. They discuss possible mechanisms of action including increased host fitness, endophyte–pathogen competition, and endophyte antagonism.

The authors propose that finding and characterizing endophytes with biocontrol potential in cereals should be a priority, and suggest (i) isolating more native endophytes within cereals and (ii) inoculating beneficial endophytes from non-cereal hosts (e.g. grasses) and assessing effects against pathogens in both cases. They stress the need for assessing host range and host specificity, and of understanding the endophyte–host relationship. They highlight constraints to progress that need to be overcome, including the need for efficient inoculation strategies as current methods are time consuming and/or have low success rates, and the importance of developing standardized testing for in vitro, greenhouse and field experimentation.

[1]O'Hanlon, K.A., Knorr, K., Jørgensen, L.N., Nicolaisen, M. and Boelt, B. (2012) Exploring the potential of symbiotic fungal endophytes in cereal disease suppression. *Biological Control* 63(2), 69–78.

How Successful is Classical Biocontrol of Weeds?

Meta-analysis is a useful tool for combining data from multiple studies and identifying broad patterns. A paper in *Journal of Applied Ecology* reports on meta-analyses of 61 studies published between 2000 and 2011 that quantitatively assessed the effectiveness of classical biocontrol of invasive plants on target plant individuals or populations, and on non-target vegetation to allow the impact on the plant community to be assessed[1]. Factors such as invasive region, native region, plant growth form, target longevity, control agent guild, taxonomy and study duration were also analysed to identify patterns in control success. Two previous meta-analyses looked at impacts on individual target plants only, and focused on Australia, respectively. The time-span for this study was chosen to restrict the analysis to current biocontrol practice, and to gain an idea of relatively short-term impacts. The authors found that the number of studies including quantitative assessments of the impact of biocontrol increased in succeeding years (although still small compared to total publications on classical biocontrol of invasive plants).

Biocontrol led to a decrease in all parameters of target plant performance, indicating the positive effect on individual plants and weed populations of the biocontrol agents assessed in the studies. Non-target diversity and abundance also increased, although the effect on abundance was not considered robust because of variation. Analysis of a subset of data that recorded impact on native non-target plants indicated a significant but not robust increase in diversity, while no significant effect was found for abundance, although these results were affected by small samples. Observed heterogeneity in analysis results was partly explained by sample sizes and by additional factors. For example, agents cause significant declines in size for plants originating from Oceania, Europe or South America but not Asia or Africa. The agent's family also had an effect, with significant differences between families in impact on plant size and flower production. In a descriptive study in 1989, Mick Crawley identified Coleoptera as providing the most successful biocontrol agents. This new study finds Coleoptera most prevalent as biocontrol agents, but not more successful than other orders. However, curculionid and chrysomelid beetles are repeatedly found to have greatest impact on plant size in multiple systems and the authors suggest they are prioritized where there is a diversity of potential agents and reducing plant size is a primary objective.

The authors conclude that the study shows positive impacts of classical weed biocontrol, with the caveat that publication is more likely for a successful than unsuccessful programme. They note that data on the recovery of native plant species and the invertebrate community remain sparse and recommend that future studies report the identity of plant species that replace target species as well as invertebrate community responses. It may never be possible to understand the mechanisms that determine whether a programme is successful since there are so many factors inherently not controlled for between biocontrol attempts. The main strength of this paper is demonstrating the broad quantitative impacts of biocontrol and not the characteristics shared between effective studies as every system has its own idiosyncrasies that are not detailed in published material.

[1]Clewley, G.D., Eschen, R., Shaw, R.H. and Wright, D.J. (2012) The effectiveness of classical biological control of invasive plants. *Journal of Applied Ecology* Early View, online 5 October 2012. DOI: 10.1111/j.1365-2664.2012.02209.x

John Lydon, USDA-ARS

Dr John Lydon of the US Department of Agriculture – Agricultural Research Service (USDA-ARS) died on 18 October 2012 in California after a car accident on the way to meet with stakeholders at an annual insect pest management research meeting. John became National Program Leader for Weed Science in the Office of National Programs in 2009 and led research initiatives involving invasive plants, herbicide resistance and biological control. Prior to that he was a research scientist for the Sustainable Agricultural Systems Laboratory at the Beltsville Agricultural Research Center in Maryland for many years.

His specialty was weeds, but he also managed the entire area-wide integrated pest management programme, was one of the main liaisons to the National Invasive Species Council, sat on the Technical Advisory Group which evaluates potential biocontrol agents for APHIS (Animal and Plant Health Inspection Service), and helped with the scientific direction of the USDA-ARS Overseas Biological Control Laboratories. Edward Knipling describes him as a truly insightful and dedicated scientist whose direct experience in science made him a realistic and respected scientific administrator at the Office of National Programs and one who had quickly become an essential member of the ARS leadership team charting the course for plant protection research.

