



General News

Why Biocontrol Practitioners Should Be More Interested in Parasitoid Sex Ratios

The use of parasitoid wasps in biological pest control pivots around a crucial event: a female wasp finding and attacking a target host. Females have to be able to find hosts, successfully parasitize them and, ideally, their offspring need to survive to maturity to sustain the process into future generations; but first there have to be females. Most species of parasitoid wasps are sexual, i.e. there are both males and females, but it is only the females that attack hosts, via parasitization and/or feeding. Males are required for mating, otherwise females will not be able to produce daughters, but since one male can generally inseminate many females, a few males can suffice. From a pragmatic perspective, female biased sex ratios are desirable to both maximize the production of female parasitoids for field release from mass-rearing facilities and for enhancing parasitoid establishment rates and the degree of pest suppression in the field.

The above points appear to be both obvious and widely known. What is also widely known, at least among evolutionary ecologists, is that there is a very good understanding of the selective factors that influence sex ratios and also that some of the most studied organisms in this respect are parasitoid wasps. There is, however, a problem: while the interconnection between what might be called 'pure' and 'applied' studies of parasitoid sex ratios has clear, and moreover long-discussed, potential to be hugely beneficial, there are hardly any instances of this potential being achieved. Our motivation is thus to bring this issue to the attention of biocontrol practitioners and outline the ways in which we think progress could most readily be made. Here we provide a distillate: a much longer treatment of this topic, in which full details and references can be found, will shortly be available elsewhere¹.

The Intricacies of Sex Ratio Theory

The evolutionarily-based study of sex ratios constitutes a large, longstanding and quite complex field of research encompassing genetic mechanisms of sex determination, game-theoretic approaches to optimal sex allocation and empirical work on a huge diversity of organisms, including many parasitoid wasps. The study of sex ratios is claimed to be one of the most successful areas of evolutionary ecology due to its refined theoretical achievements being closely and reciprocally coupled with empirical testing. Sex ratio studies can be taken right to the heart of philosophical debate about the study of evolutionary adaptation and the value of the optimality approach and also used to explore the putative existence of fundamentally important though controversial behaviours such as spite. While these research areas are deeply fascinating, they may seem esoteric to a

pragmatist. The study of sex ratio also has a more directly applicable side and it is on that facet that we focus here. Applications of an understanding of sex ratios include improving the effectiveness of epidemiology and conservation ecology, as well as pest biocontrol, which is our present concern. In the following sections we briefly outline the main areas of parasitoid sex ratio research that should be of interest to biocontrol practitioners and try to avoid the 'esoteric intricacies' by describing theory on a 'need-to-know' basis.

The Simplicities of Parasitoid Sex Ratios

Sex ratio theory started historically with a 'natural selection' explanation for why most animal species have unbiased sex ratios. The core idea is that in sexually reproducing populations that happen to have a sex ratio bias, individuals belonging to the rarer sex will be more reproductively successful than those belonging to the more common sex (e.g. if males are rare, males will usually have many mates, but if males are common, males will on average have less than one mate; in both cases females will generally average one mate). In such populations parents that tend to produce the rarer gender among their progeny will thus have more grandchildren (\approx evolutionary fitness) than those that do not. Such frequency dependent selection thus tends to return population sex ratios to, and retain them at, equality. The evidence for the operation of frequency dependent selection for sex ratio equality is surprisingly scant, and we know of no strong evidence from parasitoids. Nonetheless, many parasitoid species do exhibit approximately even sex ratios and sex ratio equality provides a baseline expectation for biocontrol practitioners who aim to mass-rear or deploy parasitoids as biocontrol agents. Further, the theory outlined above relies on a number of crucial assumptions, two of which are that individuals find mates from throughout a large population and that parental investment of resources into individual male and female offspring generates identical returns in terms of offspring future success. Examining cases where these assumptions do not hold has been a major endeavour in 'pure' sex ratio research and is also the key to the potential application of sex ratio studies to biocontrol because both scenarios can lead to a greater production of females.

Achieving Female Bias Using Population Sub-division

If the pool of potential mates is restricted to subgroups (each lasting one generation) within larger populations (a scenario called 'local mate competition') mothers are selected to adjust their progeny sex ratios in response to the number of other mothers producing offspring within the local group. When the number of mothers is small, the optimal sex ratio for each mother to produce is female biased because mothers achieve more evolutionary fitness via their

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daughters than via their sons. Consider the extreme, but not unknown among parasitoids, situation of a mother reproducing alone in a sub-group or 'patch'. If one male can mate with many females, then to maximize the number of mated daughters that will develop in and then disperse from the patch to eventually produce grandchildren the mother should produce very few sons and as many daughters as possible. The theory behind this summary has been extremely well known within evolutionary ecology for 40 years and the evidence for its operation in parasitoid wasps is strong. Given that the result of population sub-division is strong female bias, and that female biased sex ratios will enhance mass-rearing efficiency and are thought favourable to post-release pest–parasitoid population dynamics, the benefits to biocontrol practice seem obvious (indeed, such potential benefits were explicitly pointed out in the applied biology literature some 25 years ago). What is of concern, and only a little encouragement, is that we can only find one example of the explicit usage of this theory to manipulate parasitoid sex ratios in order to benefit biocontrol programmes. The example involves the mass-rearing of three species of *Gonatocerus* (Mymaridae), which are egg parasitoids of the glassy-winged sharpshooter (*Homalodisca coagulata*), a hemipteran pest of numerous crop plants. All three species have female biased sex ratios, which are dependent, in a manner consistent with theoretical predictions, on the number of mothers searching for hosts in a patch. By simply minimizing contact between females that are searching for hosts the production cost of a female parasitoid can be reduced to a third of the cost under less efficient conditions. Furthermore, females only need to be isolated while host searching as experience of other females prior to presentation with hosts does not adversely affect sex ratios. Therefore, females can conveniently be held together in insectary cages or during transport to the field for release, provided they are separated or held at very low density once in the presence of hosts. These findings have been published only recently and seem ripe to be adopted commercially.

Achieving Female Bias Using Host Quality

Insects of a given species can vary greatly in their size. Larger hosts provide developing parasitoid offspring with more food and can generally be considered to be better quality. Sex ratio theory makes predictions as to whether a mother finding a host of a given quality should use it to support male or female offspring. The decision is non-neutral if the fitness (future success) of male and female offspring is not equivalently affected by variation in host quality. In parasitoids, larger offspring emerge from large hosts and in general female fitness is thought (with reasonable evidence) to be more sensitive to body size variation than is male fitness. As therefore predicted, parasitoids tend to produce male offspring on small hosts and female offspring on large hosts. This body of theory and evidence has been well known to evolutionary ecologists for 25 years. There have also been some applications of host-quality dependent sex ratios within biocontrol practice. For instance, biological control of cassava mealybug (*Phenacoccus manihoti*) can be enhanced by

improved soil quality: better soil leads to stronger plants bearing larger mealybugs which, when parasitized by *Apoanagyrus lopezi* (an encyrtid with host-size dependent sex ratios), give rise to an enhanced proportion of female parasitoids in the subsequent generation and improved biocontrol. While this example is very pleasing, our concern is that it is one of only a very small number of such applications of the understanding of host-quality dependent sex ratio behaviour to biocontrol in the field: given the time eclipsed since the theory and sufficient empirical evidence have been widely known there could have been so many more.

We turn now to a further, and more refined, way in which sex ratio responses to host-quality can be used by biocontrol practitioners to improve mass-rearing efficiency. This is based on two further predictions of sex ratio theory: that there is a threshold to host size above which only daughters are laid and that the threshold is relative rather than absolute. Thus, a mother may lay a son in a medium-sized host that is encountered among a batch of large hosts, but would lay a daughter in a medium-sized host found among small-sized hosts. Females are expected to update their estimations of the distributions of host sizes as they encounter a succession of hosts during their lives. Several studies, on *Catolaccus grandis*, a parasitoid of boll weevils (*Anthonomus grandis*), and *Diglyphus isaea*, which attacks agromyzid leaf-miners, have now shown that increasing the size of hosts presented to females over several days leads to a greater production of female offspring than does presenting similar host sizes each day, and presenting smaller and smaller hosts leads to male biased sex ratios. The technique works not just with females held in isolation (which would be labour intensive in a mass-rearing facility) but also when hosts are presented to groups of parasitoids. Under simulated mass-rearing conditions the production costs of females can be cut by as much as a half. The first of these studies was published ten years ago, yet it seems that no commercial insectary has adopted such modified rearing techniques.

Further Considerations

In the sections above we have implicitly assumed that female parasitoids are in full control of the sexes of their progeny. The assumption is acceptable to a reasonably close approximation for a large number of species, yet there are many ways in which sex ratios can be brought out from under complete maternal control. These include that limited mating opportunities or the genetic basis of sex determination may constrain the sex ratios mothers are able to produce, often adversely from the biocontrol practitioner's point of view, since male bias is a common result. Parasitoids may also be infected by a variety of genetic and bacterial sex ratio distorters, some of which may disrupt biocontrol while others may actually be beneficial via the promotion of female production. In addition, the understanding of the interplay between all of the influences on parasitoid sex ratios that we have discussed or mentioned and of pest–parasitoid population dynamics, from both theoretical and the applied perspectives, is still in its infancy, despite many years of population-biology

research focusing on parasitoid wasps as model organisms.

Conclusion

We wish to provoke action from both 'pure' and 'applied' parasitoid biologists, preferably in the form of collaboration. The most obvious benefits of such cross-disciplinary research are, however, already on offer: simple and practicable manipulations of parasitoid rearing conditions can greatly enhance efficiency by promoting female bias. Practitioners who are trained more in 'applied entomology' than in 'evolutionary ecology' may take solace in the fact that there should be no need to delve very deeply into the fascinating, yet huge and dauntingly complex, literature on sex ratio evolution: the essential assumptions and predictions of the theory, as outlined above (and given in more detail in ref. ¹), are relatively straightforward.

