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General News

Ladybird Strikes Discordant Note

Growing public concern about *Harmonia axyridis* (multicoloured Asian ladybird or ladybeetle) in Europe reflects deep-seated and long-held misgivings within the biological control community about the inadequacy of regulation of natural enemy introductions. The latest media attention has come from the UK, where the identification of a single specimen from a garden in the southeastern county of Essex led to alarming press headlines, e.g. "The ladybird killers fly in" (*Daily Telegraph*, 5 October 2004).

Harmonia axyridis is a well-known aphid predator, attacking numerous species in its extensive native range in Asia. It is a voracious feeder, preying on not only aphids but also soft-bodied insects like psyllids, butterfly eggs and many groups of aphid predators including other ladybirds – and cannibalism is an important factor in its population dynamics. Studies in the USA suggest that it may displace native fauna by predation, competition and other indirect mechanisms[1].

Harmonia axyridis was introduced to France for the biological control of various aphid species in 1982. Ten years ago it was commercialized for the control of aphids in greenhouses and field crops in northwestern Europe. Established wild populations were first found in Germany in 2000 (Frankfurt am Main) and in Belgium and the Netherlands at the end of 2002. Large populations have since been found in all three countries, together with evidence of its dispersal to new locations. Currently, scientists in these countries are conducting surveys to monitor its presence, abundance and spread. There is considerable concern about its possible effects on native competitors, but at present it is impossible to predict what its impact might be.

The ladybird has a far longer history in North America[1]. The first record of its introduction was in California in 1916. It has been introduced, both deliberately and accidentally, many times since, particularly to many eastern US states between 1978 and 1982. It is credited with contributing to control of pests in a wide variety of field and tree crops. It was not recorded as established in the wild until 1988, when it was collected in the southern US state of Louisiana (not near any known release site). Since then it has spread rapidly and is now found in most US states and in southern Canada. On top of the nontarget effects outlined above, it has been identified as a potential pest in the fruit industry as aggregations can occur on fruit. These are particularly difficult to remove from grapes and can lead to tainted wine. While there are scientific concerns about its nontarget effects, there is also regular public outcry: perennial complaints arise in autumn when its habit of aggregating in high numbers to over-winter in crevices in light-coloured substrates leads it to enter buildings. The sight of massed ladybirds, smell (emitted when stressed), occasional bites and allergies, and even the noise of the massed ranks crawling around contribute to its nuisance status.

In 2003, a paper in *BioControl*[2] highlighted *H. axyridis* as having a high risk of nontarget impact (second only to another polyphagous ladybird, *Hippodamia convergens*) in Europe. The paper was an output of the ERBIC (Evaluating Environmental Risks of Biological Control Introductions into Europe) project, funded under the European Union (EU) 4th Framework Programme. It developed a proposed risk assessment method for biological control agents, and applied this to 31 exotic agents commercially available in the EU. Briefly, it calculated a risk index for each species based on the likelihood and magnitude of nontarget effects from dispersal, establishment, host specificity, direct effects and indirect effects. It is notable that most of the seven predatory insects assessed were given high-risk indices (three of the five top-scoring species were predatory insects, and only one was outside the top ten).

Despite mounting evidence of its nontarget impacts, *H. axyridis* is still available commercially in Europe, described as an excellent aphid predator. Alarmingly, in the context of this article, it is also noted as seeming to be very tolerant to pesticides. Can and should anything be done? It is probably too late. Given the spread and abundance of the ladybird, eradication in Europe is not an option. With the size of the populations that have built up on the continent this autumn, its establishment in the UK seems inevitable if not already reality. *Harmonia axyridis* has now been confirmed from other locations in the southeastern UK and evidence of breeding recorded in south London[3]. Only with the passage of time will it be possible to assess whether the introductions are a disaster, by weighing up the benefits of control against the nontarget impacts.

A prime reason why such apparently high-risk species are marketed lies in the need for biological control producers to make money. There is more economic sustainability (profit) in a treatment with wide-spectrum application, and this applies as much to biological control agents as to chemical pesticides. Thus, while biological control theory dictates that the best agent, for both efficacy and safety, is a highly host-specific one, economics dictates that voracious generalist species with broad host ranges are more attractive to the commercial producer. The BioControl paper notes, however, that generalist tendencies *do not by themselves* rule out a species as a biological control agent: "The likelihood of adverse ecological effects may be high, but the conditions in which they are released (e.g. greenhouse in temperate climates) may strongly limit the realization of these adverse effects." In other words, each introduction needs to be considered on its merits. Yet how far European countries do or do not regulate the introduction of invertebrate biological control agents varies, in practice, from strictly to not at all.

The issue of lack of regulation was recognized many years ago, ironically when the fledgling 'green movement' began to throw doubts on the sustainability of widespread use of pesticides, which led to the growth of integrated pest management (IPM) with biological control as a cornerstone. The advent of IPM meant that people and countries with no experience of biological control were beginning to make, or want to make, species introductions, either as natural enemies or formulated as biopesticides. Action by international biological control organizations and FAO (Food and Agriculture Organization of the UN) led to the drafting of the IPPC (International Plant Protection Convention) 'Code of conduct for import and release of exotic biological control agents' (International Standards for Phytosanitary Measures (ISPM) No. 3)[4], which was adopted in 1996. Although primarily aimed at protecting crops, it is regarded as the general international protocol for countries implementing biological control. Nonetheless, it is not international law at this time (see below). The revision of ISPM No. 3, as regular readers will know, began in late 2002 and is currently at the country consultation stage. EPPO (European and Mediterranean Plant Protection Organization) has also developed standards (PM6)[5] to provide guidelines for assessing and reducing risks associated with biological control agents and, in some cases, for comparing their efficacy. OECD (Organisation for Economic Co-operation and Development) has developed guidance on information requirements for ecological risk analysis[6]. However, although both these focus on commercial invertebrate biological control agents, they are advisory, not regulatory, documents.

With invasive species now climbing the European agenda, classical biological control, as successfully implemented by governments in many other parts of the world, offers perhaps the best hope for containing at least some of them. Biological control, properly implemented, has a good track record of safety. A few high profile, largely historical, cases have given it an unnecessarily accident-prone public image, but the emerging problem with *H. axyridis* does little to help promote modern biological control as a safe option.

Once revised and approved, ISPM No. 3 will have legal, international status, but at the moment there is no uniform regulation within Europe. Initiatives are, however, gaining pace. A workshop held in Engelberg, Switzerland in June 2004, reported on later in this issue[7], reviewed methods for assessing environmental risks from invertebrate biological control agents and a book based on the meeting will be published next year. Another workshop in Zurich, Switzerland in July 2004 marked the establishment of the IOBC/WPRS (International Organization for Biological and Integrated Control of Noxious Animals and Plants - West Palaearctic Regional Section) Commission on Harmonization of IBCAs (CHIBCA) to harmonize the regulation of invertebrate biological control agents in the EU and other European countries.

Many biological control producers view the implementation of a regulatory procedure for biological control agents with considerable alarm. They fear that lengthy, cumbersome processes will increase costs and may prevent useful agents from reaching the market. However, without buy-in by the commercial sector to the importance of safety, the future of biological control is far from assured. For the moment, perhaps the best we can hope is that the high profile achieved by *H. axyridis* may help foster the message that safety must come first for all in the biological control sector.

Further Information

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Classical Biocontrol Introduced to Timor-Leste

The release of the coccinellid *Chilocorus politus* against coconut scale, *Aspidiotus destructor*, in the Democratic Republic of Timor-Leste (East Timor) in July 2004 was the first official release of a biocontrol predator in this small island country.

Aspidiotus destructor is a widespread and serious pest of coconut, and also infests bananas and a wide range of other crops. On coconut, it has been a frequent target around the world for biological control. Severe infestations cause characteristic complete yellowing of older coconut fronds, which is visible from a distance and even from the air. In the worst cases the trees die. Yellowing symptoms were first noticed in Timor-Leste in May 2001 around the town of Baucau, but the pest may have been present for some time by then. By 2003 the outbreak was affecting most trees in the area. Anecdotal evidence suggests that it was having serious consequences on the livelihoods of Baucau farmers. It is possible that the pest outbreak was associated with potassium deficiency in the trees. The area is characterized by coral limestone, which is mineral deficient, especially in potassium. The infestation has spread beyond Baucau and it is anticipated that it will spread elsewhere in Timor-Leste as a result of air currents and movement of infested coconut and banana plant material.

Three management options were considered by the Timor-Leste Ministry of Agriculture, Forestry and Fisheries (MAFF) in consultation with CIRAD (Centre de Coopération Internationale en Recherche Agronomique pour le Développement, France):

1. Chemical control is notoriously difficult in mature coconut palms because of their height, and would have been expensive given the number of affected trees. Safety concerns also contributed to the decision not to used insecticides. If withholding periods for compounds such as dimethoate were breached, the population would have been exposed to health risks.

2. Cultural management – cutting off and burning infested older fronds – was promoted via radio programmes in 2003. However, this is very labour intensive, and also hazardous as it involves climbing trees that can be more than 10 m tall. Although the measure seems to have had success in reducing infestations, farmers' calls for financial incentives to implement the measure could not be met and its promotion lapsed.

3. Classical biological control would give much slower impact than either option above, but did hold promise. It has been successfully implemented in other countries (but, as a note of caution, not universally so). Nonetheless, agents were known, tested and available, together with protocols for rearing and release. More than 40 natural enemies have been recorded on *A. destructor*. Coccinellids have proved the most effective for biological control, although their success in any new locality is not guaranteed.

The coconut scale biocontrol project has received generous financial support from USAID (US Agency for International Development) and German Technical Cooperation (GTZ, Deutsche Gesellschaft für Technische Zusammenarbeit). Advice from CIRAD and Gadjahmada University (Jogyakarta, Indonesia) led to *C. politus* being selected for introduction. Collections were made in Jogyakarta in September 2003 and a culture was established in Triloca, west of Baucau. *Aspidiotus destructor* colonies were established on pumpkins. The coccinellids were reared on these, supplemented with cut, scale-infested palm fronds, inside locally made wood and cloth cages. Other adaptations were devised by experimenting with ways to maintain a healthy colony:

- Laboratory windows were partially papered over to prevent direct sunlight heating the cages and causing temperature fluctuations.
- Good hygiene practices included removing sweating, rotting or damaged pumpkins promptly. Ventilators above the windows aided air circulation.
- Scale-infested palm fronds were supplied regularly, and used ones removed.
- Discarded palm material was examined carefully following removal, and again later; any coccinellid larvae found were replaced in the cage.
- The cages were on a shelf, which was supported on legs sitting in Petri dishes of water to exclude ants.
- Cannibalism was minimized by separating adult coccinellids from young larvae and avoiding crowding in cages.

Even so, predator numbers were slow to increase. The first releases were not made until May 2004, when 100 adults (40 males and 60 females) were released at each of four sites. The releases featured a novel bamboo release cage, lined with banana leaves covered in scales, which was suspended in the palm canopy by plastic cable clips. By October 2004 some 1800 ladybirds had been released at 23 locations.

Local people have also been trained in how to collect the ladybirds, and how to carry them and release them at sites of infestation where the predators appear to be absent. As *A. destructor* inevitably spreads further in Timor-Leste, new releases are likely to be necessary, but providing such training will allow the predator to be redistributed on a local level.

Because the introduction of coccinellids against *A. destructor* has had mixed results elsewhere, signs of establishment were awaited with some anxiety. However, early signs in Timor-Leste gave reason to be optimistic. Numerous larvae were detected at the first sites within 2 weeks of the adults being released. Several months on, the predators seem to be thriving in the field. Where releases have taken place, it is now common to find dense aggregations of the black pupae (up to 300 on a single frond), often clustered towards the base of the frond. This is being used as one of the indices of establishment in the post-release surveys that began in November, 6 months after the first releases. Thus, although it is still very early days, signs are promising that Timor-Leste's first foray into classical biological control may be a successful one. If so, it will doubtless make biological control an option to be seriously considered for other pests in this country.

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Coconut Community Highlights Hispine Beetle Pest

The coconut hispine beetle (*Brontispa longissima*) is proving a devastating pest as it spreads to new parts of Asia and the Pacific. IPM specialists from the Asian and Pacific Coconut Community (APCC) warn that it could threaten coconut production in some of the world's major coconut growing countries if the spread continues unchecked. They point out that the pest has been successfully controlled in the past by the introduction and enhancement of natural enemies, and call for new surveys in the area of origin of the pest.

