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General News

The Dilemma of Prosopis: Is There a Rose Between the Thorns?

The genus *Prosopis* contains species with outstandingly useful qualities: they grow in arid and semi-arid zones and give high yields where little else will grow. They produce high-quality wood for fuel and timber, seeds with varied uses as human and animal food, and other non-wood products. Species from the New World have been introduced into Africa, Asia and Australia over the last 200 years. In some countries, however, introduced *Prosopis* has become a highly invasive weed, covering large tracts of land with impenetrable thorny thickets and rendering it unusable. It can even be invasive in its area of origin in the New World. As affected countries devote increasing amounts of time and money to controlling infestations that encroach on vital land resources, with limited success, is it right to continue to promote the use of *Prosopis*? Or does integrated management and improved germplasm, arising from better understanding of the taxonomy of the genus, provide expanding opportunities for a much-needed resource in impoverished and marginal lands?

The dilemma is accentuated by the confusion about exactly what genetic material is present in the various parts of the world, because different species have very different properties in terms of utility and invasive potential. The first article describes how conventional and molecular taxonomic approaches are beginning to unravel the identity of various populations of *Prosopis*. However, this will not provide all the answers as species tend to hybridize, and invasive populations in some countries behave very differently from the parent stock. This is highlighted in the second article, which describes how a study of Australia's largest *Prosopis* infestation found that important invasive characteristics were accentuated in this hybrid population.

Biological control is a popular choice against invasive plants in environments where the extent of the invasion, and lack of resources and infrastructure make other approaches impractical or uneconomic. Many *Prosopis* invasions fall into this category, courtesy of their spread in marginal, sparsely populated, remote areas. The third article sounds a note of caution for biological control in the Old World, pointing to the need for protecting increasingly rare native *Prosopis* species that are key local resource trees. The fourth article describes a biocontrol initiative on Ascension Island, but sounds another note of caution about the limitations of agents deployed so far. The fifth article argues that biological control has not and will not provide a solution to managing *Prosopis*, and, pointing to the many uses of *Prosopis* in the New World, calls for utilization to be given a more prominent role in integrated management strategies.

The last article, from South Africa, evaluates the status of *Prosopis* in that country and the conflicts of interest it has created. It addresses many of the questions raised in the articles above, discussing from South Africa's position of experience the limitations of and possibilities for both utilization and control, including biological control – also considering in this context its obligations as part of the African continental community.

These articles are followed by a tribute to Daniel Gandolfo, who died in January 2006. He worked on many weed projects for different cooperators, but his inputs into *Prosopis* biocontrol research will be with us forever as a result of the fact that David Kissinger named the seed-feeding weevil on which Daniel worked (see South African article, below) *Coelocephalapion gandolfoi*.

Implications of Uncertain Prosopis Taxonomy for Biocontrol

Prosopis species are notorious for being difficult to identify: there are so many similar species, with varieties and other subspecific designations just adding to the confusion. To this, add highly variable phenology, frequent hybridization, and changing nomenclature, and the picture becomes cloudier still. In this taxonomic fog, scientists have been host-testing a range of insects on several *Prosopis* 'species', and genus-specific agents have been approved for release (with potential implications for native Old World species, see 'Safeguarding valued Old World native *Prosopis* species from biocontrol introductions', this issue).

Taxonomists can tell the difference between species by looking carefully at the flowers and leaves, and scientists have accurately identified them by assessing their DNA, enzymes or other molecular features. However, the problem in the field remained that in many regions it was impossible for people to find out what species they had. Common confusions existed between *P. glandulosa*, *P. velutina* and *P. juliflora*, *P. chilensis* and *P. juliflora*, and *P. pallida* and *P. juliflora*, all hopefully resolved since the publication of *Identifying tropical* Prosopis *species: a field guide* in 2004 (see Bibliography, below). This arose from on-going work in the UK at Coventry University, looking specifically at the confusion between *P. juliflora* and *P. pallida*, involving the analysis of thousands of leaf samples from herbaria and sent in from around the world for identification. This study took as its starting point the use of molecular markers to confirm *P. juliflora* and *P. pallida* as distinct, closely related species. Also revealed was the fact that *P. juliflora* is a tetraploid species while *P. pallida* is diploid. With the support of ploidy and the molecular studies, it has proved possible to develop simple identification keys based on foliar characters.

To date, the authors have positively identified the presence of either or both species in 28 countries. An important finding has been that the 'common' *Prosopis* in northeast Brazil, Cape Verde and Senegal is actually *P. pallida* and not *P. juliflora* as generally thought. Also, the recent identification of *P. pallida* in Kenya, Mauritania and India suggests that it is more widely distributed than previously considered. This is especially significant considering that it is not only less invasive than *P. juliflora* but also one of the most highly valued members of the genus, with much sweeter pods, a more erect form and generally fewer thorns. If efforts are to be made to increase the utilization of *Prosopis* where introduced (see other articles on *Prosopis* in this issue), *P. pallida* could prove very useful, though not if permanently harmed by a biocontrol agent intended for its invasive and much more common relative, *P. juliflora*.

The confirmation that this useful *Prosopis* species is more widespread than previously thought adds weight to the argument for restricting classical biocontrol introductions to species-specific agents. Nonetheless, it may be that where very closely related species have been identified and all are targets for control, agents proven to be specific to the group of species or 'species complex' could be considered. This may be appropriate for *P. glandulosa*, *P. velutina* and their hybrids for example. However, *P. juliflora* and *P. pallida*, though morphologically similar and easily confused, have very different attributes in terms of invasiveness/utility. Clearly any intended biocontrol agent for use in Africa and Asia must be shown to be specific to *P. juliflora* and not to attack *P. pallida*; however, in Australia both are invasive weeds.

What may prove important is that the invasive *P. juliflora* appears to be entirely tetraploid, whereas the productive and potentially beneficial *P. pallida* is, in common with all other *Prosopis* species, entirely diploid. Resolution of the taxonomy of introduced *Prosopis* in Africa and Asia is on-going but far from complete, and further detailed surveys and analyses are still required. Until these are complete, classical biocontrol agent testing and introduction should proceed with caution.

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Prosopis in Australia: the Perils of Letting the Genie out of the Lamp

Unlike many invasive alien plants, *Prosopis* (mesquite) also causes serious problems in its native range, in the New World, where it is highly invasive. After studying the largest *Prosopis* population in Australia[1], we believe that invasions in the tree's introduced range may be even worse, and even more difficult to manage, than those in its area of origin. This has important implications for its promotion as a multi-purpose plant through tropical parts of the world.

A fire tolerant *Prosopis* hybrid (probably *P. velutina* × *P. glandulosa* var. *glandulosa* × *P. pallida*) was introduced to the semi-arid Pilbara region of Western Australia in the 1930s as a drought fodder plant and as shade for livestock[2]. The natural vegetation comprises hummock grassland and eucalypt-dominated drainage channels. *Prosopis* now infests about 150,000 ha of the region, including some 30,000 ha covered with extensive dense stands. The insect fauna on *Prosopis* in Australia is impoverished, although an exotic leaf-tying gelechiid moth (*Evippe* sp. #1 from Argentina) released in 1998 is causing heavy, prolonged defoliation. In contrast some 945 arthropod species have been recorded on *Prosopis* spp. in the New World, including species causing seedling mortality. In addition, although mammal browsing potentially causes seedling mortality in the New World, there is no evidence that it does so in Australia.

In an effort to understand its invasiveness in Australia, we determined the relationship between *Prosopis* density, canopy cover and plant size, and between *Prosopis* cover and other flora. We used the results to test whether the ecology of the population in the Pilbara is comparable with invasive populations of *Prosopis* in its native range. This is what we found:

- *Prosopis* can be even more invasive, and reach greater (typically 10-fold higher) densities in the Pilbara than observed in its native range. The maximum density recorded was 36,125 plants per hectare in one replicate. In its native range it rarely has the closed canopies that are a common feature of the Pilbara population.
- Irrespective of the level of canopy cover, seedling and juvenile *Prosopis* plants formed a sizeable sapling bank under adult plants. Saplings appeared to be in a quiescent state, meaning that canopy trees controlled by herbicides or chaining may be quickly replaced by saplings. The phenomenon of sapling banks under adult *Prosopis* plants has not been observed in the New World.
- Native shrubs, on the other hand, were rarely recorded under *Prosopis* canopies. This contrasts with the situation in the New World where mature *Prosopis* trees act as nurse plants for native woody species.
- In addition, the perennial herbaceous (grass) layer was almost completely absent under dense *Prosopis*. In its home range, *Prosopis* has varied impacts, sometimes negative, on the herbaceous plants but biodiversity and biomass remain relatively high.

The study period fell during a prolonged drought, and *Prosopis* had already been extensively defoliated for several years by the introduced leaf-tier. Nonetheless, dead *Prosopis* plants were rare, substantiating the view that, less than 80 years since its introduction, the *Prosopis* invasion is still in its early stages. Thus the impact of *Prosopis* in the Pilbara looks set to increase. This, coupled with its almost complete exclusion of herbs, grasses and native shrubs, suggests the future is grim in the absence of effective intervention.