¹Ode, P.J. & Hardy, I.C.W. (2008) Parasitoid sex ratios and biological control. In: Wajnberg, E., Bernstein, C. & van Alphen, J.J.M. (eds) *Behavioral ecology of insect parasitoids: from theoretical approaches to field applications*. Blackwell, Oxford, UK. pp. 253–291. [In press]

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Weevil, Weevil Rock You: Ten Years of *Azolla* Biocontrol in South Africa

The biological control programme launched against *Azolla filiculoides* (red water fern) in South Africa was first reported on in the March 2001 issue of *BNI*. After the first release of the curculionid weevil *Stenopelmus rufinasus* in December 1997, further releases were made at 111 sites throughout the republic, covering a wide variety of water body types and climatic zones. Quantitative post-release evaluations revealed that the weevil caused a dramatic reduction in the populations of the weed with local extinctions occurring at the majority of sites within the space of a year.

The weevil has shown a wide thermal tolerance in the field, as predicted from pre-release studies, and an ability to disperse unaided over long distances (up to 300 km). Despite local extinctions of the host plant, the weevil has been able to persist by moving between infestations of the weed. In the last ten years, the weevil has been recorded from 42 new *Azolla* sites and where the weed has reoccurred (at 22 of the original 112 release sites) these re-infesta-

tions did not reach the levels recorded prior to 1997 and were brought under control by the weevil.

A full cost:benefit analysis was performed on the *A. filiculoides* biological control programme. This showed that the economic returns would increase from 2.5:1 in 2000 to 13:1 in 2005, and are predicted to increase to 15:1 by 2010. Based on the field evidence, there is no reason to suggest that this prediction is an underestimate.

Ten years on, *S. rufinasus* is now widely established throughout South Africa and there is no need to further distribute the agent. No parasitism of the weevil has been recorded in the field and it is envisaged that there will be no need for additional biocontrol agents. *Azolla filiculoides* is now under complete control in South Africa, but with the decline of these infestations of red water fern, other aquatic plant taxa (*Lemna* sp., *Wolffia* sp., *Spirodela* sp. as well as algae) have taken the vacated niche. The successful control of these three species will rely on a commitment to reducing eutrophication in aquatic ecosystems – something that needs to be addressed in the many tropical countries of the world that are battling successive invasions by aquatic weeds.

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Progress on Biological Control of the Emerald Ash Borer in North America

In 2002, the emerald ash borer (EAB), *Agrilus planipennis*, a buprestid beetle native to Northeast Asia, was discovered as the cause of extensive ash tree (*Fraxinus* spp.) mortality in southern Michigan and Ontario. It is believed that EAB was introduced into Michigan from solid-wood packing materials during the 1990s and became established in the abundant ash resources throughout urban areas, parks, forests, and riparian ecosystems¹. In an effort to protect ash resources in North America, regulatory agencies imposed quarantines and developed programmes to eradicate and contain EAB. Although these efforts may have slowed the rate of spread, eradication was abandoned in the 'core infestation' due to the size of the infestation, the lack of effective methods to detect and control EAB, and the challenges associated with quarantine compliance and enforcement. Although researchers estimate EAB can spread 10 to 20 miles (16–24 km) per year, humans are responsible for its long-range dispersal through the illegal transport of infested ash nursery stock, firewood, and logs. Regulatory agencies have determined that EAB is established throughout Lower Michigan and areas of the neighbouring states of Ohio and Indiana; separate infestations are

also known in Michigan's Upper Peninsula, Illinois, Maryland, and Pennsylvania. This invasive buprestid is expected to continue spreading throughout North America due to the widespread use of ash as a landscape tree and the prevalence of ash trees throughout forested and riparian ecosystems. Land managers and the public are now seeking sustainable management methods to reduce EAB population densities and to slow its rate of spread.

When EAB was discovered in North America, only scant information on its biology was available in the literature from Asia where it is considered only a minor and periodic pest of indigenous ash species. To develop biological and microbial controls for EAB in North America, we began studying this beetle in Michigan and China in 2002. EAB completes its life cycle in one or two years depending on the age of the infestation, tree health, and other biotic and abiotic factors. Emergence of EAB adults typically begins in late May and peaks during June. Adults chew D-shaped exit holes in the tree bark to emerge and begin maturation feeding on ash foliage followed by mating; after about three weeks, females start to oviposit in bark crevices and between bark layers. Although egg-laying peaks toward the end of June, eggs are laid throughout the summer and into the fall due to a prolonged adult emergence period and long adult longevity. After egg hatch, EAB neonates tunnel through the tree bark until reaching the phloem where they continue feeding through four larval stages. When mature, EAB larvae chew pupation cells in the outer sapwood or bark; pupation occurs during the spring or summer. Early in an infestation, EAB attacks the upper crown of large ash trees, and as populations increase, the trees become weaker. Tree mortality is caused by larval girdling of the main trunk, when EAB populations reach lethal density thresholds for ash. This occurs over a period of several years depending on initial tree health, species, site, rainfall, and other factors. Current management strategies are being developed with the goals of containing isolated EAB infestations, slowing its spread, and suppressing population densities below a tolerance threshold for survival of North America's ash trees.

Lack of Natural Enemies in North America

We conducted natural enemy studies in Michigan from 2002 to 2004, and found 0.7% parasitism for EAB larvae; no egg parasitoids were found. The larval parasitoids reared from EAB larvae in Michigan included hymenopteran parasitoids that attack native *Agrilus* spp: two native braconids (*Atanycolus* sp. and *Spathius floridanus*), one native chalcid (*Phasgonophora sulcata*), and one exotic eupelmid (*Balcha indica*). This rate of parasitism detected for EAB in the USA is low compared to EAB parasitism rates found in China and those reported in the literature for native *Agrilus* spp. Other biological factors causing EAB mortality include entomopathogenic fungi, three predatory beetle species (*Enoclerus* sp., *Tenebroides* sp. and *Catogenus rufus*), and woodpeckers, but rates of attack were relatively low and constant at different EAB population densities. Some mortality resulted from larval starvation, dehydration, and cannibalism in over-infested trees.

The lack of natural enemies capable of suppressing EAB populations below a density threshold tolerable for survival of native ash trees is especially troubling, and supports the need to introduce parasitoids that coevolved with EAB in Asia for biological control of this buprestid in North America.

Natural Enemies of EAB in China

Foreign exploration for EAB in its native range in China resulted in the discovery of three hymenopteran parasitoids considered suitable for use as biocontrol agents in North America: a gregarious larval braconid ectoparasitoid *Spathius agrili*^{2,3,4}, a gregarious larval euphid endoparasitoid *Tetrastichus planipennisi*^{3,5,6}, and a solitary, parthenogenic encyrtid egg parasitoid *Oobius agrili*^{6,7}. We have found *T. planipennisi* overlaps in distribution with *S. agrili*³ and *O. agrili*⁶, although additional survey work is needed to identify their distributions and interactions in China.

Oobius agrili was discovered in 2004 in Jilin Province, China⁷ although it may be more widely distributed. In China, *O. agrili* is a solitary egg parasitoid with at least two generations per year. It spends the winter and spring as a mature larva in EAB eggs, and adult emergence is synchronized with the EAB oviposition period during July and August in the field. Parasitism rates of *O. agrili* in EAB eggs peak at 61.5% in August. Its distribution overlaps with that of *T. planipennisi* at one of our study sites in China, and the combined mortality of EAB by these two parasitoids is ca. 75%⁶. *Oobius agrili* is parthenogenic, thus females produce females without mating; its sex ratio from field-collected EAB eggs in China is 15:1 (female:male). Much of the knowledge of this parasitoid's biology is based on laboratory studies in our quarantine laboratory. We have found that *O. agrili* females prefer to oviposit in 0- to 6-day-old EAB eggs, live ca. three weeks, and complete a generation every three weeks. The average lifetime fecundity of each female is ca. 24 progeny, with a range of five to 62.

In Michigan, we developed methods to rear *O. agrili* in the laboratory from eggs produced by EAB adults, which are reared from EAB-infested ash logs cut in winter and held in cold-storage. After emergence from infested logs held at room temperature in the laboratory, EAB adults are fed greenhouse-grown *Fraxinus uhdei* foliage and allowed to oviposit on small ash sticks; sticks with EAB eggs are removed and exposed to *O. agrili* for parasitism in a plastic cup with a streak of honey and moist cotton ball. In the laboratory, we performed no-choice assays with eggs of six *Agrilus* spp., two cerambycid beetles, and four lepidopterans. Overlap in physiological host range was found for three native *Agrilus* spp. with eggs of similar size to EAB. For these three species, paired choice assays revealed *O. agrili* strongly preferred to oviposit in EAB eggs laid on ash than in eggs of other *Agrilus* spp. on their respective host plants. This confirms that *O. agrili* is attracted to ash for host location.

Tetrastichus planipennisi was discovered in 2003 in Jilin and Liaoning Provinces of China³ and later

in Heilongjiang Province⁵. The results of our laboratory and field studies show that *T. planipennisi* oviposits through the tree bark and oviposits into the haemocoel of actively-feeding third- and fourth-instar EAB larvae. It completes at least four generations per year and overwinters as a mature larva inside the host gallery. In the spring, the parasitoid larva pupates, ecloses as an adult, chews a round 1-mm diameter hole in the bark, and the wasp brood exits the tree. An average of 35 parasitoids (range five to 122) emerges from a single EAB larva. During 2005, the results of EAB field research in Jilin Province, China revealed *T. planipennisi* parasitism rates increased from 8% in June to 40% in August⁶.