APCC is an intergovernmental organization of 15 member countries (Federated States of Micronesia, Fiji, India, Indonesia, Kiribati, Malaysia, Marshall Islands, Papua New Guinea, Philippines, Samoa, Solomon Islands, Sri Lanka, Thailand, Vanuatu and Vietnam). Established in 1969 as the first commodity-based organization in the region, the APCC is tasked to promote, coordinate and harmonize all activities in the coconut industry which sustains the lives of millions of coconut farmers as well as those engaged in the processing, marketing and other sectors of the industry. The coconut IPM programme, currently concentrating on coconut mite and rhinoceros beetle, is working in four countries (Papua New Guinea, Philippines, India and Sri Lanka) with another five set to join next year (Malaysia, Tanzania, Samoa, Thailand and Indonesia).

Brontispa longissima was originally described from the Aru Islands (Maluku Province) of Indonesia. The chrysomelid is native to Indonesia (Aru Islands and possibly Papua Province, formerly known as Irian Jaya) and Papua New Guinea (including the Bismarck Archipelago), where it seldom causes serious problems. It has now spread widely in Asia, Australasia and the Pacific Islands attacking not only coconut palm but also several other cultivated and wild palms. In recent times it has spread to Singapore, Vietnam, Nauru, Thailand, the Maldives and Hainan Island (China) and possibly to Cambodia and Laos. In the absence of natural antagonists it has become a very serious and devastating pest in its new areas of spread. Furthermore, it is feared that *B. longissima* will find its way from the Maldives to Sri Lanka and the southern parts of India to derail the economy of these important coconut-growing regions. Emergency operations are thus necessary to try and substantially reduce its population in the Maldives. Similarly, its control in South East Asia is necessary to prevent its entry into Myanmar and Bangladesh.

The pest prefers young palms, and both larval and adult beetles are usually found in the still-folded heart leaf. They feed on the mesophyll tissue, the damage visible as long white streaks. Heavy infestations reduce photosynthetic activity to zero. Loss of eight or more leaves per tree impacts on production and prolonged attack can even kill the trees.

The first pest outbreaks of *B. longissima*, in South Sulawesi and Java, began to be reported in 1919 and continued until the pest was brought under biological control in the mid 1930s. In this first programme, control was achieved with the eulophid pupal parasitoid, *Tetrastichus brontispae*. As the pest spread through Indonesia, further outbreaks were brought under control by redistributing the parasitoid. Since then, it has been successful in several Pacific island countries. A eulophid larval parasitoid, *Aescodes hispinarum*, from Western Samoa has been successfully introduced to a number of countries. Spraying with the fungus *Metarhizium anisopliae,* isolated from *B. longissima* in Western Samoa, has also shown promise in Western Samoa and Taiwan. A number of other promising natural enemies have been recorded in the region, including egg parasitoids (the trichogrammatids *Hispidophila* (= *Haeckeliania*) *brontispae* and *Trichogrammatoidea nana* and the encyrtid *Ooencyrtus podontiae*), another fungus (*Beauveria bassiana*) and an unidentified bacteria. Predators have also been recorded, including the dermapteran *Chelisoches morio* and the ant *Oecophylla smaragdina*, together with geckoes, skinks and tree frogs. Mites (*Anoplocelaeno* sp. and *Celaenopsis* sp.) have been recorded on adult beetles.

Biological control will take some time to implement in the new areas of spread. Alternative measures are needed to replace chemical control as most of the insecticides that were recommended have been phased out owing to their harmful side effects. Although difficult to implement, an integrated approach including the use of tolerant cultivars, the adoption of phytosanitary measures, and the imposition of strict quarantine measures is recommended. In addition, relatively safer pesticides could be used to knock down the pest until biological control becomes operative and effective.

There is an urgent need to initiate an international project to provide training to coconut entomologists and create awareness in the affected countries and the countries to where the hispine beetle may spread.

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First Release against Mile-a-Minute in the USA

Polygonum perfoliatum or mile-a-minute weed (MAM) is an annual vine with sharp, reflexed prickly spines on the stem and petioles that adhere to and climb over native species. MAM infests roadsides, disturbed forest sites, stream banks, and old field and tree plantations in invaded habitats in the USA. The release of a weevil from China is an important milestone in the control programme against this weed.

MAM is native to Asia, ranging from Japan in the north to the Philippines in the south, and west to India. It is mainly limited to wetter habitats in its native range.

The first established infestation of MAM in the USA was traced to a nursery in York County, Pennsylvania in the 1940s. It was suspected that MAM was introduced along with holly (*Ilex* spp.) seeds or rhododendron (*Rhododendron* spp.) plants from Japan. The infestation in York, Pennsylvania has been considered as the centre of spread in the eastern USA. However, MAM was also reported to be present in the Glenn Dale Introduction Garden in Maryland, where it was introduced with *Meliosa* seed from Nanjing, China in 1937. Since these first recorded introductions about 60 years ago, MAM has been recorded in ten states and continues to spread aggressively in various habitats. Fifteen additional states, all within Plant Hardiness Zones 6 and 7 have climates favourable for MAM.

The first biological control initiatives focused on potential natural enemies of MAM in the USA. One of the earliest surveys for these was conducted in the eastern USA (e.g. south-central Pennsylvania in 1981–83) by Wheeler and Mengel. They recovered 34 species that developed on MAM and 12 species that fed on it only as adults. However, none of them caused significant damage to the weed. In 1997, a survey was initiated by the US Department of Agriculture (USDA) Forest Service (USFS) for arthropods associated with MAM in four states (Pennsylvania, Maryland, Delaware and Virginia). By the end of the 2000 field season, specimens representing over 112 families and seven orders had been recovered from MAM; only ten showed potential as biological control agents but none had sufficient impact on MAM to reduce its damage or spread.

The search then switched to the weed's native range. In 1996, a collaborative project was initiated between the Institute of Biological Control, Chinese Academy of Agricultural Sciences (BCI–CAAS) and the USFS Forest Health Technology Enterprise Team (FHTET) to survey for and screen potential biological control agents in China for release against MAM in the USA. A team led by Ding Jianqing conducted surveys for phytophagous insects from 1996 to 2001 in 23 provinces including northeastern China, where the climate is similar to that of the eastern USA, and southwest China, which is considered the centre of origin of the family Polygonaceae. A total of 111 species of insects representing six orders and 29 families was collected during the surveys. Most of these were recovered from leaves, although several stem borers and fruit- and seed-feeders were found. No insects were recovered from roots.

There are about 40 genera and 800 species of Polygonaceae (buckwheat family) in the USA and Canada. They include 14 economically important plant species including those grown as human and animal food (e.g. *Fagopyrum* spp. – buckwheat and *Rheum* spp – rhubarb), so host specificity in candidate agents from China was of prime importance. Among the 111 species found associated with MAM in China, 11 were initially regarded as important because of either their severe damage to MAM or their narrow host range. Based on additional information from the literature and results from lab and field tests on host range, distribution, population density and severity of damage to MAM, one species emerged that appeared to have the greatest potential, the stem-boring weevil *Rhinoncomimus latipes*. Adult weevils eat young leaves of *P. perfoliatum* and lay eggs on leaves and stems. After hatching, larvae bore into the stem where they complete development, then exit the stem and drop to the soil for pupation. Development from egg to adult takes about 26 days under laboratory conditions. Damage to the plant occurs primarily from larval feeding, which kills the stem from the exit hole to the stem terminal.

No other plant species was found to be attacked by *R. latipes* during all the field surveys in China. Choice, no-choice, and open-field tests for the weevil were conducted with more than 50 plant species from 17 families in China from 1999 to 2002. No-choice tests showed both adult and larva fed on only a few plant species in the family Polygonaceae. Based on this information, *R. latipes* was introduced into quarantine in the USA in 1999. Further feeding and oviposition tests in US quarantine gave results favourable for its release. *Rhinoncomimus latipes* was recommended for release by TAG (Technical Advisory Group for Biological Control Agents of Weeds), and approved by USDA–APHIS (USDA Animal and Plant Health Inspection Service) and the states of Delaware and New Jersey. On 19 July 2004, *R. latipes* adults were released at two sites in White Clay Creek State Park in Delaware and on 29 July 2004 at one site in southern New Jersey. Protocols for monitoring the abundance of both MAM and the weevil and evaluating the weevil's long-term impact have been developed.

In 2005, further releases are planned in New Jersey and Delaware. Releases are also expected in Pennsylvania, West Virginia and Ohio as the biological control programme against mile-a-minute weed in the USA takes to the road.

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First Rust Fungus Fully Approved for Biological Control of Yellow Starthistle in the USA

A rust fungus from Turkey has joined five introduced insect species in the battle against yellow starthistle (*Centaurea solstitialis*) in the USA. The first release of the rust, *Puccinia jaceae* var. *solstitialis*, was made in Napa Valley, California in July 2003 and successful infection in the field was confirmed later in the month. The fungus attacks the thistle's leaves and stem, forming rust-coloured pustules that rob the plant of nutrients. In sufficient numbers, these reduce root growth and seed production. The joint programme that released the *P. jaceae* var. *solstitialis* includes scientists from the US Department of Food and Agriculture – Agricultural Research Service (USDA–ARS) and the California Department of Food and Agriculture (CDFA).

The release marked the culmination of 25 years work on the pathogen, which included testing it against 65 species of plants in ten families, gaining permission to release from USDA–APHIS (USDA Animal and Plant Health Inspection Service), the State of California and the Napa County Agricultural Commissioner, and optimizing a release protocol which involves spraying the inoculum onto plants protected by a plastic tent.

Yellow starthistle is an invasive weed introduced from the Mediterranean region in the mid nineteenth century, probably in contaminated seed shipments. It has adapted to a wide range of habitats in the USA, aided by its ability to cope with both wet and dry conditions. It infests annual and perennial grasslands, pastures, shrub and open woodlands and disturbed habitats. It is now found in most of the USA apart from some southeastern states and is continuing to spread. The worst infestations are found in western states, where it infests some 7.3 million hectares of rangeland. California has the by far the largest infestations (5.8 million hectares) followed by Idaho, Oregon and Washington.

Yellow starthistle is a winter annual. Seeds germinate in autumn and grow into overwintering rosettes. Given sufficiently high temperatures and moisture, germination continues throughout the winter and into the early spring. Established seedlings are in a good position, come spring, to outcompete other plants. Long tap roots allow them to absorb soil moisture and nutrients, and they grow quickly to produce large plants whose multiple flower heads can produce as many as 100,000 seeds. Thorny spines around the flower head, often up to 2–3 times its width, interfere with livestock grazing, recreation, and wildlife management. The plant is toxic to horses, causing a chronic and potentially fatal neurological disorder, 'chewing disease'. Infestations also displace native vegetation. Biological control is one part of a long-term management strategy, which also includes cultivation, hand weeding and mowing, herbicides, burning, managed grazing and other practices to suppress the weed and enhance competition by desirable species. Under the biological control programme, three weevils and two flies, each for impact on seed production, have been released at various sites over the last 20 years. The rust is the first field release of a pathogen against yellow starthistle in the USA, and it can attack all aboveground plant parts throughout the growing season.

Although infection was observed soon after the pathogen was released in the field, immediate secondary spread was not expected and not observed. Neither were new infections detected in spring 2004, indicating it had not over-wintered at the release site. Nonetheless, the winter provided an opportunity to build up inoculum in the laboratory and this year has seen more releases of the fungus. These have led to infections being established at 24 sites in 20 counties. Little secondary spread has yet been observed despite very good infections at a number of locations, but the team anticipate that dispersal of the pathogen will gather pace over the next year. Plans for 2005 include monitoring release sites for infection and spread of the fungus, and making more releases in other areas of yellow starthistle infestation in California. The team hope that eventually the rust will complement the impact of the established insect agents and allow other plant species to begin to outcompete yellow starthistle.

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Giant Salvinia Feels the Strain

A strain of *Cyrtobagous salviniae* imported from Australia has effected a dramatic decrease in giant salvinia (*Salvinia molesta*) populations at release sites in the USA. Some water bodies once completely covered by the weed are now mostly open water, a situation comparable with the best biological control achieved by the weevil against giant salvinia in other parts of the world.

Salvinia species native to South America, in common with many invasive weeds, have been transported around the globe as ornamental plants. Giant salvinia is now recognized as one of the world's most important invasive aquatic weeds.

Like so many invasive aquatic weeds, giant salvinia has a rapid growth rate and can regenerate from fragments; it can also tolerate a wide range of environments. The species was first recorded in the wild in the USA in 1995 in South Carolina where it was eradicated from a pond. It appeared again in 1998 (although it may have been there longer) in eastern Texas. It now creates havoc in slow-moving, freshwater systems in Texas and Louisiana. The dense mats have a negative impact on other aquatic species because they block out sunlight and use up oxygen.