There are currently no cost-effective means to manage extensive, dense *Prosopis* invasions, particularly of multi-stemmed, fire tolerant varieties such as the one invading the Pilbara. Control is largely limited to cultivation (digging up plants to a depth of 30 cm) and very intense fire. Cultivation can be very expensive, and may require large machinery. The use of hot fires is often limited by limited fuel in semi-arid and arid environments (although if it can be carried out, it does help reduce the seed bank). The introduced leaf-tying moth is proving to be able to reduce substantially growth and seed production of *Prosopis* in the Pilbara. In the long-term it may reduce *Prosopis* invasiveness and enhance the effectiveness of other control options. Research is currently underway in Australia to improve integrated management techniques through an improved understanding of *Prosopis* ecology, and by combining fire, mechanical, herbicide and biological control techniques. However, besides prevention, and in the absence of further effective biological control agents, any effective management strategy is expected to be both costly and long-term.

Increasing invasions and impacts can be anticipated from the large-scale plantings conducted in Africa and Asia as well as Australia during the twentieth century. The lack of feasible means for managing *Prosopis* populations needs to be addressed, and that lack, together with the high invasibility and impact of *Prosopis* need to be considered explicitly when promoting *Prosopis* as a beneficial plant and before its intentional introduction into new areas.

Where *Prosopis* invasions do occur, management strategies need to be developed and implemented to eradicate, contain and/or manage them. A best practice management guide has been developed for Australia[3] and is available on:
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Safeguarding Valued Old World Native Prosopis Species from Biocontrol Introductions

Whereas much is written on the evils of invasive *Prosopis* introduced from the Americas, those involved in biocontrol may be less aware of the existence of, and reverence given to, two native Old World *Prosopis* species. These are not at all invasive, in fact rather the reverse, being over-exploited and becoming increasingly rare.

- *P. africana* is a highly revered tree from the African Guinea savanna. Its seeds are fermented to make a traditional food, its leaves and pods are used as animal feed, and its very hard timber has special uses[1]. ICRAF (the World Agroforestry Centre) has carried out a range-wide seed collection, and noted that "*P. africana*, one of the most valuable agroforestry tree species in the region, is seriously threatened by the increased need for tree products and for land, for both grazing and for cropping". Thus any further threat to regeneration of this valuable tree should be avoided.
- *P. cineraria* is another very valuable species in agroforestry systems from Yemen to India. The sweet pods, known as khejri in India, are an important part of the local diet, its leaves are an essential dry season fodder, and yields of millet, sorghum or

other crops are increased below the canopy of the trees[1].

It is not certain which of the biocontrol agents already released in South Africa have been tested on *P. africana* and *P. cineraria*. Whereas neither of these *Prosopis* species are present in southern Africa, introduced *Prosopis* which these agents are known to attack are found in every country from Durban to Delhi and Dakar, with no significant natural barriers to prevent eventual spread. It is not known whether these Old World natives would be affected by the introduced American seed feeding bruchids, but these beetles are a particular source of concern as the native African species have much lower seed production than the introduced *Prosopis* species, so regeneration would be severely reduced by any additional seed feeding, and fewer seeds would also affect local animal and crop production and ultimately human nutrition. Other non-bruchid insects proposed for biological control, such as twig girdlers, would only marginally reduce seed production but by severing branches would lead to more bushy *Prosopis*, restricting their use as timber.

Biocontrol introductions are being considered for Kenya and for Ethiopia, as part of projects that include the FAO (UN Food and Agriculture Organization) and CABI amongst participants. This article carries two important messages:

1. It is clear that, given the relative proximity of populations of *P. africana* and *P. cineraria* to the invasive *Prosopis* populations targeted by these initiatives, both native species *must* be included in host-range testing, and any effects on them should be grounds for immediate rejection of the natural enemy concerned as a candidate for introduction.

2. It is also important to recognize that any introduction would not just be into Kenya, or Ethiopia, but into the contiguous distribution of *P. juliflora* and other invasive New World *Prosopis* species throughout Africa and Asia. Negative effects such as plant death, altered growth habit or reduced pod production may be desirable in East Africa, but may in other regions eventually cause fuel wood crises or malnutrition, decrease timber production or affect livelihoods in other ways, and permanently impede any future efforts to secure 'control through utilization' (see Limits to *Prosopis* biocontrol: utilization and traditional knowledge could fill the gap, this issue).

Prosopis are weeds to some but very valuable to others[2], and the risks are high when considering decisions that would affect such species in perpetuity. Thus, before any agents are released in Sahelian Africa, it would be prudent to conduct environmental and socio-economic assessments including participants from other African countries, but also those as far away as the Middle East and South Asia.

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Biological Control of Prosopis on Ascension Island

Situated in the mid-Atlantic, 1200 km from its nearest neighbour, Ascension Island is one of the smallest and most remote of the UK's Overseas Territories. Extending to less than 100 km^2, its barren basalt lava fields and cinder cones reflect its volcanic origins and relatively recent formation, approximately one million years ago. The southern Green Mountain hills rise to 860 m above sea level, and once supported the island's only dense vegetation, dominated by indigenous ferns. This simple but unique plant community has now been replaced by a woodland of introduced species[1], most of which show little tendency to spread beyond the relatively cool, moist hills. One introduced species, however, is creeping across the naturally barren, arid, low-lying plains below.

Prosopis (probably *P. juliflora*) appears to have been accidentally introduced onto Ascension Island in the 1970s or 1980s. Dense thickets of trees up to 15 m tall have formed in some places, as the plant has spread across 75% of the island. On Ascension, the spread of *Prosopis* is assisted by the local population of feral donkeys, which distribute the seeds in their droppings, having fed on the seed pods. As well as causing serious amenity problems, the plant represents a significant threat to local biodiversity[2]. Further spread, for example, could impact on sites where the endemic spurge *Euphorbia origanoides* occurs. Although Ascension supports relatively few indigenous species, a large proportion is endemic, and the island is an important breeding station for seabirds and green turtles; the barren landscape itself represents a rare set of natural habitats and geological features[3].

Given the extent of spread of *Prosopis* by the mid 1990s, chemical and mechanical control methods were considered impractical, except in critical areas like key seabird and turtle nesting sites. Drawing on biological control programmes using *Algarobius prosopis* and *Neltumius arizonensis* against *Prosopis* in South Africa, CAB International introduced these seed-feeding bruchid beetles to Ascension in 1997[4]. A local programme of rearing for on-going releases was established, but this was abandoned shortly afterwards. Beetles were found attacking seed-work acacia *Leucaena leucocephala,* leading to suggestions that *Neltumius* and/or *Algarobius* had shifted to a nontarget species. It was subsequently shown that the damage to the acacia was caused by *Acanthoscelides suramerica*, an accidental introduction unrelated to the biological control programme[5].

Paucity of data hampers a detailed assessment of the status and impacts on *Prosopis* of the control agents introduced to Ascension. Initial observations suggested that both species had become established. However, subsequent work suggests that *Neltumius* may have since died out, although *Algarobius* appears to have spread through most of the Ascension range of the host plant, and can approximately halve its seed output[5]. Although the rate of spread of *Prosopis* appears to have slowed, this may simply reflect the fact that most accessible sites have now been colonized by the plant.

Recent efforts to control invasive species on Ascension have concentrated on the eradication of feral cats, and measures to control rat numbers. These activities appear to have been successful, and long absent species of seabird are returning to nest on the island now that their main predators have been removed[6]. *Prosopis* remains a priority for control, although some islanders see the 'greening' of the island in a positive light. There is also some reluctance locally to pursue biological control, in particular, as a solution. This partly reflects lingering concerns over nontarget effects arising from the discovery of *Acanthoscelides* on acacia, as well as the lack of any spectacular impact of the introduced bruchids on *Prosopis*. As seed feeders, however, they could never have been expected to eliminate existing plants from the landscape, and Fowler[4] recognised that further measures would be required to effect such a level of control. The solution to the invasion of Ascension Island by *Prosopis* may lie in an integrated control programme, in which biological control has a potentially important role to play.

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Limits to Prosopis Biocontrol: Utilization and Traditional Knowledge Could Fill the Gap

There have been significant advances in the biocontrol of *Prosopis*, though without the major successes observed with some other invasive plant species. Of the biocontrol agents released against *Prosopis* species, they have at worst had no effect and at best caused measurable damage without ever containing infestations on their own. These introductions have been made almost entirely in Australia and South Africa (see other articles in this issue), but in both countries it is apparent that biocontrol alone will never be the answer and other strategies must be considered. Australia is looking mainly at destructive methods: spraying, burning, bulldozing, etc., to complement existing and future biocontrol introductions, with some progress in integrated programmes. In contrast, South Africa, like Ethiopia, Kenya, Sudan, India and Yemen amongst others, is considering more constructive options, such as promoting *Prosopis* utilization and trying to make 'market forces' benefit the environment and the world's poor.

It is worth reflecting on the failure of almost a century's attempts at eradicating *P. glandulosa* from Texas rangelands, where a suite of natural enemies have always been abundant (it is in fact a 'native invasive species'). It appears high time to accept that wherever *Prosopis* is now, it is there for perpetuity, whatever insects or fungi are introduced from the native range. So why spend more millions of dollars on further biocontrol research when all indicators suggest little likelihood of success? Also, why try to destroy a tree that, though invasive, is clearly supporting the livelihoods of millions of poor people throughout Africa and Asia. A *Prosopis* control programme in Gujarat, India using bulldozers to uproot trees was halted by farmers, saying, "then where are we going to get the wood to cook the family dinner?".