In Michigan, we developed methods to rear *T. planipennisi* in the laboratory by exposing groups of parasitoids to fourth-instar EAB larvae inserted into small ash branches. Adult parasitoids are maintained during the exposure period with a streak of honey and a moistened cotton ball. *T. planipennisi* completes one generation every three weeks and females live about 24 days, twice as long as males. EAB larvae are acquired for parasitoid production by removal from EAB-infested ash logs or after rearing on an ash-based artificial diet. Using our laboratory rearing methods, we evaluated the host specificity of *T. planipennisi* using no-choice assays. In these assays, groups of female and male *T. planipennisi* were exposed to actively-feeding larvae of eight buprestid species, five cerambycid species, and a wood-boring sawfly, all implanted in small branches of their respective host plants. We also assayed larvae of a tenebrionid beetle and two lepidopteran species by implantation in small ash branches, and sphingid larvae by exposure on host leaves. *Tetrastichus planipennisi* rejected all species except actively-feeding EAB larvae implanted in ash branches.

Spathius agrili was first reported in Tianjin, China² where it is a prevalent parasitoid of EAB in stands of *Fraxinus velutina*, an ash species native to North America and planted extensively in this part of China. Although *S. agrili* was also found further north in Jilin Province³, most of the research on this parasitoid was done in Tianjin, which is the southern known range of EAB. In Tianjin, the emergence of *S. agrili* adults was well synchronized with the availability of third- and fourth-instar EAB larvae, its preferred host stages. It completes three generations per year with parasitism increasing from 12% in August to 42% in October⁴. Females oviposit through the tree bark, paralyzing the larva and laying a clutch of eggs on the integument. At maturity, larvae of *S. agrili* spin a cocoon and pupate within the host gallery. Each female lays an average of nine eggs (range two to 18) per clutch, with an average of 23 eggs during her lifetime; average female longevity is 29 days. Laboratory rearing of *S. agrili* is generally similar to that of *T. planipennisi*.

To evaluate the host specificity of *S. agrili*, no-choice assays were conducted in China and the USA. In addition, from 2003 to 2005, potential host larvae from other trees were collected in Tianjin, China where *S. agrili* parasitism of EAB was high. These larvae were then reared to the adult stage and all

parasitoids were collected and identified. Because this early testing showed no parasitism of species outside the genus *Agrilus*, even species attacking ash, further testing concentrated on *Agrilus* spp. In China, no *S. agrili* were reared from six species of field-collected *Agrilus* larvae ($n = 2074$). However, no-choice laboratory assays of some Chinese and North America *Agrilus* larvae showed some overlap in the physiological host range of *S. agrili*, although successful parasitism was lower in non-hosts than in EAB. Therefore, we evaluated the ecological host range of *S. agrili* using an olfactometer to determine the attractiveness of certain host plants: naïve mated *S. agrili* females were placed in vertical Y-tube olfactometers and given a choice of leaves and twigs from 14 tree species or clean air. We found *S. agrili* was only attracted to *Fraxinus pennsylvanica*, *F. velutina*, and the willow *Salix babylonica*. In nature, if parasitoids are not attracted to the host tree they will be unlikely to encounter and parasitize the non-target larvae. Given the combination of evidence from no-choice tests (lower parasitism rates or no attack on non-target species), olfactometer tests (only attracted to ash and willow), the lack of *S. agrili* reared from other *Agrilus* spp. in China, and that native *Spathius* rarely find and parasitize EAB, we predict incidental parasitism by *S. agrili* in non-target *Agrilus* spp.

Conclusions

Considering the known adverse consequences of EAB on ash resources in North America, the lack of other options (except cutting down trees), the high potential benefit of these parasitoids, and the low potential risk to native *Agrilus* spp., we requested permission from the US Department of Agriculture early in 2007 to release the three parasitoids at selected sites in Michigan. After review by scientists and land managers at federal and state agencies, by university faculty members, and a 60-day public comment period, it was agreed that the potential benefits far outweighed the risks and release permits were issued. Field releases of *O. agrili* and *T. planipennisi* began in July 2007, and releases of *S. agrili* are expected to begin later in the summer or early fall.

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Managing the Impact of Parthenium Invasions in Africa

Parthenium hysterophorus or parthenium weed, an annual herb in the family Asteraceae originating from neotropical Central and South America, is well known to cause major economic losses to crop production and grazing land, and impact severely on biodiversity, and human and animal health in many parts of the world. Its status, impacts and opportunities for its biological control, as well as results of control in Australia and India particularly, have been discussed in an extensive literature (e.g. ^{1,2,3,4}). Its prolific seed production, allelopathic properties and tolerance of a range of soil and climatic conditions enable it to be a highly aggressive invader. Parthenium is present, and highly invasive in many cases, in Australia, India, Pakistan, Bangladesh, Nepal, Sri Lanka, southern China, Taiwan, Vietnam, Israel, several Pacific islands (including New Caledonia, Papua New Guinea and Vanuatu), the Seychelles, Madagascar, Mauritius, Reunion and on the African continent (Kenya, Ethiopia, Somalia, Mozambique, South Africa, Swaziland and Zimbabwe).

Despite long-standing control programmes in Australia and India dating back to the early 1970s, and although parthenium has been present in Africa for decades and has spread widely throughout some countries (e.g. Ethiopia and Swaziland), implemen-

tation of formal control programmes against parthenium on the African continent and neighbouring islands has been lacking. This is most likely due to lack of recognition of the potential threat or extent of the problem, lack of official policies on control of invasive plants or introduction of natural enemies, and lack of funding and coordinated efforts. There has been little documented on the impact of parthenium in African countries, with the exception of Ethiopia. Although parthenium has been present in South Africa since the late 1800s, dramatic increase in spread and abundance was only noted following the cyclonic event that affected the east coast of southern Africa in 1984. Currently within southern Africa, the northern and northeastern regions of South Africa, most of Swaziland, and parts of southern Mozambique are severely invaded by parthenium and it is known to occur in Zimbabwe. Until recently, no official control programmes have been implemented.

In late 2003, South Africa initiated a biological control research programme on parthenium, through the national government Department of Water Affairs and Forestry's *Working for Water Programme*, prioritizing the introduction of the stem-boring curculionid weevil *Listronotus setosipennis*, the leaf-feeding chrysomelid beetle *Zygogramma bicolorata*, the stem-galling tortricid moth *Epiblema strenuana*, and the summer rust fungus *Puccinia melampodii*. These agents were selected on the basis of their success in the extensive Australian biocontrol programme on parthenium which was initiated in the 1970s, their impact on the plant, and their likely suitability for the local climatic conditions. The winter rust fungus *Puccinia abrupta* var. *parthenicola* is already present in South Africa, Kenya and Ethiopia – its mode and time of introduction unknown. Parthenium biocontrol agents are currently undergoing testing on relevant local plant species in quarantine in South Africa to determine their specificity and suitability, and the likelihood of their release is promising. The first releases in South Africa are anticipated in 2008, pending approval from relevant government authorities. The thermal physiological parameters of insect agents are being investigated in the laboratory; these data will be utilized to determine potential and optimal areas for establishment. Within South Africa, other research is also being conducted on the chemical control of parthenium in conservation areas, as well as the interaction of native grass species with parthenium including the effects of its allelopathic properties.

An opportunity to expand biocontrol of parthenium beyond South Africa arose with the initiation of a United States Agency for International Development (USAID) Integrated Pest Management Collaborative Research Support Program (IPM CRSP) project on 'Management of the Weed Parthenium (*Parthenium hysterophorus* L.) in Eastern and Southern Africa using Integrated Cultural and Biological Control Measures' in 2005. The objectives of this four-year project, which is being conducted in selected countries within the southern and eastern African regions, are to (1) survey and map the distribution of parthenium in South Africa, Swaziland, Botswana, Uganda and Ethiopia, (2) determine the socioeco-

onomic impacts of parthenium in Ethiopia, (3) determine the impacts of parthenium on plant diversity in Ethiopia, (4) implement biological control in South Africa and Ethiopia, and (5) determine appropriate pasture management practices for control of parthenium in Ethiopia. This project, coordinated by Dr Wondi Mersie at Virginia State University, USA, facilitates research and the implementation of parthenium control efforts among researchers from South Africa, Botswana, Ethiopia, and Uganda, with advisory inputs from Australian, Indian and other African researchers. South Africa and Ethiopia were identified as key participants within southern and eastern Africa, respectively, in which to conduct the project, based on their relevant expertise as well as proximity to dense parthenium infestations.

During this project, predictions of the climatic suitability of areas for parthenium invasion and therefore potential distribution of parthenium within Africa have been made using the modelling program CLIMEX (version 2.0). Additionally, roadside surveys were conducted during two consecutive years' growing seasons within each of the selected countries and the distribution and abundance of parthenium infestations mapped at the quarter-degree square level; this has added considerably to the limited existing knowledge of the distribution of parthenium in parts of eastern and southern Africa. These surveys have provided baseline data from which spread and abundance can be monitored, as well as site-specific information for the implementation of control options.

Formal questionnaire surveys have been conducted with more than 100 farmers in Ethiopia, to determine awareness, perceptions, local knowledge and impacts of, and losses caused by, parthenium, and the control measures practised, in an effort to determine the socioeconomic impacts of the weed. The impacts of parthenium on plant diversity in Ethiopia are being determined by conducting glasshouse and field competition trials with parthenium and selected native species in Ethiopia. Parthenium threatens pasture and rangelands that are critical to the livelihoods of more than 8–10 million agropastoral Ethiopian people. The pasture management methods that are being investigated in Ethiopia include mowing, over-sowing using selected native grass and legume species, and burning, or a combination of these methods.

Due to the lack of appropriate facilities for the handling of imported biocontrol agents in Ethiopia, existing glasshouse facilities have been modified to provide a quarantine facility suitable for research on imported insect agents for parthenium at the Ethiopian Institute of Agricultural Research's Ambo Research Centre, west of Addis Ababa. Several Ethiopian researchers have been trained in weed biological control techniques in South Africa. *Zygothrips bicolorata* will be the first biocontrol agent to be introduced into the Ethiopian quarantine facility in 2007, following screening in South Africa on selected important Ethiopian crop varieties. Soil seed banks are being evaluated in long-term studies at selected trial sites in South Africa and Ethiopia to

enable the impact of biocontrol agents to be measured once they are established in the field.