They make recreational activities such as boating, swimming and fishing impossible, which harms local economies. The weed also interferes with water use, clogging irrigation channels and hydroelectric turbines.

Classical biological control was first attempted during the 1960s in Africa, Asia and Australia, but taxonomic confusion over both the plant and its natural enemies dogged these early programmes. Once giant salvinia had been assigned species status as *S. molesta* and its native range identified, spectacular success followed. A weevil from Brazil in *S. molesta*'s home range, then thought to be a strain of *C. singularis*, was introduced to Lake Moondarra in Australia in 1980. It destroyed 30,000 tonnes of the weed in less than a year. The 'before and after' photographs have illustrated various biological control textbooks. The weevil was later described as *Cyrtobagous salviniae* and has since provided control of the weed in many countries.

Reaction to news that the weed was present in the wild in the USA was rapid. A biological control programme was initiated by Ted Center and Phil Tipping from the USDA–ARS (US Department of Agriculture – Agricultural Research Service) Invasive Plant Research Laboratory at Fort Lauderdale, Florida. There were regulatory hurdles to be overcome before the population that had been used elsewhere could be imported into the USA. The first control attempt, in 1999, involved releasing *C. salviniae* collected from common salvinia (*S. minima*) in Florida. The weevil has been found on *S. minima* in Florida since the 1960s, presumably inadvertently imported on plants from South America at some time in the past. Hopes that the locally available weevil would provide a rapid solution were dashed because herbicides, floods and drought between them destroyed all the release sites.

As this sorry tale was unfolding, molecular evidence began to suggest that there were differences between the local 'Florida' population of the weevil and the 'tried and tested' Brazil population that had controlled the weed elsewhere. The latest, yet to be published, molecular evidence now indicates that the two populations of weevils are very close to each other, especially when compared to a different species, *Cyrtobagous singularis*. However, at the time interest was refocused on the Brazil population. A new release permit had to be obtained before it could be released in the USA, and this was not achieved until late 2001 [see *BNI* **23**(1), 1N (March 2002), Salvinia: USA begins round two]. Scientists at the USDA–ARS Australian Biological Control Laboratory in Indooroopilly, near Brisbane field-collected and shipped weevils to Fort Lauderdale. Once cultures had been established, releases were made at four sites. Regular surveys of these sites since then have shown a steady, sometimes spectacular, reduction in giant salvinia. By September 2003, it covered just 1% of the water's surface at sites where the imported weevils had been released, and at two sites (one in Texas, one in Louisiana) the mats have almost completely collapsed. In contrast, at control sites giant salvinia continues to cover the water surfaces completely.

A Common Foe

Common salvinia, which has caused few problems since its arrival in Florida, *is* becoming a problem in Texas and Louisiana. Although not yet a weed on the scale of giant salvinia, it typically occurs in dense populations which show a tendency to expand. At the Jean Lafitte National Historic Park and Preserve near New Orleans, Louisiana, the results of an 8-year study show that common salvinia has completely displaced native duckweed species (Lemnaceae). This also threatens waterfowl populations for which duckweed, with its high protein content, is an important food source.

Tipping and team have been releasing and evaluating the effectiveness of weevils from the Florida population. Regular recoveries of weevils indicate that a viable population has been established. Although still early, indications are that this population of weevils will be able to suppress common salvinia in Louisiana as it does in Florida.

The team is continuing to monitor both populations of the weevils against both *Salvinia* species, and further releases are planned for new infestations in Louisiana and Texas.

Source: Flores, A. (2004) Tiny weevil beats back giant salvinia. USDA–ARS *Agricultural Research,* September 2004.
www.ars.usda.gov/is/AR/archive/nov01/

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Kenyan Efforts towards Integrated Biological Control of Water Hyacinth

Although water hyacinth (*Eichhornia crassipes*) was first recorded in Africa from the River Nile in Egypt in the 1890s, it did not reach Lake Victoria until the end of the 1980s. It is thought to have reached the lake through the Kagera River whose headwaters were invaded during the 1980s. It was reported in Lake Naivasha in the mid 1980s, in Lake Victoria (Ugandan waters) in 1990 and in the Kenyan waters of the same lake in 1992. It has since spread to many other water bodies in Kenya including rivers and ponds.

The water hyacinth cover in the Winam Gulf, a large inlet in the northeastern corner of Lake Victoria, occurred as both stationary and mobile fringes, but generally the plant was observed to form stationary fringes on shoreline environments that are sheltered from violent offshore winds and wave action. The plant preferred flat to gently sloping shores (rarely deeper than 5 metres) with a soft muddy bottom, rich in organic matter, such as found along the south-eastern shoreline of the gulf, extending from Nyakach to Kendu Bay. At its peak infestation in 1998, coverage of 17,230 ha was recorded in the Winam Gulf through satellite imagery analysis by USGS (US Geological Survey).

In cooperation with relevant organizations in Uganda and Tanzania, and several international organizations (International Institute of Tropical Agriculture, IITA; South Africa's Plant Protection Research Institute, PPRI; Australia's Commonwealth Scientific and Industrial Research Organisation, CSIRO), the Kenya Agricultural Research Institute (KARI) implemented a biological control programme for water hyacinth. This involved importation, mass rearing and releases of exotic biological control agents. It imported 13,800 adult *Neochetina eichhorniae* and *Neochetina bruchi* weevils from Australia, Benin, Uganda and South Africa for mass rearing and releases and produced over 200,000 weevils, of which approximately 180,000 were released together with 40,000 weevil eggs at 40 littoral and riverine sites in Kenya. By 1999, a reduction of over 80% of water hyacinth was recorded in the Kenyan waters of the lake, and this was mainly attributed to action by the weevils.

However, in 2000 a resurgence of water hyacinth in the Winam Gulf was noted. Nyakach Bay, to the south, was the first to experience the weed's re-invasion between August and September 2000. The emergent plants were young, healthy and rapid growing, and were the result of the germination of seeds deposited in the sediment before the previous water hyacinth mats disintegrated. Seedling germination was stimulated by light penetration of the water column following the mats' collapse. Growth was enhanced by high levels of nitrates and phosphates in the water due to runoff from agriculture and to the release of nutrients from the decaying mats. By May 2001, the coverage was 1347 ha.

The resurgence necessitated a continued supply of the *Neochetina* weevils to the lake. To ensure this, community-based weevil rearing units were established and the community taught aspects of weevil rearing, harvesting and release. So far a total of 15 such units have been established, mainly in primary schools along the shoreline in areas with persistent mats of water hyacinth. A total of 28 teachers and youths from the beach management units have been trained.

Seven years after the *Neochetina* weevils were first released into Lake Victoria for the control of water hyacinth, the population of the weed is now down to less than 15% of the peak infestation levels. Satellite images taken in December 2003 show that the infestation on the Kenyan side of the lake stands at 384 ha as compared to the peak infestation of 17,230 ha recorded in November 1998.

Water hyacinth monitoring and surveillance over the past 5 years revealed the presence of persistent water hyacinth 'hot-spots' in the lake. In Kenya, these were at Sio Port/Bukoma (Berkeley Bay) to the North, Kisumu (Kisumu Bay) to the East and Sango Rota/Kusa (Nyakach Bay), Kendu Bay, Homa Bay, Luanda Konyango (Karungu Bay) and Rakwaro (Osodo Bay) to the South. Also noted are infestations at the mouths of certain rivers entering the lake, namely the Yala, Kisat, Lambwe, Sondu and Kuja rivers. Elsewhere in Kenya, many inland water bodies such as dams and ponds are also infested. Several factors contribute to the persistence of water hyacinth at these sites. These include land-use cover, shoreline topography, pollution, urban and industrial activities/centres and human population density and distribution.

At these sites, particularly at the river mouths, the turbid and polluted conditions cannot sustain nor complete the growth cycle of the weevils. To enhance control in these areas, KARI has been undertaking studies on additional methods of control and looking into possibilities of integrated biological control strategies. Apart from the two weevil species a mite, *Orthogalumna terebrantis*, was also imported from South Africa and released in the lake in 1999. The mites have now established and damage to plants is visible in many parts of the lake. Also to this end, KARI recently imported the moth *Niphograpta albiguttalis* from IITA, Benin. The moths are currently contained under quarantine facilities at the KARI Centre, Muguga. The three East African partner states (Kenya, Tanzania and Uganda) have agreed to undertake host specificity tests on the moth before any releases can be made. As required by the Environmental Management Authorities and the East African Community Secretariat, an Environmental Impact Assessment will be undertaken before a release permit can be issued. The moths are expected to be more effective in the river mouths and ponds where the short-bulbous type of water hyacinth prevails.

The development of a fungal-based mycoherbicide to complement the action of the *Neochetina* weevils and the mites is also being undertaken at the KARI laboratories at Muguga. Surveys carried out in collaboration with CABI, under the International Mycoherbicide Programme for *Eichhorniae crassipes* Control in Africa (IMPECCA), revealed over 200 fungal isolates associated with diseased water hyacinth plants collected from infested water bodies. Among these were species that have been isolated elsewhere in the world and have been evaluated and found to have potential for the biological control of water hyacinth. These include *Alternaria eichhorniae, Alternaria alternata, Acremonium zonatum, Cercospora rodmanii, Rhizoctonia solani* and *Myrothecium* spp. Pathogenicity tests carried out under semi-controlled conditions have shown that *Alternaria eichhorniae* caused high incidence and severity of disease on water hyacinth. A host-range test was designed for *A. eichhorniae* and the fungus tested against ten food and cash crops growing around the lake region. These included cotton, rice, cassava, sweet potato, maize, beans, tomato, onion and cabbage. Water hyacinth was used as the control plant. The fungus was not found to cause disease on any test plant other than water hyacinth. The next step is to undertake formulation tests. Studies on the synergism of the various control agents will also be undertaken.

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Water Hyacinth: Ugandan Postscript

The situation with water hyacinth (*Eichhornia crassipes*) on the Ugandan side of Lake Victoria has remained largely unchanged over the past 2 years – the resurgence in weed growth appears to have stabilized. [See *BNI* **23**(2) 40N–41N (June 2002), Resurgence in Lake Victoria: a case for optimism.] *Neochetina* weevils are found on the plants in varying numbers, and some pockets have no weevils at all. Although water hyacinth remains a problem in some places, which biological control agents might be beneficial is a matter for debate. Factors such as water quality, the growth form of the water hyacinth and the life cycle of the potential agent need to be considered, and it may be that the best choice turns out to be location-specific.

At Nakivubo Channel, where waste from Kampala empties into the lake, there remains, as there has always been, very healthy 'bull' water hyacinth (up to one metre tall). From the outset, the weevils failed to establish here because of pollution. Any new agent whose life cycle does not involve the roots (as is the case with *Neochetina*) and can therefore 'escape' the pollution would be very useful. *Niphograpta albiguttalis* (see preceding article) fits the bill in terms of a larval life cycle restricted to the leaves and petioles, but it is most effective against bulbous forms of water hyacinth. These are almost completely absent from the Nakivubo Channel, so on balance it is doubtful whether the moth would enhance control there.

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Hopper Hope for Water Hyacinth Control

South Africa understands only too well the complexities of effective water hyacinth (*Eichhornia crassipes*) control. The weed remains a problem in its dams and rivers despite attempts to control it using chemical, mechanical and biological methods. Five arthropod and one pathogen species have been released against water hyacinth in South Africa and although these agents do provide good control in some areas, they have been less effective in areas that are characterized by cold and a high level of nutrients. Recent efforts have focused on identifying suitable agents for habitats where water hyacinth has evaded control. An application for release has now been lodged for the grasshopper *Cornops aquaticum*. This article discusses why this agent, rejected elsewhere because of its polyphagous habit, is now seen as a good candidate to add to the suite of introduced agents already established in South Africa.

The grasshopper was identified by David Perkins in 1974 during surveys conducted by USDA (US Department of Agriculture) as one of the most damaging insects associated with water hyacinth in its region of origin in South America. Its initial promise faltered, however, as studies of its biology and host specificity progressed. Silveira-Guido and Perkins found that under laboratory starvation trial conditions *C. aquaticum* was able to feed and develop on species in the Pontederiaceae and limited feeding, but no development, was recorded on three species within the Commelinaceae and on rice and sugar cane. They concluded that *C. aquaticum* is an oligophagous species in the Pontederiaceae and that some feeding could be expected on pickerel weed (*Pontederia cordata*), which is native to the New World including the USA. As a consequence, the grasshopper was not introduced into the USA. It appears that concerns about the insect's host specificity have also prevented it from being considered as a biological control agent for the weed elsewhere.