'Control by utilization' is a concept that is gaining ground as a means to control existing *Prosopis* infestations, and limit further spread, while also improving the well-being of rural people presently threatened by invasion. In parts of the native American range, *Prosopis* species are highly valued, with archaeological records showing their use as a food and for timber that go back over 5000 years. Such indigenous knowledge has developed, until today there is a range of food and drinks made from the pods, and furniture and flooring industries based on the wood from Mexico through Peru to Argentina. Herbal medicines, honey, gums, tannins and fibres are also among other products obtained from *Prosopis*. The tree has been widely introduced, but this knowledge has not followed. Common names reflect this, with names such as 'the bark that tans', 'good wood' and 'local maize' where it is native, but 'bastard thorn', 'mad thorn' and 'foreign thorn' where it has been introduced.

It was introduced as a fuel and fodder tree, and whereas these uses help sustain livelihoods they will rarely improve it and are not the things a gold rush is made of. The pods are the main target for biocontrol, with agents sought that destroy the seeds and prevent spread. Yet private entrepreneurs in the introduced range, as far apart as Brazil and India, independently developed pod processing facilities many years ago without external financial support. Local people earn money per sack of pods they collect and the mill owner earns profits from the sale of the high quality animal feed produced. Small pod grinders are also being promoted in Africa and Asia, ensuring that the protein in the seeds is made available for digestion and not for germination. There is enormous scope for expanding such initiatives, possibly through making credit or subsidies available, especially considering the need for animal fodder in regions where *Prosopis* is invasive. In its native range, pods are also used to make flour for cakes, biscuits and stews, and sweet syrups and other drinks; these are commercialized in well-developed national markets and there is even some international trade. Where *Prosopis* has been introduced, the pods are not consumed at all, and promoting their use must surely have nutritional benefits especially in famine-prone regions. In addition, galactomannan gums for food processing can be extracted from the seeds, and other industrial uses of the pods are developing.

If using the pods will prevent further spread, what to do with the infestations already present? It is suggested (see publication source below) that if the high density stands are thinned to 200–400 trees per hectare, the sale of wood products can more than offset the cost of the operation. Processing the wood into charcoal or wood chips increases its value substantially, as does selecting branches for sale as posts or poles, with maximum revenue to be gained by sawing trunks and the largest branches into timber. The wood has excellent physical qualities, and its value for furniture, flooring and sculpting is becoming increasing well known in its introduced range, and markets are developing. The remaining trees should be high pruned, and will form the tree component of sustainable agroforestry systems, providing a range of high value products even during the driest years. Specific training courses on the management and utilization of *Prosopis* have been run in India and others are organized for Kenya, and an increasing range of literature is available to support such programmes (e.g. see hdra.org.uk/international_programme/ip_publications.htm).

Such transfers of traditional knowledge also show potential to control a range of other alien invasive species. That they are not invasive in their native ranges may be due in part to the presence of natural enemies, but is also likely to be influenced either directly by local use of plant parts or indirectly by land-use practices that limit recruitment. It thus appears essential that a search for potential biocontrol agents within a plant's native range also be accompanied with a search for detailed indigenous knowledge on uses of the plant and its management.

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A South African Perspective on Prosopis

Background to the Prosopis Problem in South Africa

Several *Prosopis* (mesquite) species were intentionally introduced into South Africa from North and South America from the late 1880s, to provide shade, fuel wood, and fodder from the nutritious seedpods. The campaign gained particular momentum during the first half of the last century when government agencies encouraged landowners to plant *Prosopis* woodlots on a large scale. As a result of these endeavours, six taxa are currently recognized in South Africa, namely, *P. pubescens*, *P. juliflora, P. chilensis*, *P. glandulosa* var. *glandulosa*, *P. glandulosa* var. *torreyana*, and *P. velutina*. Of the introduced species, *P. pubescens, P. glandulosa* var. *glandulosa* and *P. chilensis* (the only species in South Africa of South American origin) appear to be minimally invasive and therefore of little concern. *Prosopis velutina* and *P. glandulosa* var. *torreyana* were by far the most common seeds and seedlings provided to landowners because these two species are more suited to the semi-arid conditions in the north-western Cape. All of the introduced species have readily hybridized in South Africa and it is difficult, if not impossible, to apportion names to the plants which now collectively make up the invasive 'swarms'. The hybrids may be displaying 'hybrid vigour' and appear to be far more invasive than their parent species.

More than 1.8 million hectares (equivalent to 173,000 ha at 100% canopy cover) of land is invaded, mainly in the Northern Cape Province and, to a lesser extent, in the provinces of the North-West, the Free State and the Western Cape. An analysis of the rate of spread of the plants gave an exponent of 18% per annum, which is equivalent to a doubling in area about every 5 years. The transition from open stands to dense stands was estimated to take 10–24 years. This rate of invasion is considerably less than that recorded from more tropical regions, including Kenya and Ethiopia. The difference may be linked to seedling recruitment rates because in arid areas, germination and seedling survival is sporadic and dependent on sustained, above-average rainfall events.

In areas where plants are particularly abundant, dense and impenetrable thickets form which provide very little shade and few pods. Invaded areas become unusable for livestock production and the problem is especially acute because invasions predominantly occur on low-lying land which is agriculturally four times more productive than adjoining uplands. Another major problem is the use of copious amounts of scarce underground water by prosopis. Dense stands of prosopis are estimated to use 192 million cubic metres of water annually, the equivalent of about 1100 mm of rainfall per year and almost four times the annual average of the Northern Cape Province. This could threaten many of the economic activities in the arid parts of South Africa that rely largely or completely on underground water as well as the provision of water for human demands, including the 'basic human need' as required in terms of the National Water Act. The lowering of the underground water table in invaded areas is also affecting the continued survival of *Acacia erioloba*, a keystone tree species in the Kalahari desert.

The problems caused by using prosopis as an agroforestry species could possibly have been avoided if only benign species such as *P. pallida* and *P. chilensis* had been introduced. These species have few thorns, produce long stems of usable timber, do not coppice readily and grow far more rapidly, especially in subtropical and tropical regions. Almost certainly there would currently be no problems in many countries if these had been the only species to be introduced and exploited. The introduction of *P. velutina* in particular was a major contributing factor to the creation of problems in South Africa. The choice of *P. velutina* as a suitable species for South Africa can be excused because at the time of introduction (prior to 1930) there were no cases where *Prosopis* species had become problematic and there were no indications that the plants might become invasive. This is not the case now but promoters of agroforestry do not appear to have learned. For example, relatively recent introductions of prosopis into Kenya included *P. pallida* along with several other species. The result is that the other species have become invasive, have hybridized and *P. pallida* is now branded along with the others as unwanted, invasive and troublesome. Interestingly prosopis took only 20 years to become a problem in Kenya whereas in South Africa it took about 60 years! This should be an even greater cautionary warning for the future use of prosopis as an agroforestry species in mesic tropical conditions.

Conflicts of Interest

Supporters of prosopis as a resource argue that the plants are problematic because they are incorrectly managed and under-utilized as a resource. This may be true to some extent, even in South Africa. However, utilization has only been an integral part of most integrated management plans in South Africa since the 1970s, which was too late in terms of the weed having spread far and wide by then. A real deficiency in the agroforestry programme was that there were no contingency plans when things initially started to go wrong and the problem was left for others to deal with. So far all utilization projects and other control methods that have been attempted have not had a noticeable impact on the weed and invasions have continued unabated. Despite the obvious problems, prosopis is still perceived to be a valuable asset by some, which has tempered considerations for a full biological control programme at present.

Another difficulty within the African context is that many of the affected regions are in impoverished countries, which lack the resources needed to manage and control the weed. Under these circumstances biological control and improved utilization are the only affordable and sustainable management tools. Unfortunately any utilization programme has the danger of creating new conflicts of interest that may restrict choices of control methods even further. Any utilization programmes should therefore always become part of the overall integrated management plans and should include all potential stakeholders. This approach was officially adopted for South Africa in November 2001 at a national workshop on the 'Status and Long-term Management of *Prosopis*' held in Kimberley and attended by about 50 people with a wide range of interests in prosopis.

Utilization of Prosopis as Part of a Management Tool

Utilization in South Africa is largely problematic because inappropriate species of prosopis were introduced and promoted. Furthermore, harvesting of pods and timber is impractical because the problem is predominantly in remote, inaccessible and inhospitable (semi-desert) parts of the country where labour shortages and high travel costs are limiting factors. The main constraint, however, is the harvestable material itself. The valuable attributes of prosopis are lost in areas where it forms dense impenetrable thickets or multi-stemmed trees that produce very few pods and useless narrow timber. Utilization efforts have often exacerbated the problem because stumps left after wood harvesting operations are not properly treated with herbicides, resulting in severe coppicing and densification of the plants. This problem is especially prominent where trees have been harvested on communal lands. Some potential uses of prosopis, such as for honey production and as a source of gum, do not damage the plants and will not contribute to reducing the invasiveness of the weed.