This project has facilitated capacity building and technology transfer through inter-agency collaboration. It has also enhanced national programmes and infrastructure, and has enabled the forging of contacts for further collaborative research. Parthenium is a major problem in several parts of Africa and managing it on a cooperative, regional basis is likely to lead to greater success of control.

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First Fungal Pathogen to be Utilized for Weed Biocontrol in Fiji and Papua New Guinea

Biological control of weeds has been carried out in Fiji since 1911, when the seed-fly *Ophiomyia lantanae* was introduced in an attempt to control *Lantana camara*. To date a number of other weed biocontrol projects have been undertaken, all using phytophagous insects as control agents.

In 1988, the thrips *Liothrips mikaniae* was introduced from Trinidad into the Solomon Islands at Dodo Creek Research Station by the International Institute of Biological Control in an attempt to undertake biocontrol of *Mikania micrantha* (mikania) in the Pacific. A small colony of the thrips was subsequently taken from the Solomon Islands to the Kerevat Lowlands Agricultural Experimental Station in New Britain, Papua New Guinea (PNG). However, both colonies died out during laboratory rearing and due to a flood at the Dodo Creek Station. Now two decades later and for the first time, a pathogenic rust fungus has been imported for use against mikania, one of Fiji's and the Pacific's worst invasive weeds.

In 2006, the Australian Centre for International Agricultural Research (ACIAR) approved the funding of a biological control project involving Fiji and PNG. The primary classical biological control agent being considered for use in the two countries is *Puccinia spegazzinii*, an autoecious microcyclic rust fungus. Infection by this fungus causes the development of lesions over leaves, petioles and stems, retarding growth and often leading to death of the plant. Host specificity testing of the rust was conducted at CABI in the UK and it was found to be host specific to a few species within the genus *Mikania*. Subsequently, a strain of *P. spegazzinii* was imported into Fiji. An application to import the rust into PNG is currently being prepared.

As well as the rust, two species of the Neotropical butterfly genus *Actinote* will be imported into Fiji and will be tested against 35 plant species. If found to be sufficiently host specific to mikania, an application seeking their release will be prepared and submitted. *Actinote thalia pyrrrha* and *A. anteas* are two natural enemies considered to have the potential to give good control of mikania. These two insects were initially released in Sumatra, Indonesia during the mid 1990s and are reportedly contributing to the biocontrol of the asteraceous weeds *Chromolaena odorata* and *M. micrantha*.

This work in the Pacific is being conducted under a joint country project 'Biological Control of *Mikania micrantha* in Fiji and Papua New Guinea', funded primarily by ACIAR. The Secretariat of the Pacific Community (SPC) and the Queensland Department of Primary Industries and Fisheries (DPI&F) are both working together with the Fiji Ministry of Agriculture and three agricultural research agencies in PNG to see that mikania is brought under control.

For more information visit: www.spc.int/lrd/mikania

By: Sarah Pene and Warea Orapa, SPC and Michael Day, DPI&F.

West Africa's Mango Farmers Have Allies in the Trees

A recent paper reporting work conducted in Benin has highlighted how an African weaver ant (*Oecophylla longinoda*) could provide a way of reducing the massive losses to mangoes caused by fruit fly pests and improve fruit quality¹. The next step will be to help Africa's farmers appreciate this beneficial ant and train them in managing ant colonies. Developing this kind of training should be a thrilling and pioneering challenge.

Weaver Ants and Biocontrol

As many biocontrol students learn, the Asian weaver ant (*Oecophylla smaragdina*) represents the earliest recorded implementation of biological control: In 'Records of the plants and trees of the Southern Regions', written in 304 AD, Hsi Han described how ants in bags of rush matting were sold at local markets in southern China. Farmers hung these in mandarin orange trees so the ants could kill the

insects that attacked the fruit. The farmers built systems of miniature bamboo bridges between trees for ants to move easily between them. A supply industry grew up, and by the twelfth century entrepreneurs were hanging up animal bladders filled with fat next to nests to attract ants, which could then be sold.

Weaver ants have highly organized predatory behaviour. Their success in killing or driving away potential pests is based on their habit of foraging throughout the area occupied by a colony and their ability to expand into new areas. One study found that a colony of 12 nests killed some 45,000 prey per year².

Weaver ants continued to be used by farmers in Asia, but in recent decades widespread pesticide use reduced their presence. The realization of this, and other, negative impacts of pesticides led to initiatives aimed at preserving indigenous knowledge associated with weaver ants, and integrating their use into IPM systems (e.g. see *BNI* 22(2), 40N–42N (June 2001), 'Weaver ants in citrus: a revival'). Weaver ants have also been adopted in commercial mango plantations in Australia to control major pests, including fruit flies.

The low adoption of IPM in developing countries of sub-Saharan Africa has been attributed to a variety of capacity and policy shortcomings, but one argument suggests researchers may have been concentrating on the wrong crops: while staple crops such as rice proved fertile ground for advancing IPM in Asia, the technology "is more likely to be adopted by resource-poor African farmers if it focuses on host plant resistance and biological control, high-value commodities, and helps meet farmers' wider objectives of increasing household food security and earning cash income"³.

Invasive Pests on African Mangoes

In Africa, fruit trees form an important but often neglected component of people's lives; some 40% of the mango crop alone is thought to be lost to pests annually. Nonetheless, various West African farmers with mango trees, in which the most serious pests are termites, mealybugs and fruit flies, may have experienced (often without knowing) the beneficial effects of biological control. A number of *Rastrococcus* spp. mealybugs attack mango, but damage from them reached catastrophic proportions only when the alien invasive species *R. invadens*, arrived in West Africa in the 1980s. As a serious pest of mango and citrus (amongst other trees), it had widespread economic and social impacts as crop yields plummeted to near zero in some areas. Under a classical biological control programme, two parasitoids were introduced from India and their establishment and spread led to the suppression of *R. invadens*; damage was reduced to an economically tolerable level and the cultural functions of mango trees, in particular, were restored⁴.

In 2005, the arrival of another exotic pest in West Africa, the fruit fly *Bactrocera invadens*, was confirmed from trap catches made in late 2004 and 2005 in Benin⁵. This species, which had been the cause of

mounting concern in Asia and islands of the Indian Ocean, was first reported from Africa on the Kenya coast in 2003. Its rapid spread across tropical Africa and mounting records in fruit crops (including guava, citrus, papaya, shea-butter tree and, especially, mango) testify to its potential pest status and economic significance. For instance, during the 2006 mango harvesting season in Benin, we recorded about 60% losses due to damage from these fruit fly species⁶. The two main species involved were *Ceratitis cosyra* and *B. invadens*. Despite their economic importance, fruit fly control in West Africa is still at an experimental stage. Smallholders may try and avoid damage by picking fruit early although significant damage can still occur. This practice is used by most growers in Benin but is not so common in Mali or Guinea. Others may use blanket sprays or, more rarely, imported bait–insecticide mixtures but such management is generally poor because farmers lack knowledge, access or both.

Weaver Ants in Mangoes in Benin

The results of surveys and follow-up exclusion experiments we conducted on mango plantations in the mango fruiting and harvesting period (mid March to early June) in northern Benin led us to conclude that conservation, rather than classical, biological control may provide a means of suppressing the damage these fruit flies cause to mangoes. We found that fruit damage in four cultivars in early April to mid May, which ranged from 0.8% to 24.1% of the fruit being infested with fruit fly maggots, was far less in plantations where weaver ants were present, and damage was also inversely related to number of ant nests. In one case, the fruit damage at the end of the season reached 67% where weaver ants were not present. Although weaver ants had no impact on trappable adult fruit flies in the tree canopy, we found that excluding ants significantly increased fruit fly infestations, and infestations were reduced most where ant abundance was high.

Weaver ants disturb fruit flies during oviposition, but more research is needed to elucidate the multiple mechanisms of fruit fly control by weaver ants. Also, we found that different cultivars housed different numbers of weaver ant nests; 'Gouverneur' was the best of the four cultivars we investigated, but this aspect needs further study. Equally, the effects of events such as bush fires and of ecoclimatic conditions (e.g. the annual desert wind, the 'harmattan') on weaver ant distribution need investigating. The role of fallen and damaged fruit left on the ground in the weaver ant – fruit fly system also needs evaluating; such fruit is known to provide a breeding ground for fruit flies, but fallen fruit with larvae also provide a resource for the ants after harvest is over. Larval predation is relatively important, with the ants' foraging behaviour making them remarkably effective at capturing them. This will be quantified in a future article. In addition, the impact of weaver ants on other mango pests needs to be clarified, but from farmers' feedback it is clear that fruit flies by and large constitute the major pest problem, especially in the Soudanian areas of West Africa.

Engaging Weaver Ants and Farmers as Allies

Raising awareness and giving farmers knowledge and training, through participatory techniques, is essential if they are to conserve and maximize populations of naturally occurring weaver ants. While Asia's farmers have a wealth of indigenous knowledge to draw on, this is a novel technology for most African fruit and nut farmers.

As a first step, we developed an appropriate method for farmers to assess weaver ant abundance in their plantations. We found that a simple method, counting ant trails on main branches, proved much faster and also cheaper and more reliable than a bait-based method (more than 50 trees/hour could be sampled by counting compared with a maximum of ten trees/hour using baits).

Perception is also important: weaver ants are aggressive and can inflict relatively painful bites. Nonetheless, Australian mango farmers do not apparently perceive this as an insurmountable problem. A study in Benin and Guinea on the perceptions of various stakeholders, from farmers and pickers to the marketing sector, will help with designing further research and development interventions. Various local solutions to reduce nuisance by ants during harvest are currently being tested.

Weaver ant technology is cost free, labour saving and requires little intervention. It is thus particularly suitable for smallholder farmers in sub-Saharan Africa. The long history of the technology in Asia illustrates how this conservation biological control of predators has great promise as a component of low-cost sustainable IPM for smallholders in sub-Saharan Africa. The manual *Ants as Friends*⁷, available in multiple languages, is one of the steps undertaken to promote South–South exchange of local and scientific knowledge between Asian and African farmers.