As it became apparent that the available measures were not going to control water hyacinth in all the invaded habitats, South African scientists began to survey for new agents and re-examine those previously rejected to see whether biological control could provide something new. Given the fairly cool climate of its native range in Argentina, *C. aquaticum* has the potential to control water hyacinth in South Africa's colder habitats. In addition, it is heavily parasitized in Argentina and could potentially build up large populations, in the absence of its natural enemies, following an introduction. However, its release in South Africa could only be sanctioned if nontarget species could be shown not to be threatened. In recent years, an evaluation of *C. aquaticum* as a potential agent in South Africa has focused on this question.

Grasshoppers used in these studies came from material originally collected from water hyacinth in Manaus, Brazil in October 1995, from Trinidad and Venezuela in April 1996 and from Mexico in October 1996. Once the cultures derived from the collections had all been confirmed as *C. aquaticum*, they were combined into a single culture.

The laboratory host range of *C. aquaticum* was determined through studies of nymphal development, using no-choice trials on 65 plant species in 32 families selected on the basis of relatedness to water hyacinth, degree of similarity of habitat and economic importance. If plant species were found to support nymphal development, adult no-choice oviposition and feeding trials were conducted. No-choice trials are the most cautious of all specificity tests, prone to throw up the most 'false positives', yet complete nymphal development was recorded in only three species (apart from water hyacinth):

- *Heteranthera callifolia* (Pontederiaceae, indigenous)
- Pickerel weed – see above – (Pontederiaceae, introduced and potentially invasive in South Africa
- *Canna indica* or canna (Cannaceae, invasive in wetlands in South Africa

Feeding and limited nymphal development (up to 3rd and 4th instar) was recorded on species in the Commelinaceae, Amaryllidaceae, Musaceae and other species in the Pontederiaceae.

Oviposition in no-choice trials in the laboratory was recorded on only:

- *Monochoria africana* (Pontederiaceae)
- Pickerel weed
- Canna

Subsequent multi-choice trials showed that the grasshopper preferred water hyacinth as an oviposition site and only limited oviposition was recorded on canna and *M. africana.*

Three survey trips for new agents were made to South America between 1999 and 2001. During these visits, the host plants of *C. aquaticum* in its native habitat, besides water hyacinth, were found to be *Eichhornia azurea*, *Pontederia rotundifolia* and pickerel weed, which are either not present in or not native to South Africa.

Using the results, an evaluation could be made of the threat posed by *C. aquaticum* to nontarget species in South Africa. Of indigenous plants, only *H. callifolia* supports complete nymphal development but it does not attract oviposition, and only *M. africana* attracts oviposition but it does not support complete nymphal development. Pickerel weed and canna support both oviposition and complete nymphal development, but these are introduced species, and are either potentially or actually invasive in South Africa.

Thus, although *C. aquaticum* is an oligophagous species and capable of utilizing several species of Pontederiaceae, it is argued that the results provide sufficient evidence to suggest that no native African Pontederiaceae is at risk and that the insect is thus safe for release in South Africa. Despite the heightened awareness of the importance of considering nontarget effects on native biodiversity since the USDA assessment was made in the 1970s, some 11 biological control experts (both local and international) support the release of *C. aquaticum* in South Africa. A release application has been lodged with the National Department of Agriculture and the Department of Environmental Affairs and Tourism in South Africa. It is hoped that this very effective agent will be cleared for release for the Austral summer.

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Azolla Biocontrol Grows in the UK

The floating fairy fern, *Azolla filiculoides*, native to the New World, was first recorded in the UK in the 1840s. It has been imported ever since as a popular ornamental for garden ponds. It is now a major aquatic invasive in the UK, ranking third in terms of distribution. Yet despite warnings about this, and a ban on it at Royal Horticultural Society shows, it continues to be imported and sold.

Azolla can grow from tiny fragments and is often a contaminant of purchases of other aquatic plants at garden centres. From garden ponds it has escaped into freshwater ponds, lakes, rivers and canals throughout the UK, including areas of conservation importance such as Romney Marsh and the Nene Washes. During the winter the plants' growth slows significantly, although they can tolerate all but the most severe British winters and can even survive encasement in ice. Growth resumes the following spring from vegetative fragments or via germination of spores that are produced in millions during the autumn, and sink into the substrate. During the summer, *Azolla* can form mats up to 30 cm thick, which may double in surface area every 5 days in hot weather. Consequently the weed impedes flood defences, blocks irrigation pumps and interferes with recreational activities. It also blocks out light and reduces oxygen in the water, which kills other aquatic biota. Last but not least, it can be mistaken for solid ground by animals and children.

Controlling *Azolla* in the UK has become more difficult with the banning of diquat, leaving glyphosate as the only available chemical control option. Glyphosate, although it can be effective, is non-selective, and when mats are thick will kill only the surface layers. There is, however, strong public pressure to reduce pesticide use. Manual control is doomed to failure as the plants fragment easily and soon regrow. Biological control is therefore an attractive alternative, especially as a tried-and-tested control agent is already present in the UK, meaning the weevil would not have to attempt to breach its biocontrol-shy shores.

In South Africa, where classical biological control has long been a mainstream weed management tool, the frond-feeding weevil *Stenopelmus rufinasus* was introduced from the USA and released in 1997. It was a spectacular success, clearing even large water bodies within a year.

The same species was recorded in the UK as long ago as 1921, and has probably been inadvertently introduced many times since on imported plants. Its failure to effect natural control of infestations throughout the UK is ascribed to a number of reasons: although cold-tolerant, it does not over-winter well in the UK, especially in the north; it only begins to build up damaging populations late in the season; and it may have limited capacity to reach widely dispersed water bodies infested with the weed. Nonetheless, these limitations could potentially be overcome by an inundative biological control approach.

Over the last 3 years, scientists at CABI Bioscience's UK Centre have developed methods to over-winter the weevils and mass rear them. Releases could then be made early in the year so that populations built up in time to curtail *Azolla*'s growth. Glasshouse studies indicated that the weevil, when released in large numbers, could be effective in UK summer conditions in as little as 3–4 weeks. The speed of control depends on the size of the infestation and number of weevils released. Typically a seed population of several thousand weevils are released, which rapidly multiply. Weevil densities of up to 6000 individuals per metre squared have been recorded prior to the weed disappearing. Trials at a number of sites last year showed that inundative releases were indeed effective. This year has seen an expansion of the initiative with the formation of Azolla control (www.Azollacontrol.com). With the permission of DEFRA (Department of Environment, Food and Rural Affairs) it is supplying weevils 'to order' from a maintained culture. Customers include English Nature, the Environment Agency and British Waterways, as well as local parish councils and homeowners. If the releases made so far continue to be successful, as anticipated, demand is likely to grow.

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IPM Systems

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

Checkmate for Italy's Fruit Pests

The location for the recent 6th International Conference on Integrated Fruit Production [see: Conference Reports, this issue] at Trento, part of the northern Italian region of Trentino–South Tyrol focused attention on the successful adoption of mating disruption by growers in the area to control lepidopteran pests in apple orchards and vineyards. The key to successful area-wide pheromone applications in the region is tight coordination of research, extension and industry – plus a zest for innovation and progress.

Vineyards

From a small beginning on the Piana Rotaliana of the Val d'Adige, pheromone-mediated mating disruption in vineyards has steadily gained ground. In 1990, the technology was trialled for control of grapevine moth, *Lobesia botrana*, on 14 ha of the Mezzacorona vineyards. By 2004, mating disruption was being implemented on 8600 ha, or almost 95% of the grape-growing areas of Trento (Trentino) province. During the early years the target was the grapevine moth, but since 1999 the European grape berry moth, *Eupoecilia ambiguella*, has also been targetted. Both are controlled with Isonet L+ in areas with extremely low incidence of *E. ambiguella* while Isonet LE is used where the two insects have an historical record of co-existence. Both dispensers are from Shin-Etsu Chemicals.

The Istituto Agrario di San Michele all'Adige (IASMA) (see below) and its extension service have been playing a key role, in collaboration with the Trentino Wineries Association, in this successful venture. By establishing proper scouting timing and thresholds, and organizing group applications, they have been able to reduce the insecticide input to Trentino vineyards from the 1980s average of 10–15 kg/ha down to zero.

Orchards

Codling moths (*Cydia pomonella* and *Cydia molesta*) are aggressive orchard pests, capable of achieving high population densities. At the beginning of the 1990s, growing resistance to chitin synthesis inhibitors such as diflubenzuron began to emerge in codling moths in South Tyrol (Bolzano or Alto Adige) province, where a strong orchard sector includes some 7000 growers. The limited efficacy of the organophosphate alternatives, together with demands from the strong local tourist trade for non-chemical options to be pursued, led to trials of pheromone-based control. Since then, it has become the control option of choice on some 78% of the apple-growing area with some 14,000 ha in South Tyrol and 1500 ha in Trento (in 2004). This advance has been made possible because data gathered over the last 12 years has helped to define the possibilities and limits of mating disruption. The crucial role of the extension service Südtiroler Beratungsring für Obst und Weinbau in fine-tuning treatments for local conditions brought new developments in the form of multiple species dispensers against, for example, mixed infestations of *C. pomonella* and *C. molesta,* and multiple species infestations of *C. pomonella*, *C. molesta, Pandemis heparana* and *Adoxophyes orana.*

In the final analysis, farmers have to make a living so pest control decisions have to make economic sense. What may limit the adoption of mating disruption is whether it is as cost-effective as several insecticide sprays. For this reason, more effective formulations and dispensers remain key areas for research, together with strategies to combat multiple species infestations. Another key issue is technology-transfer support and education to improve orchard scouting and mating disruption application accuracy.

IASMA and SafeCrop Research

IASMA has been a driving force in the adoption of pheromone-mediated mating disruption to control orchard and vineyard pests in Trentino–South Tyrol. The institute has a long history, having started life in 1874 as an agrarian school and experiment station. It now promotes and carries out research, education and training activities as well as providing technical assistance and services. Its remit is to promote cultural and socioeconomic growth in the agricultural sector and to develop forestry and agro-food systems, while safeguarding the environment and land.

IASMA also hosts the SafeCrop Centre, a network of international institutes focusing on research and development of sustainable crop protection with low environmental impact with the aim of reducing chemical inputs in agriculture. One strand of SafeCrop's innovative application-oriented research is directed at resolving the constraints to widespread adoption of these strategies, including lack of reliability of impact, high costs of product registration, and the need for measures to be adapted for local and crop specific characteristics and therefore small marginal markets. As the policy of the centre is to develop sustainable, low- or zero-impact control strategies, a second research strand is oriented towards questions such as unwanted side effects, and investigating possible environmental and food contamination by agents employed in its low-impact strategies.

The SafeCrop Centre houses three research units covering insect and microbial biological control and risk assessment, and their research is focusing on grapes, apples, strawberries and other small fruit and horticultural crops. Initiatives, some in collaboration with IASMA, include:

- Flying doctors: studies on the distribution and colonization of apple flowers by a bacterial biological control agent vectored by bees (collaborators: ETH-Zurich, Switzerland)
- Firefight: (a) risk prognosis systems for fire blight of pear and apple (collaborators: FAW, Wädenswil, Switzerland and ARO, Israel) and (b), field testing the efficacy of biological control agents for fire blight (collaborators: BBA-Darmstadt, Germany)
- *Cydia molesta*: developing biological control through mass-rearing and inundative release of a parasitic insect (collaborators: ETH)
- Powdery mildew of strawberry: developing microbial biological control agents for integrated control of this significant fungal disease which currently needs a high fungicide input
- Biological control agents – cross-effects: investigating reduction in codling moth oviposition by biological control agents used against fungal diseases (collaborators: Volcani Centre, Israel and INRA-Versaille, France)
- Biological control agents – R&D risk: R&D of microorganisms with potential as biological control agents can carry various risks to both the researcher and the environment. This project analyses the R&D processes with the aim of proposing protocols to allow risks to be identified and minimized.
- Pheromones – hail-nets: protective nets are frequently used by apple growers in this region, where hail damage that slashes the value of the crop occurs in many years; this project aims to identify what, if any, differences the use of hail nets makes to concentrations of pheromones, and what significance this has for codling moth control (collaborators: Lund University, Sweden and Shin-Etsu, Japan)

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Regulation and Science of Biopesticides

Filling some gaps in understanding biopesticides is the subject of a new UK research project. The project draws on the strengths of the University of Warwick's biologists and social scientists, and builds on the new status of Warwick HRI (Horticulture Research International) as part of the University of Warwick. A joint team from Warwick HRI and the university's Department of Politics and International Studies is being funded by the Research Councils UK Rural Economy and Land Use programme to investigate economic and scientific issues in biopesticide development.