Fodder

The high fodder value of the pods is not disputed and much has been published on this subject in South Africa and elsewhere. Pods are a particularly attractive resource in areas where grazing is limited and where droughts are frequent and prolonged. Most of the annual pod yield is utilized by free ranging stock and game, which historically has accounted for much of the spread of seeds and densification of the plants. Many farmers are now cautious of utilizing the pods for stock feed because the threat of further invasions is perceived to be a greater nuisance than the nutritional benefits that may accrue. Very few landowners gather pods for milling and for use as stock feed under controlled conditions, a process that would destroy the seeds and prevent spread. Milling of pods has the further advantage that it ruptures the seeds and increases the protein value of the mix but economic considerations (costs of harvesting and processing) make this an unattractive proposition on the scale that is required.

The only current commercial user of pods is a factory that produces a nutritional supplement for human consumption, but this enterprise harvests only a tiny fraction of the annual pod yield. Pods used for human consumption are collected and milled immediately.

Timber and Fuel Wood

Prosopis is a useful source of timber and there are many successful commercial enterprises in several countries that utilize the high quality wood, mainly for parquet flooring, furniture, tool handles and ornaments. Wood chips are widely used for smoking of processed foods. It is estimated that South Africa has about 600,000 tonnes of prosopis wood available. Several enterprises have been initiated in South Africa, often with public funds, but all have failed because of the unavailability of suitable logs and because of high transport costs. The most recent venture was geared to use trees with a diameter of 15–50 cm but, with 5% or less of trees falling within this size range, the factory switched to processing invasive eucalyptus trees.

Silvicultural treatments, which include pruning the trees to single-stems that could provide usable timber, or grafting benign species onto hybrid root stocks, have failed because of the low success rate and because any pruning always stimulates coppicing. Besides, in order to have any impact, the projects would need to be operational over an area that would be physically impossible to cover.

The charcoal and fuel wood industries have been more successful and many small enterprises have been operating in the Northern Cape utilizing prosopis as a resource. However, distances from the major markets and expensive transport systems have prevented these industries from competing effectively with alternative sources of fuel wood such as invasive Australian wattles. Efforts to harvest and chip the multi-stemmed trees for export to Asia have also been investigated and found to be uneconomical.

Biological Control

The ongoing conflict of interests about prosopis initially restricted biological control to the introduction of host-specific seed-feeding beetles that would reduce the invasiveness of the weed but not affect the nutritional status of its pods. Two bruchid species, *Algarobius prosopis* and *A. bottimeri*, were released in 1987 and 1990 respectively. Of the two only *A. prosopis* established and proliferated in its new environment, rapidly spreading throughout the range of the weed. The larvae of *A. prosopis* feed within fully developed prosopis seeds. These become available to the larvae because adult females predominantly deposit the eggs in fractures that develop in the aging seedpods. Neonate larvae are able to tunnel through the seedpod until reaching a suitable seed, which is then penetrated and devoured from within.

Initial surveys of the damage caused by *A. prosopis* on prosopis seed pods showed that in areas where mammalian herbivores were absent or excluded, the pods were utilized by the beetles for several months until the cumulative damage from several generations of beetles approached 100%. However, in areas where newly fallen seedpods are devoured by domestic livestock and wild animals, a considerable proportion of the seeds pass undamaged through the gut and are redistributed in dung. This apparent weakness in the system initiated a search for other beetle species that might utilize the green, immature pods before they fell from the trees and become available to stock and game. As a result *Neltumius arizonensis* was introduced into quarantine in 1992 and released in 1994 despite the fact that laboratory and field observations showed that the beetles did not lay eggs on immature pods as initially thought.

Although the larvae of both *A. prosopis* and *N. arizonensis* utilize fully developed prosopis seeds, the oviposition behaviour of the adult females is quite different. While eggs of *A. prosopis* are laid on weathered pods, *N. arizonensis* deposits its eggs on the unblemished surfaces of ripe seedpods. Before gluing an egg in place, *N. arizonensis* females meticulously inspect the pod to make sure the enclosed seed is intact and not already occupied by a bruchid larva. This difference in oviposition behaviour indicated that the two species would not compete directly for seeds because *N. arizonensis* would tend to utilize pods that have recently matured and are still hanging on the parent tree while *A. prosopis* would utilize older, weathered pods that had abscised and fallen to the soil surface. In spite of these differences *N. arizonensis* has never become particularly abundant, possibly because the eggs are extensively parasitized by native parasitoids, and *A. prosopis* remains the most prominent biological control agent of prosopis in South Africa.

Although the threat of spread of prosopis has probably been reduced by the presence of introduced bruchid beetles, which destroy the seeds but have little impact on the nutritional content of the pods, most landowners are not convinced that biological control has helped. Ongoing monitoring of *A. prosopis* and the post dispersal mortality of prosopis seeds is showing that the beetles are more damaging than previously expected but that this species alone will not provide satisfactory control of the weed. As a result, a decision has been made to seek additional agents that attack the flower-buds, flowers and immature seedpods. This unanimous decision was made by over 50 stakeholders at the Kimberley Workshop.

Surveys in Argentina have revealed the presence of a weevil, *Coelocephalapion gandolfoi*[1] which attacks the green pods of various prosopis species. In all, it has been collected on nine *Prosopis* species all in the Section Algarobia, namely *P. affinis* (Series Pallidae), *P. alba*, *P. alpataco*, *P. caldenia*, *P. chilensis*, *P. flexuosa*, *P. nigra* (Series Chilensis) and *P. ruscifoliae* and *P. vinalillo* (Series Ruscifoliae). This is significant as *P. glandulosa* and *P. velutina*, both native to the USA but invasive in South Africa, are also in the Section Algarobia, series Chilensis. Other new-association biocontrol agents from South America that have been used in Australia to control North American prosopis species include a sap-sucking psyllid, *Prosopidosylla flava*, and a leaf-tying moth, *Evippe* sp. Adult feeding and oviposition preference tests in Argentina and South Africa showed that *C. gandolfoi* is only associated with prosopis species in the series Chilensis.

The flower-bud galler, *Asphondylia prosopidis*, was selected as an additional biocontrol agent after it was decided that the costs of the seed pods outweighed their potential benefits. Initial surveys in Texas, New Mexico and Arizona found that 11.3% of 550 prosopis trees had galls. Galls were found on *P. glandulosa* var. *glandulosa*, *P. glandulosa* var. *torreyana* and *P. velutina*, but not on *P. pubescens*, the only examined species not in the Section Algarobia. Although these initial results are promising the release of *A. prosopidis* will only be considered after further consultation with interested and affected parties. The introduction of an additional seed-feeder and possibly a flower-bud galler at a later stage will impact on the amount of pods available for fodder but will not affect the other uses of the plants.

Seed-feeders alone are not a solution to the problem. They may play an important role in long term integrated management plans by reducing seed loads and thus slowing rates of dispersal and preventing thickets from forming rapidly. Indeed agroforesters need to take cognisance of the advice of C. E. Hughes, which we have also been advocating for many years, that seed feeders should be introduced at the onset of agroforestry projects when there are indications that the introduced plant species will become invasive in the new environment[2]. The impact of seed-feeders is most prominent when invasive plants are still confined and localized and not when the problem is already out of control.

Biological control using pathogens has been limited to surveys for pathogens that could be used as mycoherbicides and for pathogens that could be host-specific to prosopis and affect green pods only. Nine out of 27 fungal isolates that were collected in North and South America showed promise as classical biocontrol agents and were selected for further studies. After extensive screening tests between 2000 and 2002 it was concluded that none of these isolates would be suitable as biocontrol agents at this stage and that the only promising isolate (C 158) warranted further study at a later stage when improved quarantine facilities would be available. A total of 151 fungi were isolated from diseased prosopis material from South Africa and Namibia and screened for possible use as mycoherbicides. Several showed promise but failed during extensive tests of effectiveness. Commercially existing mycoherbicide products have also been tested (e.g. Stumpout and BioChon) but none of these products showed any potential for controlling prosopis.

The Road Ahead

Unlike Australia and some islands where prosopis is a problem, South Africa is part of the much larger continental community and the needs of other countries, particularly direct neighbours, must be considered when formulating plans for how to deal with the prosopis problem at home, particularly the use of biological control. There can be no guarantees that biological control agents will not move into other countries where people may be benefiting from prosopis as a source of fuel, protection and food in otherwise denuded areas. In Australia a unified community has made the decision to rid the continent of the weed without worrying about the loss of its useful attributes. Australia has the resources available to back this commitment and is currently dealing with the problem on a massive scale, including the use of biological control. Such an approach would not be practical in Africa.

The Working for Water (WfW) programme in South Africa is the largest ever initiative aimed at controlling alien invasive plants (www.dwaf.gov.za/wfw/). It is unparalleled in the history of alien weed control, and employs in the region of 200,000 people. During 2002/2003, prosopis was cleared from an area that would be equivalent to 1500 ha at 100% canopy cover (173,149 ha is currently under 100% canopy cover), at a cost of ZAR 1.39 million. An additional ZAR 3.26 million was spent on follow-up treatment of 4108 ha that was cleared during previous years. Based on the 2002/2003 clearing rate and with no expansion of the current infestation (currently estimated to be in the region of 18% per annum) it would take approximately 115 years and at a cost, based on the 2002/2003 figures, of about ZAR 160million to clear the current infestations, excluding follow-up costs. The value of seed feeders must be appreciated in cases like this where such a large proportion of the budget goes for follow-up control. An important component of the WfW programme is the value-added industries and small business initiatives, which are aimed at utilizing extracted plant material, including prosopis. Considerable amounts of public funds are invested in these initiatives.