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Further information: www.tephritid.org

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War Declared on South African Pompom Weed Invasions

Pompom weed (*Campuloclinium macrocephalum* (Asteraceae) is rapidly becoming one of the most serious threats to the conservation of South African grasslands. Its invasive potential was first reported on in *BNI* 20(4) in December 1999. The article by Stefan Nesoer of ARC-PPRI (the Agricultural Research Council – Plant Protection Research Institute of South Africa) forewarned of the plant's ability to invade even climax grassland and wetland habitats. Eight years on and pompom weed has lived up to researchers' worst fears.

Originating from a wide native range in South and Central America, the mechanism for the introduction of pompom weed into South Africa is unknown. Earliest records from the Pretoria National Herbarium are for a specimen collected in Johannesburg (Gauteng Province) in 1962. The weed is now prominent in Gauteng Province, but also occurs in Mpumalanga, Limpopo, North West, KwaZulu-Natal, Eastern Cape, Western Cape and Free State provinces. Currently pompom weed occurs in 80 quarter-degree squares throughout the country (22 of these are in Gauteng). The weed's large wind-dispersed seed set and underground tubers (enabling it to survive the dry season), as well as a tolerance of a wide range of soil and moisture regimes, have contributed to its invasive ability. Additionally, its attractive floral displays are leading members of the public to collect and (inadvertently) spread it for aesthetic purposes.

Several strategies have been implemented to control pompom weed throughout South Africa. The first has involved creating awareness of the weed; because it is very conspicuous during its flowering period, members of the public are able to identify, report and even control outlying populations. The 'pink menace' has received much media attention (print and television) and because many of the infestations occur along

South African major road networks, it has been suggested that roadside billboards be erected to further draw motorists' attention to the threat posed by the plant.

The second strategy to control pompom has already been implemented in KwaZulu-Natal Province – all known infestations of the weed have been treated with the only currently registered herbicide for pompom in South Africa, Brush-Off® (metsulfuron methyl, 25 g/100 litres water). The plants were spot-sprayed to minimize impact on non-target plants. A follow-up programme will be conducted in early 2008. Chemical programmes in other affected provinces have mainly focused on spraying roadside infestations of pompom weed, so as to minimize the dispersal of propagules by vehicles.

Biological control is the final strategy for sustainable control in the fight against pompom. In a nationally funded biocontrol research project on pompom weed initiated in 2003, three exploratory trips to Argentina and one to Brazil have been undertaken by PPRI to survey for natural enemies. Two leaf rust fungi and nine insect species have been recorded from the plant in its native range. Of these, one rust fungus (*Puccinia eupatorii*) and three insect species (*Liothrips* sp. – a stem-galling thrips; *Cochylis campuloclinium* and *Adaina* sp. prob. *simplicius* – flower-feeding moths) are currently being reared and tested in quarantine in South Africa, because of their damaging nature and field host-specificity. The results from laboratory host-specificity trials so far indicate narrow host ranges and it is envisaged that applications for permission to release the rust may be submitted towards the end of 2008 and the insects at the end of 2009.

The prospects in the war to control pompom weed in South Africa are encouraging. Provinces which have limited populations of the weed (KwaZulu-Natal, Free State, North West, and Eastern and Western Cape) should be able to contain spread and possibly even eradicate some infestations. Provinces with higher levels of invasion (Gauteng, Mpumalanga and Limpopo) will have to look towards reducing the spread of the weed by controlling it along roadsides. Improved land management practices (lower stocking densities, decreased disturbance, etc.) in conjunction with other control methods and agropastoral practices (mowing, burning and minimum tillage with grass over-sowing) should also go a long way to containing the weed until biological control can be implemented.

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Conserving and Using Entomopathogenic Fungi and Nematodes within Chile

Many successful biological control programmes rely on natural enemy species previously unknown to science. Initiatives to catalogue and conserve

biodiversity carried out by countries wishing to fulfil obligations under the CBD (Convention on Biological Diversity) also provide opportunities to identify promising candidate agents. One such project is currently being carried out in Chile under the Darwin Initiative. This programme, which aims to promote biodiversity conservation and sustainable use of resources around the world, is funded and administered by the UK Department for Environment, Food and Rural Affairs (Defra).

The Basis of a Darwin Initiative Project

In June 2006 scientists at CABI Europe – UK and the Instituto de Investigaciones Agropecuarias (INIA) in Chile began a three-year study into the entomopathogenic fungi (EPF) and nematode (EPN) diversity of Chile. The project, funded by the Darwin Initiative, will be carrying out a series of comprehensive and systematic surveys of EPF and EPN in Chile, and has the aim of generating information on the ecology and diversity of these microorganisms and also of identifying any with potential as biological control agents (biopesticides). The project also has a hint of romanticism about it, with a number of collections to be carried out along the route used by Charles Darwin, during his famous *Beagle* expedition in the nineteenth century.

Since the 1970s Chile's economy has gradually improved and it is now one of the strongest in South America, thanks in many respects to growth in the agriculture sector. Over the last three decades land reform has shifted production away from small-scale cooperatives to larger, intensively managed farms, with the market buoyed by increasing competition and a rise in the level of exported crops. However, economic success in the agricultural sector has come at a price: many farms have adopted high-intensity production systems, often characterized by monocultures, deforestation and a large increase in the use of chemical pesticides¹. Whilst rational pesticide use can undoubtedly play a positive role in cropping systems, pesticides are increasingly being associated with serious issues of target resistance, harmful side-effects on natural enemies and concerns over environmental toxicity; issues that are compounded by irrational, non-regulated use. The Government of Chile, through the National Commission for the Environment (established in the 1990s), has joined an international push to reduce the use of chemical pesticides on agricultural land and to search for effective, 'greener' alternatives.

EPF and EPN have the potential to provide highly virulent, cost-effective and environmentally safe means of insect pest control. Conidia of EPF can infect the insect directly through the external cuticle, adhering to the body surface, germinating through it, multiplying, and then causing death by nutrient depletion, an invasion of organs and/or a release of toxic metabolites. EPN have evolved an ability to carry and introduce symbiotic bacteria into the body cavity of insects. The bacteria can produce toxins that kill the insect by septicaemia and bio-convert the cadaver into a nutritive medium which suits the further growth and development of the EPN.

A primary aim of the project is to examine the biodiversity of the organisms of interest and, with EPF and EPN, not only look at species, but try and understand the diversity of isolates that much better. The potential financial benefits, from sustainable exploitation of these organisms, should bring real benefits to the country and improve livelihoods for the rural dweller. These improvements should not just be financial, but environmental and to health as well, as the country moves away from the use of chemical pesticides.

Research into EPF and EPN as biopesticides is already being carried out in many countries worldwide. The advance in the development and use of both EPF and EPN organisms for pest control has been huge. Many species can now be mass produced on a large-scale *in vitro*, with storage more than 12 months possible (particularly for EPF) and formulations that can significantly extend field persistency. The Insect Pathology team at INIA has been the principle biopesticide research group in Chile for over ten years, working predominately on EPF and EPN. Results from field trials at INIA have been excellent, but there has been relatively limited scaling-up or successful commercialization of products. Similarly, on a global scale, the great potential of EPF and EPN and the significant advances in their development have not been reflected in the number of commercially successful products on the market. Successful products can be found in many markets including the European Union, the USA, Latin America, India and Australia, demonstrating a wide geographical spread. However, biopesticides form only a tiny fraction of the global pesticide market and *Bacillus thuringiensis* products dominate this niche. One significant reason for the lack of commercial success is that a complex array of biotic and abiotic interactions between target, pathogen and the environment prevent effective and reliable results at the grower's end². To have any success the links and adaptations within the pathogenic complex, whether behavioural, physiological, biochemical or ecological, must be thoroughly understood.

Chile covers an area of 756,900 km² and is approximately 4350 km in length. With a maximum breadth of 360 km and bordered on the east by the Andes Mountains and on the west by the Pacific Ocean, Chile's topography is dramatic. Stretching across 38 degrees of latitude, many of the world's climates are also represented, with hot, dry deserts in the north, through the central Mediterranean zone, the cool, humid southerly regions and finally down to near-Antarctic conditions in the far south. The physiology, tolerance and behaviour of the indigenous EPF and EPN communities will have evolved in close association with abiotic factors such as the temperature, insolation and soil type, moisture and pH of these habitats. Hence, with Chile being so ecologically diverse, there is great potential to discover indigenous EPF and EPN displaying an array of adaptations. The project team have selected six survey regions covering some of the major habitat types in Chile, using climate, topography and vegetation type as indicators. Two of these regions will be surveyed each year, collecting approximately 200 soil samples from each and using larvae of the wax moth

(*Galleria mellonella*) to bait out both EPF and EPN. Those isolates obtained will undergo morphological studies, molecular identification and cryopreservation, and will then be biologically and ecologically profiled at both CABI and INIA to identify links between habitat and isolate.

The first year of the project has just ended and the first two major surveys completed. A number of isolates have been obtained and regular updates will be given in *BNI*.

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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. But as in many recent issues, we are featuring biopesticide stories.

Natural Enemies Help Green Muscle and Vice Versa

Green Muscle®, the *Metarhizium*-based bioinsecticide developed under the LUBILOSA (Lutte Biologique contre les Locustes et les Sauteriaux) programme for locust and grasshopper control in Africa, is recommended by FAO (Food and Agriculture Organization of the United Nations) for use in environmentally sensitive areas, but its use in agricultural areas has been ruled out because of its slow speed of action. Now results from trials in North and West Africa reveal interactions with locust natural enemies that both increase its speed of action and enhance its 'green' credentials.