The relative failure of biopesticides to gain a significant share of the world crop protection market (with the exception of *Bt,* or *Bacillus thuringiensis*) has been at least partly blamed on lengthy and expensive regulatory processes. In the UK, there has been poor uptake of microbial biopesticides, much of the development has been initiated in the public sector. It has then been taken up by small-and medium-sized companies who have been discouraged from taking a final product to market because of the prohibitive costs of the registration fee and associated data package. Professor Wyn Grant will probe how the UK pesticide regulatory system, built around the use of chemical insecticides, impacts on the development and use of biopesticides. The chemical regulatory model focuses attention on the short-term economic costs of pest control measures rather than their long-term impact on the environment and the sustainability of farming systems. Biopesticides have potential to bring long-term environmental protection and social benefits and any regulatory innovation that would take proper account of such innovations would be a significant spur to their future development. Professor Grant's study of UK pesticide regulation will include a comparative study with the legislation based pesticide regulation framework in Denmark.

A better scientific understanding of the operation of biopesticides, and in particular their impact on the sustainability of pest management, is clearly also needed if the regulatory climate is to be altered. Dr Dave Chandler will look at whether biopesticides persist in the environment when released on a large scale and how they interact with local microbial populations. For his study he will use as a model system the entomopathogenic fungus *Metarhizum flavoviride* as a biopesticide against aphids on lettuce.

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No Match for the Birds

Two wrongs *can* make a right. At least, that is what they are hoping on the UK Channel Island of Guernsey, where increasing populations of may bugs or cockchafers (*Melolontha*) have been causing damage to amenity grass over the last 6 years. The larvae feed on the plant roots and in large numbers they kill areas of grass. This year saw a new twist. Areas of the grass on a school playing field were completely destroyed by seagulls tearing up the grass to get at the larvae feeding on the roots.

Now amenity managers are hoping to turn the birds' taste for may bug larvae to their advantage. They want to remove as many larvae as possible before they re-seed the playing field. They have devised a plan to rotivate the field regularly to expose the pests, which they hope the seagulls will gobble up. If this works, they will have a smaller may bug population in the field next year, so both direct damage and bird damage will be reduced.

Source: Baudains, N. (2004) Gulls could turn into grub killers. *This is Guernsey*, 20 September 2004. www.thisisguernsey.com

Training News

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

LITE Profits Bangladesh Rice Farmers

Over the last 2 years, the LITE (Livelihood Improvement Through Ecology) project, led by IRRI (International Rice Research Institute) in partnership with BRRI (Bangladesh Rice Research Institute), has helped 2000 Bangladeshi rice farmers to increase yields while reducing pesticide and fertilizer use. The team found that highlighting the financial gain had more impact than teaching agro ecology. It is now training a further 4000 farmers, and hopes eventually to reach all of the country's 11.8 million rice farmers.

The project, part of the PETRRA (Poverty Elimination through Rice Research Assistance) initiative funded by DFID (UK Department for International Development), set out to investigate what caused a drop in rice yields when farmers stopped using insecticides. The goal was to find effective alternatives to the chemicals. As part of this, the project looked at ways of optimizing fertilizer (especially urea) use. Urea induces the plant to become more succulent and as a result more attractive to foliar pests. Reducing the amount of fertilizer can help reduce pest insect populations and thus insecticide applications.

The simple message of the project was, 'Do not use insecticide without need and judgment.' By following this message:

- Rice yields are not reduced
- Expenditure (on chemicals) is less
- The environment is not polluted

It came as something of a surprise to the project team to find that yields actually rose when the farmers did not apply insecticides. The increase was no flash in the pan, but was reflected across 600 fields in two districts and continued over four cropping seasons. The goal of the project became to reach as many farmers as possible with the message that they did not need to use insecticides.

There are a number of reasons why insecticides may be ineffective or even detrimental. They often kill natural enemies more effectively than the pests themselves, so may contribute to increased pest populations. Many supposed insect pests do not have any significant impact on the yield, yet farmers, believing any insect is a bad insect, may spray insects simply because they see them. Compounding this, many farmers use poor equipment to apply out-of-date or inappropriate insecticides at the wrong time.

Helping farmers off the 'pesticide treadmill' is not a new idea, but the uptake of this project so far has been exceptional. How was it achieved? The project identified 'lead farmers' – farmers who were relatively successful – and taught them how to conduct a simple experiment by partitioning their field into quadrants and giving each section a different treatment: with and without insecticide, with or without using a leaf colour chart to optimize fertilizer (urea) application dosage. Other farmers simply bisected their fields, and sprayed one half with insecticide and not the other. They also learnt to record data on insecticide and urea use and expenditure. Several hundred farmers trained in this way saw for themselves that the unsprayed crop gave higher yields.

Once the success of the no-spraying strategy became apparent, the project focused on scaling up from these trained farmers to reach thousands through a process of success case replication (SCR). After training, lead farmers train both other farmers in their own village and successful farmers from surrounding villages. The latter group then become lead farmers in their village, and train more farmers. In this way, the message ripples out across the countryside with the number of farmers trained increasing exponentially.

The success of this approach in the LITE project is clear from changes in insecticide use. This has been reduced by 99% amongst farmers participating in the project (farmers who have been trained by lead farmers and are conducting experiments in their own fields) and by 90% amongst non-participating farmers in the same villages (untrained farmers who have learnt about the project methods from trained neighbours and relatives). Even in villages where no training took place, insecticide use has dropped 55-80%. The changes reflect the degree of casual contact between farmers and are a clear indication that money talks.

For farmers, the saving on insecticides has meant greater profits, which can be turned into more rice production, which in turn brings in more income. For the funders too, this is proving to be a financially successful project, with a cost–benefit ratio of 1:4 in its first year. So long as the project impact can be sustained, the benefits will continue to accrue; in 5 years the ratio could reach 1:20.

The assumption that trained farmers will train other farmers underlies many participatory initiatives, but this does not always happen and indeed the trained farmers themselves do not always continue with innovations once a project has finished. In this case, the LITE team are optimistic because farmers have seen the results in their own fields, and the impact can clearly be seen to advantage them. In addition, not spraying takes less time and money than not spraying. They project team also ascribe the uptake of the project message and its spread to non-participants to its simplicity: spraying insecticides wastes money. They point out that farmers understand money more easily than agroecology.

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Announcements

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

Second-Instar ISBCA

The 2nd International Symposium on Biological Control of Arthropods (ISBCA) will be held on 12–16 September 2005 in Davos, Switzerland. This conference continues the symposium series established with the 1st ISBCA organized by Roy Van Driesche and colleagues in Hawaii in January 2002. The conference themes will be:

- Invasion biology and lessons for biological control
- Biological control of arthropods of conservation importance
- Recent successes in classical biological control: an impact analysis
- Cultural manipulations to enhance biological control
- Contribution of biological control to the global development agenda
- Implementation of biological control through farmer participatory training and research
- Compatibility of insect-resistant transgenic plants with biological control
- The role of food supplements in biological control
- Role of generalist predators in biological control
- Augmentative biological control in outdoor annual crops
- Augmentative biological control in greenhouses
- Environmental risk assessment of invertebrate biological control agents
- Predicting natural enemy host ranges: strengths and limitations of lab assays
- Legislation and biological control of arthropods: challenges and opportunities

To foster interchange of information among attendees, concurrent sessions have been avoided. The conference organizers aim was to stimulate ideas by providing a forum for presenting new information. They have therefore given preference to submissions that present original data from specific projects pertaining to biological programmes with predators and parasitoids, rather than overviews, summaries or material that is already widely known.

An important goal of this second meeting is to be truly international. Regional coordinators are promoting awareness of the meeting in their geographic areas, while leaders of the sessions have also encouraged global participation. See the website for further information:

www.cabi-bioscience.ch/ISBCA-DAVOS-2005/

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Endophytes and Biocontrol Agents Meeting

The 1st International Conference on Plant–Microbe Interactions: Endophytes and Biocontrol Agents (EBA) will be held in Saariselkä, in the Lapland region of Finland, on 18–22 April 2005. See: www.bioweb.fi/

The aim of the Conference is to promote multidisciplinary information exchange, discussion and collaboration between scientists working in different areas of plant/microbe interactions.

Contact: Seppo Sorvari, Conference Convener,
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EMAPi in Poland

The 8th International Conference on the Ecology and Management of Alien Plant Invasions (EMAPi) will be held on 5–10 September 2005 at the University of Silesia in Katowice, Poland. It is being co-organized by the Institute of Botany, Jagiellonian University, Białowieża and the Geobotanical Station, Warsaw University. Themes of the conference will include:

- Invasive alien plants in floras (exotic/alien floras; checklists; black lists and warning lists)
- Ecological impacts of invasive plants (dispersion, distribution and dynamic tendencies; impact on ecosystems)
- Biology and genetic studies of invasive plants (case studies; taxonomy and microevolution)
- Predicting and detecting invasions with geomatic tools
- Human perception and its role in biological invasions
- Legislation, international cooperation and management solutions
- Biological and integrated control (case studies; removal experiences)

Registration and abstract submission should be completed via email by 28 February 2005. See the website for further details.

Email: emapi@us.edu.pl
Web: www.emapi.us.edu.pl/

Turning the Tide Online

An alternative (html-based) online 'gateway' page is now available to the contents of *Turning the tide: the eradication of invasive species*, the Proceedings of the International Conference on Eradication of Island Invasives, held in Auckland, New Zealand in 2001.

The new page, which includes a link to allow downloading of the entire text of the document as a single PDF file, is:

www.hear.org/articles/turningthetide/

IPM Reviews Closes with LGB

A special issue of Integrated Pest Management Reviews (volume 7, number 4), '*Prostephanus truncatus* Research and Management', contains the following four papers on larger grain borer (*P. truncatus*):

- Ecological Studies on the larger grain borer, *Prostephanus truncatus* (Horn) (Col.: Bostrichidae) and their implications for integrated pest management. M. G. Hill, C. Borgemeister & C. Nansen
- Detection and monitoring of larger grain borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae). R. J. Hodges
- Chemical, physical and cultural control of *Prostephanus truncatus*. P. Golob
- Phytosanitary measures against larger grain borer, *Prostephanus truncatus* (Horn) (Coleoptera: Bostrichidae), in international trade. P. S. Tyler & R. J. Hodges.

The journal ceases publication with this issue and the completion of volume seven.

Web: www.kluweronline.com/issn/1353-5226

Conference Reports

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

Weed Biocontrol against a Broader Canvas in Durban

Approximately 450 delegates from 50 countries moved into Durban, South Africa for the 4th International Weed Science Congress, which was hosted by the Southern African Weed Science Society in association with the International Weed Science Society, on 20–24 June 2004. The event was preceded by a variety of tours of general interest and followed by technical tours which covered aquatic and environmental invasive weeds as well as agricultural weed problems. Apart from one or two minor glitches (our hotel bus ran either 55 minutes before or 5 minutes after the keynote speakers commenced each morning!) the event was well run and congratulations and thanks are due to the organizing committee.

Each day started with a dawn-patrol plenary address before the conference split into six concurrent sessions. Biological control took pride of place (along with five other topics) by being allocated a slot during the first session of the first day! In all there were eight half-hour papers and six 15-minute verbal presentations interspersed with a poster session consisting of 16 posters that dealt with different aspects of biological control.

There was no specific theme for the session and a variety of topics were addressed. John Hoffmann (South Africa) set the ball rolling by pointing out that if expectations are moderated, biological control becomes much more plausible and an enormous amount can be achieved with even moderately damaging agents, including those that reduce only the reproductive capacity of the target weed species. Robinson Pitelli (Brazil) then discussed the future role of bioherbicides in biological control, identifying situations where bioherbicides would be especially useful and concluding that their future lay in the hands of small companies capable of large-scale production of a variety of formulations.

Mic Julien (Australia) broadened the scope of the discussion by looking at the opportunities and challenges for biological control in Australia, New Zealand and the Pacific island states, notably the low proportion of weeds currently being tackled with biological control, especially grasses, and the difficulty of getting support for projects in remote, sparsely populated, low-economic lands that characterize the Australian outback and Pacific islands. Joachim Sauerborn (Germany) brought the discussion back to specifics and addressed the issue of using biological control against parasitic weeds in crops, noting that agents that reduce seeding would be especially beneficial because most damage has already occurred by the time the weeds emerge from their host plants and are amenable to other types of control.