The time has come to take stock, through proper cost/benefit analyses, and to determine the extent to which biological control should and could be used against prosopis in South Africa. The progress of the WfW programme over the next years will be crucial in deciding the future management strategy for prosopis and whether a full biocontrol programme should go ahead. South Africa may become a model for other African countries. The stakes are high for agroforesters because as problems caused by prosopis escalate, biological control will become increasingly necessary. It is unfortunate that the agroforestry fraternity is not becoming more involved in finding solutions to the problems that they have created and in preventing future invasions from new species.

[1]Kissinger, D.G. (2006) A new species of *Coelocephalapion* Wagner (Coleoptera: Curculionoidea: Apionidae: Apioninae) from Argentina and Chile associated with the genus *Prosopis* L (Fabaceae). *Coleopterists Bulletin*, in press.

[2]Hughes, C.E. (1995) Protocols for plant introductions with particular reference to forestry: changing perspectives on risks to biodiversity and economic development. In: *Weeds in a changing world,* Stirton, C.H. (ed). British Crop Protection Council Symposium Proceedings No. 64, pp. 15–32,

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Daniel Gandolfo – Obituary

At the age of 49, we have lost a loved colleague and friend, Daniel Gandolfo. He died on 6 January 2006 in a car accident while collecting insects in the province of Misiones in northeastern Argentina.

In 1985 the SABCL (South American Biological Control Lab, US Department of Agriculture, Agricultural Research Service) was looking for a young researcher so I went to the University of Buenos Aires and spoke to the distinguished entomology professor Dr Axel Bachmann. He strongly recommended one of his favourite and brightest students, who was at the time working with him as a laboratory teacher. This was Daniel Gandolfo. Twenty years of working, travelling and spending time together with Daniel leave me strongly agreeing with the wise old man. Daniel was a special person; sharp, with personal magnetism and charm and full of humour. Everyone liked him. If I had to select just one word to describe him I would say that he was seductive. Always pleasant, polite, happy, with a wide smile in his face. His particular disposition for making friends made him a very good teacher so he was always surrounded by students and young colleagues to whom he easily conveyed his love for science. Most recently he was the Weed Program Supervisor of SABCL and involved in a number of projects for the USA, South Africa and Australia. The partner for most of his adult life, his loving wife Ana, and his children Ailen and Nicolas will miss him very much.

Daniel departed too early but during his intense life he showed us how human relationships should be. Adios amigo.

By: Hugo A. Cordo, Past Director of SABCL, 1974 to 2002.

Biocontrol of Chromolaena in South Africa: Recent Activities in Research and Implementation

Chromolaena odorata, an asteraceous shrub from the Neotropics, is highly invasive in several parts of Africa including South Africa, as well as in South East Asia and Australia. The biological control programme against *Chromolaena odorata* in South Africa, operational from 1988–1991 and again from 1996, is active in the fields of research and implementation. Two biocontrol agents are now established in South Africa, in the moister coastal belt to the south of Durban, and several other natural enemies are being investigated.

Pareuchaetes insulata: a Defoliating Moth

Pareuchaetes insulata is an arctiid moth with defoliating larvae that was tested for host specificity in the early 1990s. A starter culture for rearing for release was collected from Florida, USA in late 2000. The insect was mass-reared and releases began in KwaZulu-Natal province (KZN) in 2001. This mass-rearing programme was conducted by the insectary of the South African Sugar Research Institute (SASRI) with funding from the Department of Water Affairs and Forestry's Working-for-Water programme (DWAF WfW). Although the congeners *P. aurata aurata* and *P. pseudoinsulata* had previously been released without successful establishment in South Africa, it was considered worthwhile releasing *P. insulata* because it came from an area with a similar climate to the area of southern Africa where chromolaena is invasive. Following successful establishment of *P. pseudoinsulata* in Ghana and Sumatra in the 1990s, the release of large numbers of individuals over an extended period of time was considered critical to achieving establishment for *Pareuchaetes* spp., due to a probable need to overcome Allee effects (of a small population size on fitness) caused by factors such as predation and dispersal. In addition, it was considered important to employ an experienced, industrial-scale insectary to conduct the mass-rearing, given the susceptibility of *Pareuchaetes* to disease under confined conditions. A total of about 830,000 insects, mainly larvae, were released at 17 sites between 2001 and 2003. These sites were distributed over a range of climate and vegetation types within KZN province, from the drier Zululand region in the north to the wetter coastal region south of Durban. Numbers released at each site differed, in order to determine the minimum number for establishment. Almost half of these (380,000) were released at a site near the coastal town of Umkomaas, 50 km south of Durban, over a period of one year. Regular monitoring of these 17 sites showed that the insects did not persist long after releases had ended, although at the Umkomaas site very low numbers continued to be recorded. Chromolaena (or at least the southern African biotype) is an opportunistic species in that it grows extremely quickly under favourable conditions, but it rapidly wilts under dry or very hot conditions. Under prolonged dry-stress, chromolaena sometimes loses its leaves, and its stems may even die back, but it recovers quickly after the first rains, and has invaded drier areas of southern Africa than previously expected. Some of the *P. insulata* release sites became very dry during winter following and during releases, particularly under the drought conditions experienced during the early part of the decade, and the chromolaena plants lost their leaves. It was unsurprising that a non-diapausing leaf feeder did not establish under such conditions. At other sites, it is probable that too few insects were released to enable establishment to occur. However, there were several sites at which the apparent non-establishment could not be explained, especially as climate-matching modelling indicated reasonable compatibility[1].

Poor matching between the insect and host-plant biotypes seemed to be the only outstanding factor that had not been controlled for: high intraspecific variation in the morphology of *C. odorata* exists in the Neotropics, and the biotype of the weed invading southern Africa appears to originate from an island in the northern Caribbean[2]. The form of chromolaena in Florida is different to that occurring in southern Africa. Because *P. pseudoinsulata* is oligophagous (it uses *Ageratum conyzoides* as a secondary host), biotype matching had previously been considered an unlikely factor in explaining non-establishment in *P. insulata*. However, this idea was revised after the apparent failure of the release programme of *P. insulata* from Florida, and cultures of *P. insulata* were collected in Cuba and Jamaica late in 2002, in a final attempt to establish the species in South Africa. SASRI was again contracted to mass-rear the insect, and releases began at four sites within KZN province in 2003. Ezemvelo KZN Wildlife (the provincial conservation body) provided funding for this programme on condition that releases were also made within Hluhluwe-iMfolozi Park in northern KZN, one of the province's flagship conservation areas that is severely threatened by chromolaena. Two drier sites in KZN were selected for the Cuban insects as they originated from a drier area than those from Jamaica, and two wetter ones for the Jamaican insects. Initial results were promising at one each of the Cuban- and Jamaican-strain sites (the former in Hluhluwe-iMfolozi Park and the latter in Umdoni forest on the KZN south coast), at each of which about 100,000 larvae were released. At these sites, the insect both spread from the release site and increased in numbers more quickly than the Florida strain had done, and persisted longer after releases were ended. However, insects have since completely disappeared from the drier Cuban-strain release site, and are persisting currently only in very low numbers at the wetter Jamaican-strain site. Subsequently, at the end of 2004, 21 months after releases had been terminated there, an outbreak of the Florida strain was discovered unexpectedly about 1 km from the release site at Umkomaas, on a patch of young chromolaena plants. During the course of the summer following discovery, numbers of the insect built up over an area of at least 4 km^2 around the site, with defoliation occurring in some patches. As it is now almost 3 years since releases were terminated there, it is considered that *P. insulata* has definitely established in South Africa.

How can these patterns and results be explained? We think that the following factors played a role: (i) Climate: the Zululand area as a whole seems too dry for *P. insulata*, even where chromolaena plants stay in good condition year-round (here, low humidity may also play a role). This may also apply to other inland chromolaena infestations, i.e. those in South Africa's northern Limpopo and northeastern Mpumalanga provinces and in Swaziland. It will be interesting to see to what climatic limits *P. insulata* eventually spreads naturally. Even within the wetter regions, habitats exist where chromolaena quickly loses condition, e.g. on vegetated sand dunes near the coast, and *P. insulata* may struggle to establish in such areas. (ii) Numbers of insects released and duration of release: at 380,000 larvae released, the Umkomaas site received four times the number of Florida insects during one year than those released at any of the other 17 sites. (iii) Insect – host plant biotype matching: qualitatively, initial patterns of spread and build-up of Cuban and Jamaican insects were considerably different to those of the Florida strain, and we thought that this may have been due to better compatibility of Cuban and Jamaican insects with the host plant biotype as they were collected off a similar form of chromolaena to that invading South Africa. If establishment is achieved with the Jamaican insects at the Umdoni site, it will be with 25% of the number of individuals used to establish the Florida insects at the Umkomaas site. (iv) Local adaptation: numbers of insects at both Umkomaas and Umdoni sites decreased initially; it is likely that local adaptation occurred at Umkomaas, and is possibly also occurring at Umdoni.