Recent field demonstrations of Green Muscle® under more or less operational conditions have shown that mortality of treated desert locust (*Schistocerca gregaria*) nymphs can be much faster than expected. A demonstration of the bioinsecticide performed in 2005 in Algeria led to the disappearance of treated hopper bands in about a week instead of the expected two to three weeks. This was suspected to have been the result of natural enemy activity, though this could not be directly observed because of the stringent security arrangements. Numerous body parts, especially leg segments and head capsules, were found at the spots where hopper bands had roosted. A number of potential predators and parasitoids were observed in the area, including several bird species, lizards, ground beetles, scorpions and wasps. The action of birds in particular was confirmed later that year during a demonstration in Niger, where immature adult desert locusts were treated with Green Muscle®. Birds captured significantly more locusts around the time that peak mortality was suspected based on cage observations.

The action of natural enemies had been observed and documented before, but had initially been seen as a nuisance that prevented researchers from observing the 'real' effect of Green Muscle®. This attitude changed after the operation in Algeria. By that time, it had become clear that the slow mode of action of *Metarhizium* was one of the factors inhibiting the uptake of Green Muscle® by locust control agencies. If natural enemies could speed up mortality, this would be great news and a boost for the product. It would also enhance its green credentials, because it would mean that it more or less handed locust nymphs to the natural enemies on a silver platter by making the former easier to catch. In contrast, only a small proportion of nymphs treated with chemical insecticides is taken by natural enemies. Cadavers of such nymphs often lie around for weeks or months, while those killed by *Metarhizium* are quickly utilized by scavengers.

To confirm the notion that natural enemies can speed up the destruction of hopper bands treated with Green Muscle®, care was taken to study this aspect during the next demonstration, in November 2006 in Mauritania. This time, there were no security limitations on observations of the experimental hopper bands. A total of 15 species were confirmed to parasitize and prey on the nymphs, while a further five species were suspected of doing so. Several species of beetles and ants were active in removing dying nymphs and cadavers, so that relatively few cadavers were recorded at any one time. It was also striking to see that birds like the Sudan Golden Sparrow had much more trouble catching healthy nymphs than sick ones. This species and the Brown-Necked Raven between them probably accounted for most of the mortality of treated locusts, though there is reason to believe that kangaroo rats and mice (properly called jerboas and gerbils) also took a heavy toll at night. Thus it was clear from the observations that predation was heavier on the treated nymphs. On the other hand, the rate of parasitism was difficult to measure and no apparent difference was found between treated and untreated nymphs.

The latest demonstration on the Red Sea coast of Sudan in March 2007 was unfortunately not conclusive. One objective of this operation was to show the

effect of a component of the adult desert locust pheromone, PAN or phenylacetone, on locust nymphs alone and in combination with Green Muscle®. The study of predation, parasitism and scavenging was again another important objective. However, the post-treatment observations were disrupted half-way through by large untreated bands of fourth-instar hoppers invading the study area. Consequently, the operation had to be terminated. Flocks of Yellow Wagtails were observed attacking the hopper bands, but it was not possible to determine a difference between treated and untreated bands. However, the fact that all treated hopper bands were still present a week or more after the treatments means that the natural enemies in this area were not capable of eliminating the bands in such a short period. The most likely reasons for this are that the bands were much larger than in previous operations and that natural enemies were not as abundant, possibly because of the almost total lack of rain for three years. The low density and/or activity of scavenging ants and beetles meant that many cadavers of *Metarhizium*-killed nymphs were found among the bands treated first.

Nonetheless, it can be concluded that under some circumstances natural enemies can play a part in reducing the time needed for Green Muscle® to eliminate hopper bands. The effect is greatest where natural enemies are abundant and when hopper bands are not too large, say in the range of a few thousand to several hundred thousand hoppers per band. During very large infestations, natural enemies will usually be overwhelmed and the fungus-induced disease will then have to run its full course in most nymphs. Under favourable circumstances, i.e. moderate temperatures, moderately-sized hopper bands and abundant natural enemies, hopper bands can be expected to disappear within about a week of the application of Green Muscle®. In such cases, the product can be used in relative proximity to crops. Green Muscle® also makes a much larger proportion of nymphs, sometimes close to 100%, available to natural enemies and scavengers than chemical insecticides. This will contribute to survival and breeding success of a good number of species and thereby favour biodiversity in invaded areas.

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Microbial Net to Protect India's Brassicas

The first registration of an oil-based formulation of an entomopathogenic fungus developed in India was achieved early this year by Bio-Control Research Laboratories (BCRL), a division of Pest Control (India) Pvt. Ltd.

Myco-Jaal®, an oil-based emulsified suspension concentrate of *Beauveria bassiana* with a spore count of 1×10^{10} conidia/ml, is a new tool for managing diamondback moth, *Plutella xylostella*. 'Jaal' in Hindi

means net, and the name reflects the product's role as a 'microbial net' to protect brassica crops. Although Myco-Jaal® is particularly effective against diamondback moth, the most serious pest of cruciferous crops such as cabbage, cauliflower, Chinese cabbage and broccoli, it is also capable of infecting sucking pests such as aphids and mites. The oil-based formulation protects the active ingredient from the degrading effects of UV radiation, and can achieve rapid infection and good field efficacy. Insects do not develop resistance to it, unlike synthetic chemical pesticides, and neither does it affect natural enemies.

In trials in a farmer's field situation, application of Myco-Jaal® (at 2 ml/litre) reduced the DBM population by just over 55% compared with an untreated control, with control maintained for up to 25 days after treatment. This was on a par statistically with chemical insecticide treatment (indoxacarb 14.5% SC) which gave 60% control, and control of 63% achieved with a Myco-Jaal®/indoxacarb combination and 62% from the farmers' usual practice, which relies on a combination of insecticides to prevent the development of resistance in DBM populations. Best yields were recorded in plots given combined applications of Myco-Jaal® and indoxacarb with an increase of 6.8 t/ha over the control; Myco-Jaal® alone gave a yield increase 3.6 t/ha. However, the best cost:benefit ratio was calculated for Myco-Jaal® (at 5.41), followed by the Myco-Jaal®/indoxacarb combination (4.23), with sole insecticide treatment and farmers' practice giving lower values.¹

Myco-Jaal® is applied as a spray suspension in water at 5×10^{12} conidia in 250–300 litres of spray suspension/acre (1 acre = 0.405 ha) using a high volume sprayer; thus 500 ml Myco-Jaal® will treat about an acre per application, with 3–4 applications per crop cycle. The product is compatible with synthetic chemical insecticides.

The research behind the development of this product, led by Dr Swapan Kumar Ghosh, was inspired by the LUBILOSA project (see 'Natural enemies help green muscle and vice versa', this issue) and also benefited from visits by CABI staff who had been involved in that project.

¹Ghosh, S.K., Chaudhary, M. & Prabhakar, M. S. (2007) Bio-efficacy of Myco-Jaal® 10% SC, an oil based commercial formulation of *Beauveria bassiana* (Bals.) Vuillemin against diamondback moth *Plutella xylostella* (L.) (Lepidoptera: Yponomeutidae) on cabbage. *Pest Management in Horticultural Eco-systems*. [In press]

Contact: Dr K. P. Jayanth, General Manager, Bio-Control Research Laboratories, A division of Pest Control (India) Pvt. Ltd, 36/2, Sriramanahalli, Nr. Rajankunte, Doddballapur Road, Arakere Post, Bangalore 561 203, India.
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Web: www.pcilindia.com

Announcements

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

News from IOBC

The IOBC/WPRS (International Organization for Biological and Integrated Control of Noxious Animals and Plants – West Palaearctic Regional Section) have a number of meetings coming up in the latter part of this year, including:

- The IOBC/WPRS Working Group ‘Integrated Protection of Olive Crops’ third meeting on 10–12 October in Braganca, Portugal. (Contact: Jose Alberto Pereira, CIMO/Escola Superior de Braganca; jpereira@ipb.pt; web: www.esa.ipb.pt.)
- The IOBC/WPRS Working Group ‘Pesticides and Beneficial Organisms’ on 10–12 October in Berlin, Germany. (Contact: H. Vogt, BBA, Dossenheim; H.Vogt@bba.de.)
- The IOBC/WPRS Working Group ‘Integrated Protection in Oak Forests’ fifth meeting on 22–25 October in Tlemcen, Algeria. (Contact: Rachid Tarik Bouhraoua, Université de Tlemcen; rtbouhraoua@yahoo.fr / rt_bouhraoua@univ-tlemcen.dz.)
- IOBC/WPRS Working Group ‘Integrated Control in Viticulture’ on 25–27 October in Marsala, Sicily, Italy. (Contact: S. Ragusa; ragusa@iobc-wg-viticulture.org; web: www.iobc-wg-viticulture.org.)
- IOBC/WPRS Working Group ‘Integrated Control in Citrus Fruit Crops’ on 5–7 November in Catania, Sicily. (Contact: G. Siscaro, University of Catania; gsiscaro@unict.it; web: www.iobc-wprs-citruswg.net.)

Meanwhile the 30th ‘Congreso Nacional de Control Biológico: Control Biológico sin Fronteras’ and IOBC symposium is being held on 11–15 November in Merida, Yucatan, Mexico. (Contact: V.A. Sandoval; smcb@colpos.mx; web: www.controlbiologico.org.mx).

If you attend these or other IOBC meetings and send us a report, we’ll publish it in the next issue.

IOBC celebrated its fiftieth birthday in 2006 with the publication of a book telling its history:

Boller, E.F., van Lenteren, J.C. & Delucchi, V. (eds) (2006) *History of IOBC – the First 50 Years (1956–2006)*. IOBC, Zürich, Switzerland, 287 pp.

If you don’t yet have a copy, you can order one by sending €10 by normal mail to:

J.C. van Lenteren, Laboratory of Entomology, Wageningen University, PO Box 8031, 6700 EH Wageningen, The Netherlands.

New Theoretical Ecology Journal

As biological control depends on ecological theory, it seems pertinent to highlight a new quarterly journal from Springer. The first issue of *Theoretical Ecology* will be published in February 2008, although first online articles are available now.