Cheryl Lennox (South Africa) used the case of the deliberate introduction of *Prosopis* into Africa to castigate agencies that continue to promote agroforestry with exotic species, many of which become substantial weeds. She highlighted the difficulties and restrictions this practice imposes on biological control because of the conflicts that arise between those promoting the plants as a useful resource and those trying to remove the plants from invaded areas. Mark Wright (Hawaii) concluded the morning session with a proposal that probabilistic risk assessments should be used during decision-making stages in biological control. He suggested that a series of probabilities can be incorporated into 'precision trees' (or equivalents) to evaluate overall potential risk (or not).

The poster session on biological control included 16 posters which covered a range of topics including: the use of pathogens (three) and viruses (one) as classical biological control agents; a study showing no non-target effects of ragwort natural enemies on native *Senecio* species in Australia (one); the ecology of *Rubus* species and their native natural enemies in Iran (one); biology and host specificity of potential agents for specific weeds (two); prospects for biological control of wild radish (*Raphanus raphanistrum*) in Australia (one); the development and use of bioherbicides (three); overviews of incomplete programmes (two); and weeds as alternate hosts for pest and predatory mites in agricultural situations (two). The organizers are to be complimented on allocating ample time in the middle of the day for the poster presentations and Raghavan Charudattan added a sparkle by allowing the presenters a few minutes on the podium to emphasize the essence of their work. Both of these arrangements enhanced exposure to the posters and gave them more coverage than is normal for a conference such as this.

The day concluded with a series of six 15-minute verbal presentations on various aspects of biological control including: ways of successfully involving communities in biological control (Raelene Kwong, Australia); how PCR-denaturing gradient gel electrophoresis (DGGE) has been used to determine the diversity and types of soil-borne natural enemies of weeds (Steven Hallett, USA); the role of defensive leaf trichomes in determining, and explaining, the host specificity of a potential biological control agent (Chrysomelidae) of tropical soda apple (*Solanum viarum*) (Daniel Gandolfo, Argentina); the recent release and establishment of *Gratiana boliviana* on tropical soda apple in USA and progress with screening two additional agents for this weed (Julio Medal, USA); the potential use of pathogens to control a grass weed (*Imperata cylindrica*) in West Africa (Fen Beed, Benin); and the use of toxic metabolites of fungal pathogens as natural herbicides for grass weeds (Mariano Fracchiolla, Italy).

In summary this was an excellent day to be in Durban listening to, and reading about, a fascinating range of topics dealing with biological control. Our sincere thanks go to Raghavan Charudattan and Helmuth Zimmerman for organizing a very successful, informative and enjoyable session.

Having filled the first day with biological control, opportunities arose during the rest of the week to learn more about aquatic weed management (which inevitably included a considerable contribution from biological control), technology transfer, herbicide resistance and degradation, integrated weed management, molecular and biotechnology approaches to weed control, natural products and allelopathy, physical approaches in weed management, and organic farming, among others.

As always, besides the formal presentations, the meeting provided ample opportunity for colleagues from different backgrounds to meet and interact on an informal level over good food fortified with excellent beverages. In contrast to the 4-yearly International Symposia on Biological Control of Weeds (the last in Canberra during 2003) the International Weed Science Congresses bring together a broad mix of people from different research backgrounds. Any biocontrollers who want to learn more about how 'the other half' deal with their weeds should attempt to get to the next (5th) Weed Science Congress in Vancouver, Canada – it should be well worth the trip.

By: John Hoffmann, University of Cape Town

SIP in Finland

The 37th Annual Meeting of the Society for Invertebrate Pathology (SIP) and the 7th International Conference on *Bacillus thuringiensis* were held at the University of Helsinki, Finland on 1–6 August 2004. The meeting had two plenary sessions ('SIP the past, present and future' and 'Invertebrate pathogens as pests'), together with symposia and workshops on the following topics: Second generation transgenic crops; Significance of the entomopathogenic nematode infected-host in the soil ecosystem, and potential impact on microbial control; Virus ecology; Honeybee pathology; Nematodes and cold adaptations; Insect–fungal associations; Bringing pathogens from the laboratory to the field; Risk assessment and non-target effects of *Cry* toxins in sprays and transgenic plants; Can microsporidia be seriously considered as biological control agents; *Oryctes* virus – from discovery to classical microbial agent; Genome analysis methodology; Fungi and nematodes under unfavorable conditions; Genomics and pathogenesis of invertebrate pathogens; New advances in research and development of insecticidal proteins; Risk assessment; Microbial control in greenhouses and nurseries; Status of microbial control products; Microbial control education. Although sessions in other areas would make interesting reporting too, this report focuses on presentations relevant to the (particularly fungal) biopesticide sector.

Participants were not universally optimistic about the prospects for biopesticides, especially fungal products. At the first Plenary Session Jeff Lord (US Department of Agriculture – Agricultural Research Service) gave a presentation on the commercialization of microbials which drew attention to the importance of making realistic assessments of product potential, the timeframe for product development and the degree of market penetration that might be achieved. He also cautioned against allowing biopesticide development to be product- rather than market-led.

There was an excellent workshop on risk assessment and registration. A paper by Anita Fjelsted (Danish Environmental Protection Agency) gave an overview of registration of microbial plant protection products and active microorganisms in the European Union (EU). Another by Hermann Strasser (Leopold-Franzens University, Innsbruck, Austria), Claudio Altomare (Institute of Food Production Science, Bari, Italy) & Tariq Butt (University of Wales – Swansea, UK [UWS]) dealt with the EU project RAFBCA (Risk Assessment of Fungal Biological Control Agents). There is great concern about metabolites such as oosperein or destruxins entering the food chain. The safety of present products was indicated by the statistic that it would take 338 kg of oosperein to kill 50% of *Paramecium* in 1000 m^3 of pondwater – equivalent to 2.4×10^6 kg of product per hectare! [Also see: 'European insights on fungal biocontrol agents', this section.]

A session on microbial products indicated that there are relatively few new fungal products coming onto the market. Apart from Emerald Bio (who acquired Mycotech and still produce Mycotrol) there is very little attention to, and commercialization of, mycoinsecticides, although some *Trichoderma* products are available. In contrast, *Bacillus thuringiensis* (*Bt*), virus and nematode products, where effective production, formulation and marketing have been achieved, are still making successful, but small, impacts on the global pesticide market.

In the fungal session, a paper by Ernst-Jan Scholte (Wageningen University, Netherlands) and collaborators in Austria, the Netherlands and Tanzania described how *Metarhizium anisopliae* might be used to reduce malaria by targeting adult mosquitoes. In first field trials using black cloth impregnated with conidia, he had achieved 34% control and a very significant decline in daily survival rates. Otherwise, an increasing emphasis was discernible from other presentations on the ecological value of conserving entomopathogens and of interactions with other beneficials such as parasitoids and predators. A paper by Zengzhi Li, Meizhen Fan, Bin Wang & Degui Ding (Anhui Agricultural University, China) on control of masson pine caterpillar (*Dendrolimus punctatus*) in southeastern China suggested that inoculative application of *Beauveria bassiana* could result in unstable control, but that endemic levels of the pathogen were able to maintain control because isolates survive when pine caterpillar numbers are low by infecting other hosts. The topic of formulation, although frequently aired, indicated that no significant developments had been made.

The conference had a very healthy entomopathegenic nematode (EPN) content. There is increasing interest in formulating nematodes and, as reported last year, use of cadavers as carriers for EPNs.

The major messages about biopesticides from this conference were that: (1) registration of biopesticides is a stumbling block to their increased use; (2) the science has not progressed significantly in the last few recent years, and perhaps a major funded research campaign or project is needed to change this; (3) funding is increasingly difficult to obtain; and (4) there is strong interest in conservation of entomopathogens; much of the fungal work reported was related to enhancing the pathogen or exploiting natural levels.

European Insights on Fungal Biocontrol Agents

A workshop held on 30 September 2004 in Brussels, Belgium, 'New Insights into Risk Assessment and Registration of Fungal Biocontrol Agents in Europe', brought together industry, policy makers, regulators and scientists to give new insights on the risk assessment and registration of fungal biocontrol agents (BCAs), currently covered largely by European Commission (EC) Plant Protection Directive 91/414. The workshop was organized by the RAFBCA consortium (Risk Assessment of Fungal Biological Control Agents EC Project coordinated by Tariq Butt in collaboration with IBMA [International Biocontrol

Manufacturers Association] and IOBC [International Organization for Biological and Integrated Control of Noxious Animals and Plants]).

Presentations and round table discussions covered the following topics: (1) Biocontrol industry IBMA perspective: experiences in registration of microbial BCAs in Europe (Willem Ravensberg, Koppert, Netherlands); (2) Registration consultant perspective: comparison of chemicals *vs* BCAs: experiences, problems, solutions and suggestions (Wolfgang Oellrich, GAB Consulting, Germany); (3) European Union – United States – Organisation for Economic Co-operation and Development perspective on registration (Anita Fjelsted, Danish Environmental Protection Agency); (4) How has RAFBCA contributed to the risk assessment of BCAs? (Tariq Butt, University of Wales – Swansea, UK [UWS]); (5) EC Directive 91/414 : how can the introduction of new BCAs on the European market be facilitated? (6) Case study 1: Fungal BCA for pest control in a field crop: potato (Hermann Strasser, Leopold-Franzens University, Innsbruck, Austria); (7) Case study 2: Fungal BCA for pest control in a glasshouse crop: tomato/cucumber (Anke Skrobek, UWS); (8) New methodologies and tools for assessing risks of metabolites (Milton Typas, University of Athens, Greece); (9) Conclusions and RAFBCA strategy for risk assessment in view of Directive 91/414 (Tariq Butt). There was also a poster session and time for discussions with the RAFBCA team and participants.

The presentations pointed to differences between US and European markets for BCAs (the latter is much smaller), and that the return of investment in Europe is unacceptable mainly owing to costs for registration and the registration period, which are much higher and longer, respectively, than in USA. The technical presentations focused mainly on the RAFBCA contributions to the development of methodology for extraction, identification and evaluation of metabolites (e.g. oosporein) from fungal BCAs. RAFBCA research data from case studies showed that metabolites did not enter the food chain (www.rafbca.com).

Although many of the participants felt that some extensive changes to the current registration requirements would help the European Union (EU) regulatory process, the regulators were not in favour of any kind of rewriting of the Directives simply because of the length of time it takes to get anything through the EC process. However, they were keen to keep up a dialogue and use each new microbial registration package to build on their experience with the intention that the process would thus become easier with time. The EC also plans to conduct a study of the differences between US and EU regulations for registration of BCAs. This exercise would promote a better understanding of the technical requirements of the US regulations, and allow the evaluation of features which could be incorporated into the EC Directive to facilitate the registration of BCAs in Europe.

By: Marilena Aquino de Muro, CABI Bioscience

Environmental Impact of Invertebrates for Biological Control of Arthropods: Methods and Risk Assessment

The biological control community is taking seriously the calls for better-structured and more detailed environmental risk assessment of invertebrates for arthropod biological control. Recently some 25 experts from all over the world gathered for an intensive full-week workshop (19–25 June 2004) in Engelberg, Switzerland (funded by the Swiss Agency for the Environment, Forests and Landscape and Agroscope FAL Reckenholz, and organized by Agroscope FAL Reckenholz and CABI Bioscience Switzerland Centre) to put together a synthesis of current knowledge, and to provide recommendations for further research and regulatory guidance in this area. The emphasis was on providing science-based guidance for those assessing and evaluating environmental risks, and on providing up-to-date information on existing methods and their application for evaluating nontarget effects. The starting point was to address all the information requirements for environmental risk assessment laid out in a recent OECD publication[1]. A further aim was to compile all this information for a book, which is to be published by CABI Publishing during 2005.

Altogether, 15 specific topics were examined and discussed in detail. Authoritative experts summarized each topic (see below) using the following framework:

1. Introduction of the topic and explanation of why it is important from the point of view of nontarget effects and environmental risks.

2. Description of methods used (or that can be used) to answer questions that arise:

   - Methods described in detail, where possible highlighting examples
   - Methods evaluated, advantages and disadvantages summarized, highlighting gaps in knowledge where no proper methods are available
   - Where appropriate, methods used in other fields of ecology, entomology or biological control considered for application in the assessment of nontarget effects

3. As a final step, guidance provided on what methods should be used to gather the information requested in the OECD guidelines[1].