The future for this programme is now to field-collect and mass-rear insects from the Umkomaas site for release elsewhere. For the moment, the Jamaican strain also continues to be reared and released. However, the Cuban strain will be discontinued: it has become inbred, and no opportunity exists to re-collect it in Cuba at the moment.

Is Biological Control Always Appropriate?

Despite the status of chromolaena as the most serious terrestrial invasive alien plant (IAP) in the warmer eastern regions of South Africa, it has proved quite difficult to find suitable release sites for *P. insulata*. In addition to using coastal sites in which chromolaena remains in good condition year-round, several logistical criteria must be met: (i) The insect appears to need large expanses of dense chromolaena for initial establishment. In South Africa, many clearing programmes are currently under way for chromolaena and other IAPs, therefore such sites are often difficult to find. (ii) The site must be accessible by vehicle because of the large numbers of larvae being released at any one time and the duration of releases. (iii) The site must be safe from deliberate or accidental damage, criminal attack for people releasing and monitoring insects, and theft of monitoring equipment.

Hluhluwe-iMfolozi Park is an example of some of the difficulties surrounding the selection of biocontrol release sites, and we discuss it here because of its high profile and in response to a recent online National Geographic article highlighting the threat to the park from chromolaena (http://news.nationalgeographic.com/news/2005/09/0916_050916_triffidweed.html). This park of 96,000 ha was established late in the 19th century in the drier savanna area of Zululand and was instrumental in conserving the then critically endangered white rhinoceros (*Ceratotherium simum*) as well as the black rhinoceros (*Diceros bicornis*). It is considered one of the flagship parks in KZN province and attracts many foreign tourists and income for the impoverished Zululand region. A reduced burning regime and overgrazing in the park during parts of the 20th century led to dramatic vegetation changes, particularly a decrease in grassland and its replacement by fire-resistant bush and secondary forest. This has allowed chromolaena to proliferate; the southern African biotype of *C. odorata* is highly susceptible to burning and would not have taken hold in frequently burned grassland. In the early 1980s, a warning was issued[3] on the potential danger of chromolaena to the park. Little was subsequently done, due to low budgets available for clearing IAPs and a lack of appreciation of the potential seriousness of the problem. By the late 1990s, the northern, wetter Hluhluwe region was choked with chromolaena, severely affecting grazing, browsing and game viewing, as well as the general health of the ecosystem (although, generally in South Africa, frustratingly little research has been published on aspects such as the direct effects of chromolaena invasions on ecosystems and on individual, prominent species such as rhinoceros; or on economic and sociological impacts of chromolaena; or on cost-benefit analyses). In 2003, a 'Chromolaena Clearing Project' for the park was set up within EKZN Wildlife, with funding from the provincial government, in a concerted effort to remedy the situation before the entire northern area of the park became unusable. The initial annual budget was ZAR 5 million, and for the 2005/6 financial year it has risen to ZAR 13.5 million. The programme employs over 500 people to mechanically and chemically clear chromolaena at a cost for initial clearing of ZAR 450/ha, and a more aggressive burning programme has also been instituted in non-forested areas. This clearing programme has made significant inroads into the chromolaena infestation, but much remains to be done (an estimate of 14 years on a budget of ZAR 5 million per annum is required). In the context of biocontrol of chromolaena, despite considering Hluhluwi-iMfolozi to be marginally suitable for *P. insulata*, the Florida strain was released at a site there in 2001 (i.e. before the initiation of the concerted clearing programme), due to political pressure to control chromolaena in a flagship park. However the plants at the release site lost their leaves during winter and the insect did not establish. The Cuban strain was released at a site on the Hluhluwe river in 2003–2004, selected because it was one of the few areas in the park where chromolaena appeared to maintain condition year-round, and because the funding conditions stipulated that the park be used for releases. Despite promising results during the first year, it does not appear likely that establishment has occurred. The park management was understandably disappointed in the results, even though they had not been given a guarantee of establishment. However, even if the agent had established, it is unlikely that it would have effected a degree of control satisfactory to park management, as the ultimate goal is essentially a chromolaena-free park. Under the current circumstances it seems that biocontrol release sites should not be sited within the park (of course in the long run the funding for clearing may well be reduced or terminated – and if a biocontrol agent able to tolerate the dry conditions were already widely established in the area it would still be useful to such a clearing programme); it would be better to select release sites in 'unimportant', neglected areas that are unlikely to be targeted for clearing operations: it is somewhat ironic that landowners who do not manage their land properly are 'rewarded' with biocontrol release sites in preference to those who do. Nevertheless, the use of biocontrol remains a crucial element in the management of chromolaena on a national scale, particularly as chromolaena has invaded many rural, impoverished areas such as those surrounding Hluhluwe-iMfolozi Park, reducing grazing for livestock for communities that cannot afford to maintain expensive clearing programmes. Also, for as long as there are chromolaena plants in the landscape, the prolific numbers of seeds produced per plant will continue to contribute towards the plant's presence and spread, and natural enemies will be required to keep chromolaena at manageable levels.

Calycomyza eupatorivora: a Leaf-mining Fly

This agromyzid leaf-mining fly is widespread on chromolaena in the Neotropics. In the late 1960s when Rachel Cruttwell McFadyen conducted her survey in Trinidad on phytophagous insects as potential biocontrol agents of chromolaena, it was considered the same species as *C. flavinotum*, which had a fairly wide host range. It was thus not considered as a biocontrol agent. However, it was imported into quarantine in South Africa in 1997 following opportunistic collection in Jamaica, and host-specificity testing indicated that it fed on only *Chromolaena odorata*. Permission to release it was granted in 2003, and it has subsequently been released at several sites in KZN, Mpumalanga and Limpopo provinces; it has also been forwarded to Papua New Guinea, where the South African test results were used to obtain permission to release the fly. Establishment was confirmed in March 2004 at one coastal site, at Amanzimtoti, 10 km south of Durban, where chromolaena maintains a reasonable condition year-round. About 500 pupae were released here over 4 months. The fly has subsequently spread at least 6 km along the coast and 2 km inland. The larval leaf mines are still at very low densities, and it is uncertain whether the fly will eventually have a significant effect on *C. odorata*. If it does, it will probably be the seedlings that are affected significantly in terms of growth rates or propagule production. Fairly high levels of parasitism or predation of larvae have been observed, but still need to be quantified. *Calycomyza lantanae* on *Lantana camara* is heavily parasitized in South Africa, and still occurs at low densities, despite being released in 1982.

It is likely that *C. eupatorivora* did not establish at the other sites at which it was released because of climatic incompatibility, inadequate number of individuals released per site, or both. As a non-diapausing leaf feeder it is not well adapted to drier areas. At one of the sites at which it did not establish, it showed great promise during the first summer, with many mines present up to 100 m from the release site, but it disappeared during the subsequent dry winter, when the chromolaena became very wilted. In terms of release techniques, it appears that the use of pupae and of plants containing larvae in mines is more successful than using adults. However, numbers needed to enable establishment and the length of time over which these should be released have not yet been determined, and may vary depending on the climate at the release site. A one-year mass-rearing contract whereby SASRI provides adequate numbers for release on a regular basis has been initiated.

Research in Quarantine and Countries of Origin

Clearly, species with a biology that can tolerate seasonally drier conditions are needed for much of the range of chromolaena in southern Africa. Several species of insects are currently being studied in quarantine in South Africa and in countries in the Neotropics, for a multi-faceted approach using a suite of natural enemies, some of which are tolerant of seasonally dry conditions, attacking different plant organs.

Lixus aemulus

This curculionid weevil, collected in western Brazil in 1995, has larvae which bore down younger chromolaena stems. Host-range tests were completed in 2002, indicating a high degree of host specificity, and an application to release the insect was submitted to the National Department of Agriculture in late 2004. Given the current processes involved in granting permission for release, and the shortages of capacity in the relevant government departments, this is expected to take up to several years. Because the young weevils overwinter in the stems, the species is probably well adapted to seasonally drier areas. It has also been shown to dramatically reduce stem growth and seed production in the laboratory. However, although the weevil has bred well enough in the laboratory, in the field compatibility between insect and host-plant biotype may become an issue, as *L. aemulus* was collected from a hairy form of chromolaena quite distinct from the southern African form.

Longitarsus sp.

A root-damaging insect is considered an important agent for chromolaena, both because it is likely to cause high seedling mortality and because, having soil-dwelling stages, it is suitable for seasonally drier areas and areas which experience fires in the dry season. *Longitarsus* chrysomelid fleabeetle species have been collected on chromolaena in Amazonian Brazil, in Trinidad and in northern Venezuela. Insects from the latter two localities were initially identified as *L. horni* but this was recently changed to *L. amazonas* or *L.* nr *amazonas* (the Brazilian specimens were originally identified as this same species). Unfortunately it seems likely that this species is polyphagous, feeding on a variety of Asteraceae, and therefore unsuitable as a biocontrol agent. Dr Catherine Duckett is currently studying the specimens collected by us in Trinidad and Venezuela on several species of Asteraceae, to confirm by morphological and molecular means that the species found on chromolaena is the same as that on these other Asteraceae. Unfortunately, as yet, no *Longitarsus* species or other root-attacking insects have been found on chromolaena in Jamaica and Cuba, where plants identical to the southern African biotype of chromolaena occur.