The Editor-in-Chief is Alan Hastings (Department of Environmental Science and Policy, University of California, USA). The aim of the journal is to offer “a healthy balance among theory, concepts and modeling.”

Web: www.springer.com/

Biotechnology for Biocontrol Agents

Also available from Springer is a new book in the NATO Science for Peace and Security Series:

Vurro, M.M. & Gressel, J. (eds) (2007) *Novel Biotechnologies for Biocontrol Agent Enhancement and Management*. Proceedings of the NATO Advanced Study Institute on Novel Biotechnologies for Biocontrol Agent Enhancement and Management, Gualdo Tadino, Italy, 8–19 September 2006 NATO Science for Peace and Security Series A: Chemistry and Biology, 374 pp. ISBN: 978 1 4020 5798 4.

Web: www.springer.com/

Banana and Plantain Conference

The pan-African conference: ‘Banana and plantain in Africa: harnessing international partnerships to increase research impact’, organized by the International Institute of Tropical Agriculture (IITA) in partnership with the Kenya Agricultural Research Institute (KARI), Bioversity International, the Forum for Agricultural Research in Africa (FOR A) and the International Society for Horticultural Science (ISHS) will be held in Mombasa, Kenya on 7–10 April 2008.

Fostering international partnerships is a major objective of the conference, with particular emphasis on establishing the role of research in promoting future commercial activities and trade. There is an urgent need to target basic and applied research that connects to existing and emerging markets. This conference will be the first pan-African meeting to link research to markets in an African context. Key priorities:

- Develop an African strategy for the next decade to exploit banana and plantain research
- Strengthen research partnerships to overcome production bottlenecks
- Harmonize research with production trends, emerging markets and trade networks

Information: www.banana2008.com

Cuba Hosts Plant Health Meeting

The VI International Scientific Seminar of Plant Health, 'Plant health for the environmental sustainability', will be held in Havana, Cuba on 22–26 September 2008. Organized by INISAV (Institute of Plant Health Research), CENSA (National Centre for Animal and Plant Health) and CNSV (National Centre for Plant Health), themes will include:

- Diagnosis and identification of tropical agriculture pests
- Molecular markers as a support for phytosanitary programmes
- Agroecological alternatives to pest management
- Production and use of biological control agents and natural substances
- Safety and food security in agriculture
- Pesticides and their environmental impact
- Plant quarantine and risk analysis
- Technology transfers in the agriculture sector
- Phytosanitary surveillance
- Invasive species and their impact on agriculture

- Environmental changes and their effect on agriculture pests
- Informatics and mathematics applied to plant health
- Knowledge and technological innovation in the agriculture sector

The seminar will incorporate the following events:

- 48th Annual Meeting of the American Phytopathological Society –Caribbean Division
- Second International Conference on Methyl Bromide Alternatives
- Second Latin American Workshop of Phytopathogen Biocontrol
- Second International Phytoplasma Workshop
- Second International Workshop on Production and Agroecological Management of Beneficial Arthropoda

Contact:

Seminar Organizer: Msc. Dr. Rodolfo Arencibia Figueroa [arencibia@palco.cu]

Secretaries to the Organizing Committee: Dra Orietta Fernández-Larrea Vega [oflarrea@inisav.cu] & Dra Yamila Martínez Zubiaur [yamilamz@infomed.sld.cu]

Web: www.palco.cu

Conference Report

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

ISBCW in Montpellier

The XII International Symposium on Biological Control of Weeds (ISBCW) was held on 22–27 April 2007 at La Grande Motte, Montpellier in the south of France, hosted by CSIRO's European Laboratory and the US Department of Agriculture's European Biological Control Laboratory (USDA-EBCL).

As far as biocontrol of weeds goes, the International Symposium series, which takes place every four years, is the key event for exchanging ideas and creating new opportunities through networking with colleagues and sponsors. The Symposium was widely considered a success. It was attended by some 238 delegates from nearly 40 countries and was sponsored by eight organizations. Seventy oral presentations and nearly 180 posters were presented addressing the nine symposium themes:

- Ecology and modelling in biological control of weeds
- Evolutionary processes
- Benefit-risk – cost analyses
- Regulation and public awareness
- Target and agent selection
- Pre-release specificity and efficacy testing

- Release activities and post-release evaluations
- Management specifics; integration, restoration, implementation
- Opportunities and constraints for biological control of weeds in Europe

Eight workshops were also held during the course of the symposium.

Amongst many excellent presentations, some that seemed particularly significant for weed biological control are featured here. We apologise for presentations that limited space has led us to omit, and invite readers to contact us if they would like these to be featured in future issues.

In the keynote address for the session, 'Ecology and modelling in biological control of weeds', Yvonne Buckley (University of Queensland, Australia) asked 'Is modelling population dynamics useful for anything other than keeping researchers busy?' This proved to be an omnibus presentation that addressed issues of how to better choose agents. Accepting that modelling is time- and funding-hungry, she reviewed models of varying complexity to support her argument that modelling work can answer questions about the biocontrol process that would be difficult to resolve any other way.

Peter McEvoy (Oregon State University, USA) *et al.* described research on cinnabar moth (*Tyria jacobaeae*) on ragwort (*Senecio jacobaeae*) in North America. This striking, once-iconic agent has fallen

from grace as other agents appear more effective, it has been found to attack non-targets, and it carries a host-specific *Nosema* microsporidian disease. Conventional biocontrol theory predicts that host shifts might happen if fitness is higher on novel compared with traditional host plants. However, McEvoy *et al.* conducted a complex tritrophic study of the moth, a new host and the disease using experimental and modelling methods, from which they concluded that the net result of the interactions is likely to be a reduction in the likelihood of host shift through the presence of *Nosema*, thus aiding biological control.

In 'Seed feeders: why do so few work and can we improve our selection decisions?', Rieks van Klinken *et al.* (CSIRO Entomology, Australia) used data from field assessment and modelling of the seed-feeding bruchid *Pentobruchus germaini* on *Parkinsonia aculeata* to explore these questions. In particular, their modelling work led them to conclude that seed-feeding insects can reduce invasion rate and so should be introduced early.

A presentation by Harry Evans (CABI), 'The endophyte release hypothesis: implications for classical biological control and plant invasions', discussed possible effects of symbiotic endophytes on the success of biological control. Fungal endophytes are asymptomatic colonizers of higher plants. Evans portrayed the relationship of endophytes and their plant hosts as mutually beneficial: the endophytes provide extra defences against pests and diseases, but set against the reduced natural enemy pressure is a trade-off in terms of reduced growth because the endophytes sequester host nutrients. While the natural enemy release hypothesis has long been used to explain the success of introduced exotic plants in outcompeting native species, Evans suggested that the absence of co-evolved endophytes is a cryptic, additional significant factor that, in the absence of natural enemies, increases the fitness of exotic plants compared with native species.

The keynote address in the section, 'Benefit-risk – cost analyses' was by Rachel McFadyen (Weeds CRC, Australia). In 'Return on investment: determining the economic impact of biocontrol programmes' she reported that the annual return on investment in weed control in Australia is a staggering A\$95.3 million from an annual investment of A\$4.3 million per annum. She also gave a stark warning about the need for biologists to seek advice from economists at all stages in a biocontrol programme.

A presentation by Quentin Paynter *et al.* (Landcare Research, New Zealand) on 'New biological control agents for *Cytisus scoparius* (Scotch broom) in New Zealand: dealing with the birds and the bees and predicted non-target attack to a fodder crop', gave them an opportunity to describe how they addressed several conflicts of interests raised by the prospect of introducing two new biological control agents against this highly detrimental weed. The conflicts arose because: (a) on the one hand, beekeepers rely on the weed's flowers, and on the other, bee pollination contributes to increased weed risk, (b) broom pods are seasonally important for an endemic pigeon, and (c) the new agents may attack a non-native but useful

fodder crop, tagasaste (tree lucerne) which is used to stabilize soil in marginal hill areas. Nevertheless, their benefit-cost analysis and ecological studies paved the way for the new agents to be released, indicating that good science can overcome objections.

Theoretical and experimental evidence of host specificity often do not convince the 'what if' brigade. In 'Novel approaches for risk assessment: feasibility studies on temporary reversible releases of biocontrol agents', Jim Cuda (University of Florida, USA) *et al.* explored novel approaches to host range testing, particularly using F₁ sterility from sterile male technique which allows field testing in the exotic range without risk. They used natural enemies of the Brazilian peppertree (*Schinus terebinthifolius*) to illustrate this interesting and attractive approach. Nonetheless, it has yet to be tested, or even permission obtained to try it. It is also technologically involved and very expensive – perhaps a high-profile, highly damaging pest will provide an opportunity to test the system.

In the 'Target and agent selection' section, Ronny Groenteman (University of Canterbury, New Zealand) *et al.* asked, 'Which species of the thistle biocontrol agent *Trichosiromia* are present in New Zealand? The story behind this is that New Zealand biocontrol scientists sent *T. horridus* (an agent previously introduced to New Zealand for control of nodding thistle, *Carduus nutans*) to Australia in 2002. But a revision of the species since then has redescribed *T. horridus* as three species (*T. horridus*, *T. mortadello* and *T. briesei*) with different host ranges (*Cirsium*, *Carduus* and *Onopordum*, respectively). Examination of field-collected material has revealed two paradoxes: all the Australian material has been identified as *T. mortadello* (from New Zealand), but so far all adults collected in New Zealand, from both *Cirsium vulgare* and *Carduus nutans*, have proved to be *T. horridus*. Further collections from a range of thistle species and sites are planned to clarify what is present in New Zealand – and we look forward to the next instalment of the story.