Source: Edward Knipling, USDA-ARS.

Annual and Other Reviews

The 2013 *Annual Review of Entomology*, Volume 58, includes two reviews of particular interest to *BNI* readers: 'Biological pest control in Mexico' by Trevor Williams, Hugo C. Arredondo-Bernal and Luis A. Rodríguez-del-Bosque; and 'Biology and management of palm dynastid beetles: recent advances' by Geoffrey O. Bedford, which reviews use of *Metarhizium anisopliae*, *Oryctes* nudivirus and pheromones.

Other recent 2012 reviews brought to our attention:

'Meta-analysis and research on host–parasite interactions: past and future' by Robert Poulin and Mark R. Forbes. *Evolutionary Ecology* 26(5), 1169–1185. This includes a helpful overview of the use of meta-analysis.

'U.S. regulatory framework for genetic biocontrol of invasive fish' by Stephanie Showalter Otts. *BioControl* Online First™, 4 September 2012.

'Use of beneficial bacteria and their secondary metabolites to control grapevine pathogen diseases' by Stéphane Compant and co-authors. *BioControl* Online First™, 17 August 2012.

Conference Report

IOBC Global – Symposia at ICE

The International Organization for Biological Control (IOBC Global) convened three symposia at the recent International Congress of Entomology (ICE) in Daegu, Republic of Korea, 19–25 August 2012. A symposium on 'Biological Control: Benefit Sharing and the Balance between Benefits and Risks', convened by Jacques Brodeur, Barbara Barratt, Peter Mason, George Heimpel and Helen Roy, attracted considerable interest. The involvement of the IOBC Global Commission on Biological Control and Access and Benefit Sharing (ABS) was the subject of papers by Jacques Brodeur, Barbara Barratt and Marie Schloen, who outlined the issues, IOBC involvement, and the challenges ahead for biological control as the Nagoya Protocol is implemented. Many biocontrol researchers are only now starting to realise that the practice of biological control could be seriously hindered if compliance with a stringent ABS regime is to be required in the future. Johanna Klapwijk discussed issues for the biocontrol industry, and Ohseok Kwon (Republic of Korea), Franz Bigler *et al.* (Europe) and Jose Parra (Brazil) described, for their countries/regions, the impact that ABS might have on the future of biological control. In the case of Brazil it was pointed out that the ABS regime has led to far more native natural enemies being considered for biological control. As a comparison with biological control, Jeff Skevington *et al.* presented views on how ABS might impact on taxonomic research in the future. The presentations of these authors are available on the IOBC Global website: www.iobc-global.org/news.html.

The session on benefits and risks of biological control included a paper on impacts of climate change on biological control (Pip Gerard) which summarized aspects of the scoping study carried out on behalf of the FAO (UN Food and Agriculture Organization) Commission on Genetic Resources for Food and Agriculture. Potential disruption of biological control as a result of differential changes in developmental rates and loss of synchrony was discussed, but it was considered also that many biocontrol agents are likely to track their hosts successfully. Marc Kenis talked about measuring the ecological risk of the predatory ladybird, *Harmonia axyridis*; Barbara Barratt *et al.* reported on a retrospective case study to determine whether knowledge of the natural host range of a parasitoid (*Microctonus aethiopoides*) in Morocco could have helped predict non-target host range in New Zealand. They concluded that current-day knowledge of weevil phylogeny and molecular techniques would have helped predict risk for this species. George Heimpel's paper on biological control and the carbon cycle attracted considerable interest. He demonstrated that biological control can lead to significant reductions in carbon emissions as a result of decreases in the use of pesticides (manufacture, transport and application); using an analysis of data for soybean aphid (*Aphis glycines*) as an example, he calculated that by using a damage threshold for spraying, 3–7 million kg CO_2 equivalents could be saved per year.

The symposium organised by Joop van Lenteren and Franz Bigler on 'International Exchange and Risk Assessment of Biological Control Agents' started with a very good summary of the history and developments in risk assessment over the last 20 years by Franz Bigler *et al.* Case studies discussing the selection of non-target species for risk assessment included papers by Marc Kenis (cabbage seedpod weevil [*Ceutorhynchus obstrictus*] biocontrol agents) and Lisa Berndt *et al.* (biocontrol of gum leaf skeletonizer, *Uraba lugens*). Russell Messing presented research on indirect ecological interactions resulting from biological control, and the difficulty of making predictions in quarantine. He presented a framework for considering indirect effects and improving the prediction of a biocontrol agent's role in the ecological community. Josep Jacas *et al.* gave examples of successful inoculative biological control programmes for greenhouses throughout the Western Palaearctic eco-region using biocontrol agents sourced from the Mediterranean region. These can be used safely with minimal risk of establishment in the colder northern parts of Europe. Patrice Bouchard *et al.* provided the case study of the parasitoid *Trichomalus perfectus*, for which host-range studies demonstrated that it should not be intentionally introduced, yet the species has established adventively in Canada, providing an opportunity to validate the empirical findings that it presents a risk to non-target species.