Conotrachelus reticulatus

This stem tip-galling curculionid weevil has a wide distribution in South America and preliminary host-range tests in quarantine in South Africa of a culture collected in northern Venezuela indicated high specificity. In addition, none of seven other species of Asteraceae inspected in the field in Venezuela showed signs of *C. reticulatus* feeding in the presence of high numbers of the weevil on adjacent chromolaena plants. Galling of stem-tips by the weevil reduces or terminates growth of affected stems. The agent is considered promising for seasonally dry or fire-prone areas because it pupates in the soil, and diapauses in the soil over winter. Northern Venezuela has been identified as a region with a seasonally dry climate that is fairly similar to that of the chromolaena-invaded areas of southern Africa. Poor culturing success in South Africa led to the suspicion of a degree of incompatibility between insect and host plant for the southern African chromolaena biotype. Research on the biology and host range of this species is continuing in Venezuela under a contract between PPRI (the Plant Protection Research Institute, South Africa) and the Universidad Central de Venezuela (UCV).

Carmenta n.sp.

This day-flying sesiid moth, discovered on chromolaena in northern Venezuela in 1998, lays its eggs in chromolaena stem tips. The young larva girdles the stem tip, thereby killing it, tunnels through the stem pith and pupates lower in the stem, once it has created an emergence window. The moth seems to favour large plants in hot, exposed areas for oviposition, and may therefore be useful in South Africa, where many such situations exist. The larvae of *Carmenta* appear to overwinter in stems, and the species may therefore again be tolerant of seasonally drier conditions. The species is currently being described by Dr Thomas Eichlin of the California Department of Food and Agriculture. Some research on its biology has been conducted by UCV, but it was not mated in captivity there. *Carmenta* spp. are notoriously complicated in terms of inducing mating and oviposition under confined conditions, but have been used with success in several weed biocontrol programmes once the correct rearing techniques were found. A large number of larvae were imported into South African quarantine recently in an attempt to start a culture. It has proved difficult to obtain sufficient numbers of adults simultaneously from field-collected larvae in order to allow mating and oviposition, due to the asynchronicity of adult eclosion in combination with a short adult lifespan. However, techniques are being investigated to circumvent this problem.

Mescinia n.sp.

The biology and host range of a damaging stem tip-galling pyralid moth identified as *M.* nr *parvula* was studied by Rachel Cruttwell McFadyen in Trinidad. The moth was found to be highly host specific in no-choice trials using field-collected larvae, but mating in captivity was never induced, and therefore it was never used as a biocontrol agent. More recently, a very similar species was collected in Jamaica and induced to mate for the first time in a large walk-in cage in South African quarantine. The moth is currently being described, and specimens from Trinidad are being compared to those from Jamaica (by Dr Alma Solis of the US Department of Agriculture – Systematic Entomology Laboratory, USDA-SEL). If they prove to be one species, this would represent a breakthrough, as most host-range work has already been conducted and the insect shown to be host specific. A few supplementary tests would be conducted on indigenous South African Eupatorieae, Jamaican Eupatorieae and some commercial species, after which an application would be submitted to the government for the release of this promising agent.

Recchia parvula

This is an extremely damaging cerambycid beetle from northern Argentina possibly collected from *C. jujuiensis* rather than *C. odorata*. Adults kill stem tips through feeding, and lay eggs in stems. The larvae bore down to the root crown, where they pupate. They often reduce the stems to a frass-filled paper-thin epidermis, and can kill whole plants. The insect is univoltine, overwintering in the root crown as larvae, and the adults eclose in spring. Preliminary host-range tests in South African quarantine indicate high host specificity.

Melanagromyza eupatoriella

The larvae of this ubiquitous, damaging agromyzid fly kill chromolaena stem tips by girdling them with a spiral mine. It has long been recognized as a good potential agent, but was not studied by Rachel Cruttwell McFadyen because it could not be induced to mate in captivity. It is likely to be highly host specific. It has been reared several times in quarantine in South Africa, but only for short periods. The plan is now to conduct most of the necessary biology and host-range research in Jamaica before introducing the fly into South African quarantine again for supplementary tests on a few indigenous and commercially important species, to shorten the time spent in South African quarantine. Research in Jamaica will involve field host-range tests by the University of the West Indies (UWI) under contract from PPRI.

?Dichrorampha sp.

This small tortricid moth from Jamaica, which according to Dr John Brown of USDA SEL could also be a *Cydia* species, lays eggs in the shoot tips of chromolaena plants. The yellow larvae bore down the shoot tip for 2–3 cm, causing the tip to swell slightly and to stop growing. Pupation occurs on an adjacent leaf inside a folded piece of leaf. A culture was imported from Jamaica in large numbers for the first time in November 2005, and reared successfully in small cages. The larvae can also be transferred easily between plants. This appears to be a promising agent so far although nothing is known about its host range. If this proves to be a new species, we will arrange for it to be described.

Fungal pathogens

Starting in 1988, various species of pathogens were collected on chromolaena from throughout the native distribution of chromolaena and isolates were reinoculated onto the southern African chromolaena biotype in South African quarantine. However, the first to show at least some compatibility were 14 isolates of *Pseudocercospora eupatorii-formosani* from Jamaica, Cuba, Florida, Mexico and Costa Rica, and one isolate of *Mycovellosiella perfoliata* from Florida in 1999; of these, three Jamaican isolates of the first species proved to be the most pathogenic. No highly damaging pathogens were found during a field survey in Cuba and Jamaica in 2002, but a further collecting trip was undertaken recently in Jamaica by Estianne Retief, a pathologist from PPRI. Isolates from these collections will be inoculated onto South African chromolaena plants in 2006, to determine their compatibility with the plants. If any prove to be acceptably pathogenic, host-range testing will be undertaken.

Conclusions

Two biocontrol agents, *Pareuchaetes insulata* and *Calycomyza eupatorivora*, are established and spreading on chromolaena in South Africa. Their long-term efficacy is unknown at this stage, but they are likely to be restricted in distribution to the wetter parts of chromolaena's invasive range in southern Africa. Permission is currently being awaited from the South African government to release the stem boring weevil, *Lixus aemulus*. A number of candidate biocontrol agents continue to be studied either in quarantine or in the country of origin, and some of these appear very promising. Two important factors to be taken into consideration for the South African chromolaena biocontrol programme are (i) compatibility between the agent and the southern African chromolaena biotype, and (ii) climatic compatibility between the region of origin and the region of introduction of the agent. The northern Caribbean islands have been shown to be the most likely origin of the southern African *Chromolaena odorata* biotype. A climate-matching model using FloraMap™ recently developed by Costas Zachariades and Mark Robertson indicates that this area is not very similar climatically to areas in southern Africa invaded by chromolaena. More similar areas are northern Venezuela, northern Argentina and higher lying areas of Central America and north-eastern Brazil. Of course, some species have a wider host range than others and will therefore accept a range of *C. odorata* biotypes: they could be collected from an area from which the southern African biotype is absent and still establish in South Africa. Other species have wider climatic tolerances than some and therefore could be collected from the northern Caribbean and still establish in South Africa. Another point to take into account is that the diversity of the phytophagous insect fauna on chromolaena on the Caribbean islands is much lower than on the South American mainland[4], and that the latter tend to include species which, by virtue of their biology, should be more dry- and fire-tolerant. Therefore we are not restricting the search for candidate agents to only the northern Caribbean islands.

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South African Chromolaena is Something Else

Strategies for managing weeds and threats from invasive alien plants are increasingly using climate modelling as a tool. Under these circumstances, it is vital that a model is as good a predictor of reality as reasonably possible, and that its limitations are clearly explained. Such reasoning was behind the revision[1] of a model of the estimated potential distribution of *Chromolaena odorata,* developed in 1996 using the computer-based eco-climatic modelling package, CLIMEX. It was argued that unsound model formulation meant that the predicted climate suitability of the original model was unreliable, and could potentially incorrectly influence management policies. The recognized difference in climatic requirements between the South African biotype and invasive chromolaena elsewhere was further motivation for re-visiting of the model. On a more generic level, the publication of the revised chromolaena model may stimulate re-examination of climate models for other invasive species.

In revising the model, Kriticos *et al.*[1] used data from chromolaena's native distribution in the New World and its introduced range in Asia. Data from its African distribution were used as the primary means of validating the model. In an earlier paper, Kriticos & Randall[2] argued that it was crucial to include data from exotic as well as native ranges of invasive species. The native range of a species is defined by the range of conditions and resources under which the species can exist in the presence of competitors and natural enemies; in their absence, however, most species usually survive and even thrive under a significantly wider range of climatic conditions.

In its spread through five continents, the highly invasive species *C. odorata* has had plenty of opportunities to show what it can do. The revised model gave a substantially better fit for the existing distribution of *C. odorata* in some regions (e.g. southern China). However, it reduced its estimated potential distribution, particularly the northernmost and southernmost limits, and spread into inland Australia. Mediterranean, semi-arid and temperate climates are considered unsuitable. Nonetheless, much of tropical Africa, the northeastern coast of Australia and the Pacific islands remain at risk.