Selection of Nontarget Species for Host Specificity Tests

This topic was summarized by Ulli Kuhlmann, Urs Schaffner and Peter Mason. The overall aim was to provide guidance on selecting those species for host specificity tests which will allow generalization of the results to describe the host range of the candidate agent without undue expansion of the test list. Key concepts had to be defined first, such as host specificity, performance, ecological preference, behavioural preference, fundamental host range, ecological host range, host range expansion and host shift. The methods for selection of nontarget species can be grouped into four categories:

- Phylogenetic: representative species from taxa related to the target
- Ecological: geographical distribution, habitat, feeding niche
- Biological: feeding and oviposition behaviour, temporal occurrence
- Availability: field-collected material, commercial sources

A flow-chart was produced for selecting appropriate test species, with three categories (habitat/microhabitat; phylogeny; safeguard species) leading to an initial test list. Two filters are then used to narrow the list down: one considering the relevant ecological and biological attributes, and the other accessibility and availability of the material. This leads to a revised test list and host specificity testing, with an additional feedback loop considering behavioural attributes of the organisms.

Relevance of Host Specificity in Biological Control and Methods for Testing

The topic was introduced by Joop van Lenteren, Don Sands, Matthew Cock and Thomas Hoffmeister. Host range tests aim to demonstrate whether or not a natural enemy can feed, develop or reproduce on a nontarget species. Knowledge of the biology and behaviour of the natural enemy is essential when designing such tests. To design powerful laboratory tests is a challenge, as it is difficult to include factors such as multitrophic chemical communication, learning, and wide host ranges involving many host plant species. Points to take into account when designing host specificity tests include:

- Knowledge of natural enemy foraging behaviour
- Quality and rearing conditions of the host plant, host and natural enemy
- Genetic changes
- Unnatural hosts, artificial diets
- Host or natural enemy infection with pathogens
- Behavioural variation in natural enemies: know its origin!
- Importance of relevant multitrophic conditions (all relevant stimuli should be present, host should have been on the host plant long enough to produce herbivore-induced synomones)

Difficulties in interpretation of data obtained with host-range testing include confusing effects of test design, leading possibly to false positives (non-host attacked in absence of natural host *or* non-host attacked in close proximity to natural host) and false negatives (valid but less preferred host neglected in presence of preferred host).

The conclusions from this session include recommendations to express the degree of polyphagy by the number of species, genera, tribes, subfamilies, families, etc. attacked, rather than simply designating a natural enemy as monophagous or polyphagous. The determination of host specificity of non-specialist natural enemies will always be a complicated and time-consuming affair, while it will be relatively simple for monophagous and oligophagous natural enemies. However, there is as yet little quantitative data, making it difficult to generalize. Currently most host-range testing data arise from relatively simple experiments, and many of the issues raised here have not been taken into account. Based on discussions a revised guideline has been suggested for a sequential test to determine the host range of invertebrates used in classical and inundative biological control of arthropods. In particular, host specificity choice tests using a small-scale arena are not considered appropriate in the revised guideline whereas choice tests using a large-scale arena are considered to provide reliable results.

Effects of Competition, Displacement and Intraguild Predation in Biological Control and Evaluation Methods

This topic was summarized by Russell Messing, Bernard Roitberg and Jacques Brodeur. They started with a clear question: “Can we measure and predict indirect impacts of biological control using competition, displacement, and secondary interactions?”, and provided a simple answer: “no”. These indirect effects may involve killing (one kills another), interference competition (one excludes another), exploitation competition (one uses up the resources), apparent competition (one raises biotic mortality) and circuitous competition (enrichment; subtle and convoluted). Some rules of thumb can be presented, however, to aid in selecting natural enemies. These include:

- r-selected species should be imported first; K-selected species withheld (counter-balanced competition)
- Moderately effective agents pose greatest risks
- Lack of density dependence on the target increases the risk to nontargets
- In weed biological control: avoid introducing herbivores that are especially vulnerable to acquiring predators and parasites
- In tephritid biological control: avoid pupal parasitoids

The Risks of Interbreeding and Methods for Determination

A synthesis of this topic was provided by Keith Hopper and Eric Wajnberg. Different levels of interbreeding were delineated: (1) Court: recognize as potential mates, but may not copulate; (2) Mate: copulate, but may not produce progeny; (3) Hybridize: produce F1 hybrids, which may be inviable or sterile; (4) Introgress: transfer DNA sequences between species, which may spread and affect fitness, behaviour, or ecology.

The consequences of interbreeding may include changes in fitness (without introgression), evolution (from changed fitness or introgression), and changes in abundance (from changed fitness or evolution). In biological control it will be difficult and expensive to predict and detect interbreeding. If necessary, one might consider introducing only agents, which (1) have no close, native relatives, (2) do not mate in the laboratory with close, native relatives, and (3) have little or no likelihood of introgression with native species.

Factors that Determine Establishment of Natural Enemies and their Evaluation Methods

Guy Boivin, Ursula Kölliger and Franz Bigler summarized this topic. Clearly, establishment is not detrimental but rather a pre-requisite of successful classical biological control while it is generally considered detrimental in inundative biological control if exotic agents are being used. Establishment is affected by abiotic factors such as temperature and humidity, and many biotic factors including the availability of host/prey, competition, the presence of other natural enemies, and the availability of other food sources. For establishment studies the priorities appear to involve first the temperature responses and the availability of host/prey, and secondly factors such as humidity, competition and other natural enemies and food sources.

Significance of Dispersal and Assessment in Environmental Risk Evaluations

A synthesis was provided by Nick Mills, Dirk Babendreier and Antoon Loomans. Again, dispersal in relation to nontarget effects is relevant for inundatively released biological control agents only. Dispersal is defined as the exploratory undirected movement of individuals away from the habitat of origin. Dispersal distance of biological control agents defines the radius of potential nontarget impacts; this in turn depends on the application strategy and species specific traits. The density of dispersers defines the potential population-level impacts on nontarget hosts. Modifiers that influence the density include agent longevity, biotic resources available and abiotic factors. Existing study methods include various mark–release–recapture (MRR) techniques producing density–distance curves; following of movement paths of individuals to produce spatio-temporal coordinates, and boundary flux recaptures.

Risks Posed by Contaminants and Methods for Determination

This topic was introduced by Mark Goettel and Doug Inglis. 'Contaminants' include all unwanted substances that may be associated with biological control agents, such as human pathogens, insect pathogens, all microorganisms, pesticide residues, radioisotopes, frass, hyperparasites and all other invertebrates. They may constitute a risk to the biological control agent itself, to the user (human health issues) or to the environment (biodiversity issues). The occurrence of contaminants is typically a quality control issue for biological control agent producers. There are, however, no government standards for it, and typically no in-house standardization, poor training of production personnel in microbiological methods, very limited support from public institutions and limited formal training opportunities in this area. The conclusion was that enormous effort is necessary to screen for all potential contaminants and that instead one may test only for those organisms that are known to be harmful and to occur together with the biological control agent. The extent to which measures for prevention of transfer of contaminants are implemented must be weighed in relation to the present transfer of unknown or unwanted substances by other means. For example, presently there are no regulations for the importation of many invertebrates. Consequently one must consider the possibility of introduction of contaminants via biological control agents in the context of other methods of inadvertent introduction. (i.e. movement of people, forestry and agricultural products, etc).

Evaluation of Post-Release Nontarget Effects

Barbara Barratt, Heikki Hokkanen and Bernd Blossey provided the background for this discussion. Monitoring nontarget impacts of biological control agents is likely to be the most effective means by which real progress can be made in improving the pre-release decision-making process. Only by validating the predictions of pre-release studies made in the artificial environment of quarantine facilities can the level of scientific uncertainty be reduced, and the confidence of biological control practitioners and regulators improve in the future. Given that we will never, in the foreseeable future, achieve complete certainty of knowledge of the extremely complex ramifications of releasing a new species into any new environment, there is potential for a progressive improvement that can be attained by feeding back information from field releases into each new biological control proposal. The significance of this improvement will depend upon the quality, scale and time-scale of post-release information that can be obtained. At a higher level, the ideal would be for nationally or internationally based environmental monitoring programmes to provide sufficient detail to detect environmental changes precipitated by biological control. This situation seems to be a long way off, and so our recommendations for post-release monitoring are by default second best. However, given appropriate multidisciplinary collaboration, one might be able move the goal posts slightly nearer.

Environmental Risk Assessment of Invertebrate Natural Enemies and the Use of a 'Quick Scan' Method

Antoon Loomans and Joop van Lenteren presented the results of a 'quick scan' exercise involving some 150 currently used biological control agents. These agents are well known and applied in various parts of the world. The rationale of the exercise was to reduce effort involved in conducting a risk assessment for these agents by making a quick scan of available information. The quick scan method is built on the methodology outlined in a paper by Van Lenteren *et al.*[2]. There is a basic difference in approach between the advanced evaluation and the quick scan methods. In the advanced evaluation the lead question is, "Do we have sufficient and reliable information to issue a permit for import and release?" and it is based on a quantitative evaluation. On the other hand, when using the quick scan method the question is, "Do we have good reasons (e.g. are there any nontarget effects and environmental risks known elsewhere and/or expected in the area of release) to stop continuation of release?", and is thus based on a qualitative evaluation. The results of a quick scan could help to establish lists of species that can be used in certain, specified areas or (parts of) ecoregions of the world. This would result in greatly reduced costs for regulation of the majority of biological control agents currently used.

The quick scan method was applied to the some 150 species of natural enemy currently commercially available in northwestern Europe. Based on a thorough review of available information, application of the quick scan method to these natural enemies results in the conclusion that 5% of the species are too risky for release, that for 15% of the species more information is needed before being able to conclude that they may continue to be released, and that for the remaining 80% of the species releases can be continued.

The Usefulness of Ecoregions for Safer Import and Release of Exotic Species

Matthew Cock, Dirk Babendreier, Franz Bigler, Ulli Kuhlmann and Urs Schaffner provided the basis for this discussion. An ecoregion is an area of similar climate, landform, soil, potential natural vegetation, hydrology, or other ecologically relevant variables. The concept could be useful for predicting spread of alien pests, for predicting spread of alien biological control agents, for decision making for introductions, and for quarantine decisions for study purposes. It was concluded that ecoregions are more useful than artificial delineations, e.g. political boundaries, in biological control, but that they cannot be used for making predictions in specific cases.

The workshop also discussed in some detail a few other issues, about which there will be more in the forthcoming book. Richard Stouthamer explained the potential of 'Species and strain identification and the use of molecular methods', and Thomas Hoffmeister, Dirk Babendreier and Eric Wajnberg discussed 'Statistical tools to improve the quality of experiments for assessing nontarget effects'. A further contribution by Ralf-Udo Ehlers ('Risks and reasons') emphasized the socioeconomic impacts of regulations and, in particular, the dangers of overregulation to the future of biological control.

By: Ingeborg Menzler-Hokkanen, Dirk Babendreier, Franz Bigler, Heikki Hokkanen and Ulrich Kuhlmann

Further Information

[1]OECD (2003) Guidance for information requirements for regulation of invertebrates as biological control agents (IBCAs). OECD, Paris, 19 pp.

[2]Van Lenteren, J.C.; Babendreier, D.; Bigler, F.; Burgio, G.; Hokkanen, H.M.T.; Kuske, S.; Loomans, A.J.M.; Menzler-Hokkanen, I.; Van Rijn, P.C.J.; Thomas, M.B.; Tommasini, M.G. and Zeng, Q.Q. (2003) Environmental risk assessment of exotic natural enemies used in inundative biological control. *BioControl* **48**, 3–38.

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Sunn Pest Meeting

The 2nd International Sunn Pest Conference, held in Aleppo, Syria on 19–22 July 2004, attracted nearly 150 participants from 23 countries, which reflects the status of this important pest. The conference allowed participants to reflect on the progress made during a DFID (UK Department for International Development) funded project, which came to an end in September, and to discuss issues.

Sunn pest (a complex of pentatomid bugs) is a major pest of wheat and barley, injecting salivary toxins which reduce yield and seed germination and destroy the baking qualities of the flour. It occurs in a broad sweep across North Africa, the Middle East and Central Asia. Fifteen million hectares may be sprayed with chemicals each year, yet there is lack of agreement on fundamentals such as injury levels, where the pest over-winters and what its basic behaviour is. The DFID-funded project aimed to fill some of these information holes, and to begin the search for sustainable control options. These include policy changes, monitoring, the development of resistant cultivars, the use of pheromones, and biological control including egg parasitoids and the development of mycoinsecticides.

There were over 60 oral presentations and two poster sessions together with some excellent, stimulating and fresh keynote talks in this exceptionally well-organized conference. Papers covered policy matters, moving from aerial to ground spraying (which is equivalent to moving from government to farmer responsibility – and cost), economics and practical control. Sessions on sunn pest biology and ecology led on to those concerning control, with a number of papers on the use of *Beauveria bassiana* to control both over-wintering and summer populations.

Keynote speakers covered IPM in the CGIAR (Consultative Group on International Research) (Khaled Makkouk); lessons from IPM programmes (Peter Kenmore); the development of Green Muscle, the locust mycoinsecticide (Christiaan Kooyman); rational biopesticide use (Charles Vincent); economics of IPM research (Doug Gollin); and furthering the cause of IPM through public and private enterprises (Lukas Brader).