The regulatory system for biological control in Brazil was described by Vanda Bueno *et al.* who outlined the difficulties of obtaining registration for biocontrol agents, which is being addressed by the recently established Brazilian Association of Biological Control Industry (ABcBio). Joop van Lenteren *et al.* closed the session with a paper on the current 'patchwork regulation' of biocontrol agent import and release in Europe. The IOBC Western Palaearctic Regional Section Commission on 'Harmonised Regulation of Biological Control Agents' along with EPPO (European and Mediterranean Plant Protection Organization) have developed a set of guidelines which several countries are using. Examples were given from the Netherlands on the efficiency of evaluating biosafety of a large number of biocontrol agents using the process outlined in the guidelines.

The symposium organized by Leo Beukeboom and John Werren on the 'Genetics & Genomics of Insects Used in Biological Control & Their Relatives' aimed at integrating knowledge of recent genomics technology towards improvement of biocontrol agents. In the last few years revolutions have taken place in high-throughput molecular biological techniques and bioinformatics and these are progressively being applied to beneficial insects. For example, several whole genome sequencing projects of parasitoid wasps are currently underway, so it was considered timely to compile these efforts and exchange information with the aim of evaluating the extent to which these new developments can be applied to questions and needs of the biological control industry. The symposium brought together scientists that work on genetic aspects of invertebrate biocontrol agents in a broad sense, including some allied groups of interest. The symposium started with a presentation by John Werren on current knowledge of *Nasonia* genetics with clear examples of how this work could be exploited for improvement of biocontrol agents. Subsequent talks focused on genetics of sex determination (Leo Beukeboom), immunity (Xuexin Chen), life history and symbionts (Fabrice Vavre) and reproductive behaviour (David Shuker). The final two talks reported on genetics and genomics studies in other Hymenoptera, sawflies (Masatsugu Hatakeyama) and fig wasps (Jin-Hua Xiao). There was strong enthusiasm among the participants for application of their results to improve the efficiency of biocontrol agents.

By: B.I.P. Barratt, J. Brodeur, P.G. Mason, G.E. Heimpel, H.E. Roy, J.C. van Lenteren, L.W. Beukeboom and J.H. Werren.

Society for Invertebrate Pathology

The 45th Annual Meeting of the Society for Invertebrate Pathology (SIP) was held in Buenos Aires, Argentina, on 6–9 August 2012. Several hundred scientists attended, presenting current research in the field of invertebrate pathology; some 170 papers were presented, together with about 160 posters. Following the opening addresses by the organizing committee and the President of SIP, the Founder's Lecture was an emotional tribute to the work of Sérgio Batista Alves and Flávio Moscardi, two pioneers of invertebrate pathology in South America, both of whom are no longer with us.

As ever at SIP, microbial control of invertebrate plant pests was heavily represented, with sessions running throughout the week on viruses, bacteria, fungi, nematodes and microsporidia as control agents. However, in conjunction with this was an array of somewhat alternative topics, including diseases of beneficial invertebrates, invertebrate pathology in veterinary and human medicine, the use of RNAi to control insect diseases, and applications of nematodes and bacteria in other scientific disciplines, particularly as model organisms in the undergraduate classroom, all in all reflecting the diversity of invertebrate pathology research presently being done. The poster sessions were very well attended and, as with contributed papers, covered a rich diversity of invertebrate pathology topics. It was great to see many undergraduate students from Central and South America; while there were many from the host country Argentina, Chile, Brazil, Colombia, Venezuela and Mexico were also well represented.