A second look at ragwort (*Senecio jacobaea*) biocontrol came in the section 'Pre-release specificity and efficacy testing'. Urs Schaffner (CABI) *et al.* addressed the difficulties of selecting representative test plant species, especially in a species-rich genus such as *Senecio*, for their paper, 'Host-use by the biological control agent *Longitarsus jacobaeae* amongst closely related plant species?' Previously found to be monophagous in the field, a range of tests of a cold-adapted Swiss strain of *L. jacobaeae* on a large number of European and American *Senecio* species threw up some surprising results, which they discussed in relation to phylogeny, secondary plant metabolites and physiology of the test plant species.

In the session, 'Regulation and public awareness', Lynley Hayes *et al.* (Landcare Research) discussed, 'Avoiding tears before bedtime: how biocontrol researchers could undertake better dialogue with their communities'. They highlighted how disagreement between parties who view biocontrol as safe and those who do not, together with the lack of agreement about what constitutes a weed, could

jeopardize attempts to implement biocontrol unless effective communication with communities is established. They described a technique for encouraging dialogue, with the emphasis on both expressing opinions and concerns *and* listening to improve understanding, in an environment where all parties are treated as equal as a way of resolving conflicts. They used their experience of the process to identify key messages about weed biocontrol and how better public acceptance could be gained by doing things differently.

An entire session with five oral presentations was devoted to 'Opportunities and constraints for biological control of weeds in Europe'. Through this session in particular it was hoped to attract delegates from outside the scientific community, i.e. from government, NGOs and industry, although this did not really happen. As yet there have been no classical introductions to Europe and the joint keynote address by Maurizio Vurro (Istituto di Scienze delle Produzioni Alimentari, Bari, Italy) and Harry Evans gave a comprehensive overview of the current status of the classical and inundative approach in biological control with respect to its uptake in Europe. Major constraints for the implementation of classical biological control they highlighted included legislative and bureaucratic hurdles as well as identifying suitable funding sources. In the inundative field, by contrast, the obstacles are very much technological and commercial. Two of the presentations in this session covered classical biological control: one addressed experiences of implementing classical biological control in European overseas territories (Thomas Le Bourgeois [CIRAD, Reunion] *et al.*), i.e. against *Rubus alceifolius* and *Ligustrum robustum* subsp. *walkeri* in Reunion and *Miconia calvescens* in Tahiti, while a striking presentation on Japanese knotweed (*Fallopia japonica*) by Djami Djeddour (CABI) *et al.* examined its potential for becoming the first target for a classical release in Europe. After sustained media coverage of the Japanese knotweed problem in the UK, a biocontrol programme which began in 2003 is nearing its conclusion with the psyllid, *Aphalara itadori* and a leaf spot, *Mycosphaerella* sp., emerging as the best candidates. The other two presentations discussed strategies for use of augmentation – the enhancement of the populations of natural enemies already present – to target alien weeds, such as *Euphorbia esula* in France (René Sforza [USDA-EBCL] *et al.*), as well as native weeds, i.e. *Rumex* species (Paul Hatcher [University of Reading, UK] *et al.*). The *Euphorbia* project has focused on the recent spread of *E. esula* subsp. *esula* in ecologically important water meadows in France's Saône Valley, and Sforza *et al.* examined the potential for augmentative use of a cerambycid beetle. In northern Europe, lack of effective control measures for *Rumex* infestations of grassland is often cited by farmers as a reason for not converting to organic agriculture. Hatcher *et al.* discussed research in English, Norwegian and Swiss farming systems on integrated non-chemical approaches, including augmentative or inundative releases of a chrysomelid beetle, for management of the weed.

In the session, 'Release activities and post-release evaluations', Simon Fowler (Landcare Research) *et*

al. began with a keynote address asking, 'Release strategies in weed biocontrol: how well are we doing and is there room for improvement?' Their presentation was a call for a more rigorous approach, pointing out how much could be learned if – especially initial – releases were treated as opportune experiments, which would allow predictions from ecological theory and retrospective studies to be tested. They considered key problems and identified areas where an experimental approach might be profitable, and concluded that the 'commendable' improvements seen in establishment success are at least in part due to better release methods, but there may indeed be more room for improvement.

There were then two 'good news' stories in this session, both of which have featured in the *BNI* new pages before, but bear repeating. In 'Benefits to New Zealand's native flora from the successful biological control of mistflower (*Ageratina riparia*)', Jane Barton (consultant, New Zealand) and Simon Fowler described how the impacts of introducing a white smut fungus (*Entyloma ageratinae*) and then a gall fly (*Procecidochares alani*) were carefully documented over the five years after the fungus was released. Gratifyingly, this exemplary post-release programme has been rewarded with successful control of the weed [see: *BNI* 28(2) (June 2007), 27N–30N, 'Native flora emerges a winner as mist flower clears']. Then in 'Beginning success of biological control of saltcedars (*Tamarix* spp.)' Jack DeLoach (USDA – Agricultural Research Service [ARS]) and nine co-authors from nine different US institutions (which testifies to the extensive cooperation in this programme) told of patience and diligence rewarded, by outlining the successes of this programme (together with research still needed). The first releases had led to establishment and initial control of saltcedar by the Asian leaf beetle, *Diorhabda* sp., at northern sites. Releases further south had failed, but subsequent releases of beetles from Old World sites matched for geography and climate have led to extensive spread and defoliation in many release areas [also see: *BNI* 26(2) (June 2005), 41N–44N, 'Saltcedar biocontrol: a success story in the making' by Tom Dudley].

Conference Workshops

Six workshops, in addition to the VII International Bioherbicide Group Workshop (see below) were organized before the symposium began, and another was squeezed in. We give brief notes about some of these, and hope to include more about all the topics in future issues.

- Brassicacea weeds: chaired by Harriet Hinz (CABI) and Mark Schwarzländer (University of Idaho, USA), discussed whether invasive brassicas are good targets for biocontrol in North America considering the large number of native and important economic species.
- Risk assessment: chaired by Ernest Delfosse (USDA-ARS).
- Aquatic weeds: chaired by Mike Grodowitz (US Army Engineer Research and Development Center).

- *Ambrosia* weeds: chaired by Dominique Coutinot (USDA-EBCL), considered the potential for biological control of *Ambrosia artemisiifolia* in Europe, also including presentations about biological control of ragweed in Australia by Rachel McFadyen and in Russia by Mark Volkovitsh (Zoological Institute, St Petersburg), together with an interesting discussion on a rust associated with *Ambrosia* in the USA.
- Rearing insects: chaired by Harriet Hinz and Rosemarie DeClerck-Floate (Agriculture and Agri-Food Canada), concluded that rearing issues can be a significant obstacle during a biocontrol programme, but that these are often underrated and rearing methods are difficult to publish. Alec McClay (McClay Ecoscience, Canada) volunteered to establish a website where weed biocontrol practitioners can exchange information on rearing issues.
- Swallow-worts (*Vincetoxicum* spp.): chaired by Lindsey Milbrath (USDA-ARS) considered the development of a biological control programme in North America and heard research updates.
- Japanese knotweed: Dick Shaw (CABI) and Fritz Grevstad (University of Washington, USA) squeezed in an impromptu workshop attended by people from both sides of the Atlantic. The goal of consortium funding for North America was presented and Linda Wilson from the University of Idaho agreed to become a nodal point.

VII IBG Workshop

The VII International Bioherbicide Group Workshop was held, in conjunction with the main conference, on 22 April 2007.

The workshop, which constitutes the forum of the International Bioherbicide Group (IBG), was organized by Geoff Hurrell and Graeme Bourdôt (AgResearch, New Zealand) and Jane Barton. The meeting was attended by 45 participants from around 18 countries. There were 13 talks dealing with new aspects in research and implementation of the bioherbicide approach for control of invasive weeds.

Application was given appropriate prominence, including two presentations by Raghavan Charudattan (University of Florida, USA) on scale-up and commercial production, and substrates for solid-state production, and one given by Maurizio Vurro on drip irrigation. Vurro also talked about sophisticated molecular methods for tracking biocontrol agents in the field. The challenges of finding virulent pathogens were highlighted by Nick Waipara (Landcare Research). Alan Wood described a clever and inexpensive method for applying bioherbicide to acacias. The wide range of target weeds covered in the various presentations also included giant buttercup (*Ranunculus acris*), nutsedges (*Cyperus* spp.), barberry (*Berberis* spp.), old man's beard (*Clematis vitalba*), gorse (*Ulex europaeus*), waterweeds in the

form of alligatorweed (*Alternanthera philoxeroides*), and parasitic weeds such as broomrape (*Orobancha* spp.) and *Striga* spp.

Presentations were followed by a general discussion on the future of bioherbicides. Bioherbicide development appears to be at a crossroads. Despite enthusiasm evident at the meeting, success stories are few, and funding for the development appears to be in decline. Participants also discussed how the IBG group can get more publicity and attract new members and how the IBG newsletter can best be revived; *IBG News*, which is produced on a voluntary basis, has not been published recently because of a dearth of articles from IBG members.

There was a focus on going back to basics in this field, addressing fundamental technical and registration issues, in order to move forward in a field not progressing perhaps as fast as would have been expected from its early days. With respect to publicity it was generally felt to be a good strategy to attach the working group meetings to a variety of international meetings:

- The next IGB Workshop will be held in conjunction with the conference of the Weed Science Society of America in Orlando, Florida in February 2009. For information on this, contact: Joseph Neal (joe_neal@ncsu.edu).
- A session on biological control of weeds is also planned for the IPPC (International Plant Protection Convention) meeting in Turin, Italy in August 2008. The organizer and contact for this session is Bill Bruckart (William.bruckart@fdwsr.ars.usda.gov).

And Finally

The Proceedings of the XII ISBCW will be published by CABI who are also abstracting the previous two proceedings as this issue goes to press.

This is a convenient point to highlight CABI's commitment to provide the widest possible coverage of the world's scientific literature on its CAB Abstracts database. So if you have proceedings or other useful 'grey' literature gathering dust on your shelves, please contact us (bni@cabi.org).

- The XIII ISBCW will be held in Hawaii, at a date yet to be fixed. The convenor will be:

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This report was compiled with the help of the BNI Editorial Board and CABI conference participants.