It would be impossible to describe the full range of country reports and other presentations made by the many participants. Further information can be obtained via ICARDA (International Center for Agricultural Research in the Dry Areas; www.icarda.cgiar.org). However, policy and economic issues were covered by Aden Aw-Hassan (ICARDA, Syria), Aykut Gul (University of Cukurova, Turkey) and Hossein Noori (Qazvin Agricultural and Natural Research Centre, Iran).

Amongst the scientific presentations, a paper by Steve Edgington (CABI Bioscience, UK) reported that a *B. bassiana* formulation had given 86% mortality in field trials at ICARDA in 2004. It was suggested that an effective mycoinsecticidal product could be achieved in 3–4 years. Stress was laid on the likelihood that a successful mycopesticide would greatly reduce the land areas requiring treatment, perhaps to 10% of that sprayed now, as natural enemy complexes were restored. Bill Reid (University of Vermont, USA) described significant effects from using granular formulations of *B. bassiana* applied around the edges of a field to control the migrating insects as they invaded the crop.

Egg parasitoids were covered by Mohammed Abdulhai (General Commission for Scientific Agricultural Research, Syria) amongst others; plant breeding by Mustapha El-Bouhssini (ICARDA, Syria); and David Hall (Natural Resources Institute, UK) outlined latest developments on pheromone use.

Clearly, the science has gone well in the first phase of this project, and new funding for a second phase is being sought so that the results achieved can be translated into solutions to this key pest for cereal farmers in the immediate and wider region.

Further information:
www.uvm.edu/~entlab/sunnpest/

Fruitful IOBC Meeting

The 6th International Conference on Integrated Fruit Production, held on 26–30 September 2004 in Trento, northern Italy, was organized by the IOBC (International Organization for Biological and Integrated Control of Noxious Animals and Plants) West Palaearctic Regional Section (WPRS) Working Groups (WGs) on Integrated Protection of Fruit Crops and on Pheromones[1] and Other Semiochemicals in Integrated Production[2], together with IASMA (Istituto Agrario di San Michele all'Adige) and its associated SafeCrop Centre (Centre for Research and Development of Crop Protection with Low Environment and Consumer-Health Impact)[3].

The meeting was divided into two parts: the Orchard Group (WG Integrated Protection of Fruit Crops) and the Pheromone Group (WG Pheromones and Other Semiochemicals in Integrated Production) had 2 days each.

The Orchard Group part of the meeting was organized around the themes: (1) Integrated fruit production: state of the art; (2) The use of biological control agents and semiochemicals in integrated fruit protection; (3) Side effects of pesticides on beneficial organisms; (4) Pesticide resistance and its integrated management and control (5) Organic fruit production; and (6) Pesticides shortages, especially for soft fruits.

The Pheromones Group part of the meeting, which is covered in the remainder of this report, saw presentations on the increased use of pheromones in Italy, Germany and Switzerland. Its theme, 'As mating disruption gains ground', underlined that insect control by pheromones has become a reality. Mating disruption, by aerial dissemination of synthetic sex pheromone, is used on approximately 100,000 ha of European orchards and vineyards. The area treated may grow further in view of increasing problems associated with the use of conventional insecticides. More widespread use of pheromones, however, demands more reliable and economic application techniques. Four decades of pheromone research have laid the groundwork for practical applications, but tools and knowledge could still be improved. In the face of increasingly limited resources, this meetings series aims to stimulate further development by enhancing communication and collaboration between the academic world, extension services and the plant protection industry.

The over-riding impression gained at the Pheromone Group meeting was that mating disruption has moved from being an 'alternative' technology to being mainstream. Various participants, including representatives of agrochemical companies and researchers working on insecticide resistance, acknowledged the role of mating disruption in resistance management. They agreed that the expected reduction in compounds registered for use in orchards (with many compounds on their way out) plus the European Union drinking water protection threshold of 0.1 μg/litre[4] will increase resistance problems – and that mating disruption is the solution to the problem. It was also clear that pheromone-mediated mating disruption is expected to become the most widely used method for insect control in orchards by the end of this decade.

A young scientist (<30 years old) poster competition was well supported. Young scientists and students submitted posters on the use of semiochemicals and/or biological control agents in integrated fruit (included grape) protection. The first prize of €2000, donated by CBC Europe, was won by Asya Ter-Hovhannesyan (Institute of Zoology of National Academy of Sciences of RA, 7 Sevak Str, Yerevan 375014, Armenia) with a poster entitled 'Development of the IPM programs in apple orchards by autosterilization wild populations of codling moth'. The second prize of €1000, given by Andermat Biocontrol, was awarded to the Algerian Nadia Lombarkia, for a poster about her research carried out at IASMA, 'The relationships between granulovirus Madex® efficacy on *Cydia pomonella* fruit damage and apple tree surface metabolites'.

[1]IOBC/WPRS WG on Integrated Protection of Fruit Crops:
www.iobc-wprs.org/wg_sg/index.html

[2]IOBC/WPRS WG on Pheromones and Other Semiochemicals in Integrated Production:
www.iobc-wprs.org/wg_sg/index.html and http://phero.net/iobc/

[3]IASMA and SafeCrop Centre:
www.ismaa.it

[4]Proposal for a directive of the European Parliament and of the Council on the protection of groundwater against pollution. COM (2003) 550 final, 2003/0210 (COD):
http://europa.eu.int/comm/environment/water/water-framework/groundwater.html

Aquatic Invasives Conference in Ireland

The 13th International Conference on Aquatic Invasive Species was held on 20–24 September 2004 in Ennis, County Clare (Ireland), hosted by the Institute of Technology, Sligo. This conference series began life as the Zebra Mussel Conference but has expanded in size and scope to become the biggest conference of its type in the world. This year's conference brought together over 300 participants from 36 countries who presented 210 papers. Sessions included international cooperation, shipping, invasive crustaceans, fishes, plants and bivalves, impacts on marine and freshwater systems, industrial biofouling, policy and prevention, vectors and corridors, and control methods including biocontrol.

Invasive species are relatively new to the European agenda. A team from Queen's University, Belfast (Northern Ireland) have just completed a cross-border initiative, the Invasive Species in Ireland study and their guidelines look likely to be implemented. As more and more European countries are waking up to invasive species, a number of 'famous' invasives are emerging as problems in European waters, including *Azolla* in Spain and water hyacinth (*Eichhornia crassipes*) in Portugal. There is a huge body of knowledge on the biology and control of weeds such as these from programmes around the world, which Europe could draw from. However, the need for management of information on aquatic invasive species and international cooperation were overarching themes, revisited repeatedly by speakers during the conference. Another issue that was often commented on was that many species were being presented as problematic invasive species in one ecosystem whilst being endangered or protected/valued species in their areas of origin.

Web: www.aquatic-invasive-species-conference.org/

British Ecologists Recognize Aliens

The British Ecological Society (BES) Annual Meeting was held at Lancaster University on 6–9 September 2004. One of its thematic topics, 'Non-native and invasive species: defining the problem, identifying research needs and applying practical solution', was addressed over four sessions comprising 24 papers. The event also provided the opportunity for a joint meeting, hosted by the BES Invasive Species Specialist Group, of the UK Biodiversity Research Group and the Biological Control Working Group of the European Weed Research Society (EWRS).

It was clear not only from the invasives sessions, but also from more general ecology sessions (especially on biodiversity) that invasive alien species (IAS) now occupy an increasing high profile within the BES and the chairman of the opening session described it as an historic coming together of specialist groups working on all aspects of IAS. It became obvious, however, that many ecologists remain wary of biological control and still need convincing as to its safety and benefits.

It is not possible to summarize the plethora of papers presented within the different sessions but it is worthwhile flagging several which provided unpublished data on some key invasive weeds. For example, within the thematic topic 'Intractable clonal weeds' (two sessions comprising 13 papers all on bracken), papers from Denmark, India, Venezuela and the UK dealt specifically with human and health problems posed by carcinogenic substances released by bracken into the environment. This strengthens the case for management of bracken, not just in the UK but worldwide, and specifically the use of classical biological control tactics. In a session on 'Invasive species ecology', results were presented which showed how *Rhododendron ponticum* impairs ecosystem function in Irish streams due to the high density of poor quality leaf litter which has severe impacts on algal and invertebrate populations, with subsequent knock-on effects on game fisheries, tourism and local economies: yet further evidence of the multifarious, cryptically-sinister activities of this plant in the British Isles.

The Presidential Address by Alastair Fitter (University of York) entitled 'Darkness visible: reflections on underground ecology' highlighted the pivotal role of soil fungi, and in particular vesicular-arbuscular mycorrhizae, in ecosystem stability. Moreover, Prof. Fitter succeeded against all odds in inspiring the audience in what is, as he admitted, an alien and potentially uninspiring subject to the great majority of ecologists. Indeed a fervent mycologist could not have sold the idea better that fungi underpin all terrestrial life systems. The biodiverse nature of soil was emphasized by an on-going study of "a small and insignificant patch of Scottish hillside – the most studied soil system in the world". Astonishingly high numbers of 'species' of all life forms were recorded, based mainly on molecular characterization rather than classical taxonomy since systematic expertise was often not accessible, especially in mycology and nematology.

This meeting flagged that IAS are now firmly on the agenda of the BES and, importantly, more pragmatic biocontrol-related, rather than theoretical, solutions to their long-term management are now being considered in the UK.

Proceedings

Mimosa pigra Symposium

The proceedings of the 3rd International Symposium on the Management of *Mimosa pigra*, held in Darwin, Australia on 23–25 September 2002, have been published*.

In the 10 years since the last meeting in this symposium series there has been marked progress in the management of *M. pigra*, particularly in the areas of biological and integrated control. Also, indigenous management issues have assumed much greater importance in mimosa management in a number of countries.

More than 70 participants from Australia, Cambodia, Indonesia, Sri Lanka, Thailand and Vietnam attended the 3-day workshop that formed the 3rd International Symposium. The meeting included a daylong field visit to inspect integrated management trials near Darwin, and two days during which participants heard 26 presentations. The papers, which represent the most up-to-date source of information on research and management of *M. pigra*, are incorporated into these proceedings, together with a summary of recommendations on key issues, which emerged from discussion sessions held during the workshop.

Topics covered included taxonomy (one paper), risk assessment (one), status, threat and impact (four), mapping (two), modelling (one), use (two), public awareness and education (one) and prevention and early intervention (one). However, the important advances made in management and control are reflected in the other 13 papers on these topics.

Except in Australia, control initiatives for *M. pigra* are relatively recent. A paper from Sri Lanka describes community-based activities, and evaluates chemical and mechanical measures; it also notes that *Panicum maximum* was observed to prevent *M. pigra* germination. Two papers from Vietnam also assess chemical and mechanical measures, and describe the threat the weed poses to sites of conservation importance. A paper from Thailand evaluates introduced bruchid biological control agents and concludes that limited seed damage means further measures are needed.

The remainder of the control and management papers are from Australia, reflecting its 40 years' experience with the weed (including 23 years with biological control). One paper discusses choice of chemicals and application methods, another the integration of mechanical and biological methods. Other papers deal with biological control *per se*, covering prospects for fungal agents through inundative methods, and methods for assessing agent impact; tantalizingly, as the results of the evaluations are to be published in peer-reviewed journals, readers will have to wait for those, but the methods described can be adopted elsewhere. A paper on the impact of control on the seed bank in Australia indicates that further measures are still needed. Nonetheless, there is encouraging news in two papers describing how the weed is being successfully contained by mechanical means at a small, recently invaded site, and through community-based action on another, much larger, established area of infestation. A useful review of the assessments made on 45 prospective agents by the Australian programme (13 of which have been released there) and seven more currently being studied is one of several papers in these proceedings that provide information for countries embarking on *M. pigra* counter-initiatives. Another of these, the final paper, looks to the future; it identifies agents currently having an impact in Australia (the beetles *Acanthoscelides puniceus* and *Coelocephalapion pigrae* and the moths *Neurostrota gunniella* and *Carmenta mimosa*) together with insect and fungal species considered to have potential, and provides an overview of the prospects for mimosa control in Australia and other affected countries the 21st century.

*Julien, M., Flanagan, G., Heard, T., Hennecke, B., Paynter, Q. & Wilson, C. (eds) (2004) Research and management of *Mimosa pigra*. Papers presented at the 3rd Symposium on the Management of *Mimosa pigra*, 23–25 September 2002, Darwin, Australia. CSIRO Entomology, Canberra, 173 pp.

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