Financial support from CABI, the British Mycological Society and the Royal Entomological Society meant I was able to present a paper in the Microbial Control session on the biopesticide potential of organisms from ecological extremes, describing insect-killing fungi and nematodes collected from areas of southern Chile and Antarctica. The paper combined data on the taxonomy, growth, environmental adaptation and virulence of isolates collected during the last 3–4 years by scientists at CABI, the British Antarctic Survey and INIA (Instituto de Investigaciones Agropecuarias, Chile), and described in particular the insecticidal activity of a number of fungal isolates from far-South latitudes; these isolates were collected from soil in Antarctica and represented genera with no history of attacking insects. Other presentations of note included one by Andrés France of INIA which described the progress and opportunities in microbial control in the Chilean fruit industry, highlighting some excellent results against codling moth, *Cydia pomonella,* (amongst other serious pests) using microbes discovered during Darwin Initiative (www.darwin.defra.gov.uk) surveys in wild areas of Chile, and 'Hurricane Warning!' by Richard A. Humber from the US Department of Agriculture – Agricultural Research Service (USDA-ARS), on how changes to nomenclature rules will affect fungal entomopathogens; these are significant changes that those working within invertebrate pathology should be made aware of (www.sipweb.org/fungi).

By: Steve Edgington, CABI.

New Books

Mérillon, J.M.; Ramawat, K.G. (Eds)
Plant defence: biological control (Progress in Biological Control, Vol. 12). Springer (2012) 412 pp.
ISBN 9789400719323
Price: £117.00, $179.00, €139.05
Email: orders-ny@springer.com / orders-hd-individuals@springer.com
Web: www.springer.com

Roy, H.; De Clercq, P.; Lawson Handley, L.-J.; Sloggett, J.J.; Poland, R.L.; Wajnberg, E. (Eds)
Invasive alien arthropod predators and parasitoids: an ecological approach (Progress in Biological Control, Vol. 13). Springer (2012) 275 pp.
ISBN 9789400727083
Price: £90.00, $129.00, €106.95
Email: orders-ny@springer.com / orders-hd-individuals@springer.com
Web: www.springer.com

Smagghe, G.; Diaz, I. (Eds) Arthropod-plant interactions: novel insights and approaches for IPM (Progress in Biological Control, Vol. 14). Springer (2012) 226 pp. ISBN 9789400738720
Price: £90.00, $129.00, €106.95
Email: orders-ny@springer.com / orders-hd-individuals@springer.com
Web: www.springer.com

Muniappan, R.; Shepard, B.M.; Carner, G.R.; Ooi, P.A.C. Arthropod pests of horticultural crops in tropical Asia. CABI (2012) 184 pp.
ISBN 9781845939519
Price £75.00, $145.00, €100.00
Email: orders@cabi.org
Web: http://bookshop.cabi.org

Panizzi, A.R.; Parra, J.R.P. (Eds) Insect bioecology and nutrition for integrated pest management. CRC Press (2012) 750 pp.
ISBN 9781439837085
Price: £108.00, $169.95
Email: orders@taylorandfrancis.com / internationalorders@taylorandfrancis.com
Web: www.crcpress.com

Hodek, I.; Honek, A.; van Emden, H.F. (Eds)
Ecology and behaviour of the ladybird beetles (Coccinellidae). Wiley-Blackwell (2012) 600 pp.
ISBN 9781405184229
Price: £120.00, $199.95, €143.50
Web: www.wiley.com

Abrol, D.P.; Shankar, U. (Eds) Integrated pest management: principles and practice. CABI (2012) 544 pp. ISBN 9781845938086
Price: £125.00, $240.00, €165.00
Email: orders@cabi.org
Web: http://bookshop.cabi.org

Bostanian, N.J.; Vincent, C.; Isaacs, R. (Eds)
Arthropod management in vineyards: pests, approaches, and future directions. Springer (2012) 505 pp. ISBN: 9789400740310
Price: £153.00, $239.00, €181.85
Email: orders-ny@springer.com / orders-hd-individuals@springer.com
Web: www.springer.com

New, T.R. Hymenoptera and conservation. Wiley-Blackwell (2012) 232 pp. ISBN 9780470671801
Price: £60.00, $99.95, €72.70
Web: www.wiley.com

Goddard, J. Public health entomology.
CRC Press (2012) 230 pp. ISBN 9781439848814
Price: £63.99, $99.95
Email: orders@taylorandfrancis.com / internationalorders@taylorandfrancis.com
Web: www.crcpress.com

Cheek, T.E.; Coleman, D.C.; Wall, D.H. (Eds)
Microbial ecology in sustainable agroecosystems (Advances in Agroecology series). CRC Press (2012) 308 pp. ISBN 9781439852965
Price: £63.99, $99.95
Email: orders@taylorandfrancis.com / internationalorders@taylorandfrancis.com
Web: www.crcpress.com

Price, P.W.; Denno, R.F.; Eubanks, M.D.; Finke, D.L.; Kaplan, I. Insect ecology: behavior, populations and communities. Cambridge University Press (2011) 816 pp.
ISBN 9780521834889
Price: Hbk £100.00 (Pbk £42.99)
Email: directcustserve@cambridge.org
Web: www.cambridge.org