An anticipated anomaly emerged when South African data were compared with the revised model: the South African populations were persisting in a cooler climate than any other reliable records of *C. odorata* elsewhere. This finding is in line with observations that the South African biotype is more cool-adapted.

This, alongside mounting molecular and biological evidence on the differences between the South African biotype and the biotype found in Asia and most of tropical Africa[3], raises the question of how taxonomically distinct the South Africa chromolaena is. Perhaps it is now time to define *C. odorata* more narrowly and describe the South African biotype as a different species.

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New Guidelines Replace Original FAO Code of Conduct for Import and Release of Biocontrol Agents

The International Plant Protection Convention (IPPC) is publishing the new *Guidelines for the export, shipment, import and release of biological control agents and other beneficial organisms*[1] on its website in all five official languages of the UN Food and Agriculture Organization (FAO). These guidelines are the revised International Standard for

Phytosanitary Measures (ISPM) No. 3, and replace the original FAO *Code of conduct for the import and release of exotic biological control agents*[2,3].

During country consultation last year, nearly 550 comments about the proposed revision were submitted to the IPPC Secretariat from contracting parties (countries), the European Union as a group, and regional meetings held to analyse draft standards. Other bodies, such as CABI's various centres, also commented on the text. All comments received during the consultation period were considered, and incorporated as appropriate, by the IPPC's regionally-representative Standards Committee before being presented to the Interim Commission for Phytosanitary Measures (ICPM), which acted as the membership body of the IPPC at the time. Additional minor changes were made at the Seventh Session of the ICPM[4], held in April 2005, and some definitions were referred to the Glossary Working Group for further review. Subsequently, the 1997 revision of the convention entered into force (2 October 2005), thereby leading to the conversion from the ICPM to the Commission for Phytosanitary Measures (CPM). The 2006 session of the CPM will include formal adoption of all decisions of the ICPM, including the ISPM No. 3.

Somewhat surprisingly, few comments related to what an earlier FAO-convened group of experts considered to be the most significant changes: primarily the removal of the focus on 'exotic' rather than risk per se and the addition of other categories of intentional releases of living organisms for plant protection that do not fit under the definition of biocontrol. The latter was addressed finally by adding the concept of 'beneficial organisms' rather than by altering the IPPC's definition of biocontrol agents. Other concerns raised by this earlier workshop (held in 2002) that were not included in the final revision consist of the need for more guidance on: (a) the actual risk analysis process; (b) the economic and environmental impact; and (c) the interests of neighbouring countries when considering risk of import and release[5].

As with other 'concept' standards, the new ISPM No. 3 gives plenty of leeway for national approaches to the issue of shipping and releasing biocontrol agents, making it unlikely that those countries that developed legislation in the past will need to prepare new legislation in order to come into line with the international guidance. In fact, proposals to prepare the revised ISPM following other formats were not taken on board as a conscious effort was made to maintain as much of the original Code as possible in order to avoid causing confusion or additional challenges to those countries that have designed their own legislation on the international standard, examples of which appear in Kairo *et al.*[6]. Such changes in national regulations that may be required will be due to the expanded scope, which now covers beneficial organisms intentionally released for purposes of plant protection or that may have some indirect impact on plant health. Specifically noted in this category are pollinators, sterile insects and soil aggregates. It is likely, in the opinion of the authors of this news article, that the IPPC will rely on other international organizations to prepare more detailed technical guidance for implementation of ISPM No. 3, although additional standards could be developed in support. An unofficial commentary in the form of an explanatory document for ISPM No. 3 could be forthcoming by the end of the year and would appear on the IPPC website.

In the absence of more detailed guidance from the IPPC, National Plant Protection Organizations may rely on a few technical documents developed through international consensus or technical working groups to support implementation of the expanded scope. For example, the FAO and the International Atomic Energy Agency (IAEA) coordinate development and revision of resources for sterile insect technique, such as the *Manual for product quality control and shipping procedures for sterile mass-reared tephritid fruit flies*[7]. Gaps in technical guidance will remain, however, so that countries may take some time to implement and harmonize regulations on issues such as release of exotic pollinators – an issue of concern to the Convention of Biological Diversity as well.

The IPPC and its international standards gained much wider recognition when it was cited as a standard setting body under the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) of the World Trade Organization (WTO), an agreement that is binding to all members of the WTO. Despite now having passed the 50th anniversary since the first version of the convention came into effect, the IPPC did not begin a formal standard setting process until circa 1995. New ISPMs have been developed every year since, with the number of new proposals increasing significantly in the past 3 years. Other than the official glossary (ISPM No. 5), which is revised annually, the ISPM No. 3 was the first standard to be revised. Revisions of both ISPM Nos. 1 and 2 are up for endorsement this year (2006). The development of the original FAO Code of conduct is described in Quinlan *et al.*[5].

In the future, all ISPMs will be presented in a unified book, by language, rather than as individual publications, similar to the format used by the World Organisation for Animal Health (OIE) for publication of its Animal Health Code. For the present, the full text of the revised ISPM No. 3 will be available on the IPPC website (www.ippc.int, under adopted standards) in English, Spanish and French, Arabic and Chinese, the official languages of the FAO, where the convention is deposited, by clicking on the language desired (rather than the document icon).

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[2]IPPC (1996) *Code of conduct for the import and release of exotic biological control agents.* Rome; FAO, ISPM No. 3, 23 pp.

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IPM Systems

This section covers integrated pest management (IPM) including biological control. This time we follow up the September 2005 issue with two more articles on biopesticides.

Tsetse's Lethal Path (Part II)

The tsetse fly (*Glossina* spp.) has been labelled 'Africa's scourge or bane'. It is the one pest largely preventing full utilization of the best agricultural/grazing lands on the continent. About one-third of the continent, or nearly 9 million km^2, is infested. The flies feed exclusively on vertebrate blood and are responsible for the transmission of protozoan parasites of the genus *Trypanosoma,* which cause human and animal trypanosomosis, otherwise referred to as sleeping sickness and nagana, respectively.

With regard to human trypanosomosis, there are an estimated 200 foci of infection occupied by nearly 60 million people in inter-tropical Africa, and each year more than 300,000 new cases are reported. A spectacular recrudescence of the disease has occurred since 1970. Animal trypanosomosis is also often fatal, especially in cattle. Direct losses in animal production have been estimated at US$ 800–1600 million annually. Between 60 and 90 million cattle are at risk, as well as tens of millions of goats, sheep, and camels. This undermines food security, as sick animals produce less milk and meat, in addition to reproducing less. There is also a considerable reduction in the economic self-reliance of affected states.

The initial success of insecticide spraying was so overwhelming that their side effects and potential long-term consequences were not considered in advance. More recently, less environmentally contaminating methods have been developed that involve the attraction of flies to traps or other devices which have been treated with insecticides, including animals ('pour on'). The sterile insect technique (SIT) has been tested on a large scale and the possibility of 'eradication' of an isolated tsetse population has been demonstrated (in Zanzibar).

Sterilization of tsetse by insect growth regulators or juvenile hormone mimics as alternatives to chemical insecticides has been proposed by some workers[1,2]. These hormones are known to have unquestionable advantages such as good persistence and the possibility of transmission of the product from male to female during mating. Rather than killing the insects, they affect their capacity to reproduce. Consequently, in epidemic foci, the disease cannot be stopped quickly, which goes against the principle of rapid anti-vectorial control. Considering that any control technique must be effective, fast, cheap, and at the same time be easily applicable in all circumstances, one of the approaches could be the use of insect pathogens that occur naturally in insect populations. Entomopathogenic fungi, whose infection occurs through the cuticle, are able to kill the insect, and can be transferred from one individual to another by simple contact, offer better prospects than entomopathogens such as bacteria and viruses that need to be ingested to infect their hosts. In March 1999, Maniania and Nadel reported [see *BNI* 20(1) 7N-8N, Tsetse's lethal path] on the prospects of using the entomopathogenic fungus *Metarhizium anisopliae* in a contamination device (Cd) mounted on a standard tsetse trap, such that captured flies passing through the Cd are contaminated with fungal spores before they return to the environment and transmit conidia to healthy flies during mating and other interactions. Here we report the results of a trial conducted from 1999–2000 on Mfangano Island in Lake Victoria, Kenya to evaluate the potential of the Cd technology for control of *Glossina fuscipes fuscipes,* a vector of both human sleeping sickness and nagana[3].

One hundred and sixty pyramidal traps mounted with Cds were deployed along the lakeshore and rivers on the island. Cds were loaded with dry conidia of *M. anisopliae*. On a second island, Nzenze Island, three pyramidal traps fitted with plastic bags were deployed to serve as the conventional 'trap and kill' population suppression method. A third island, Ngodhe Island, was untreated and served as a control. Fungal conidia were recharged monthly by removing the old spores. Plastic bags were also changed monthly. The apparent changes in population density were monitored weekly using biconical traps set at random on the three islands. To assess the incidence of *M. anisopliae* in tsetse flies on Mfangano Island, flies captured during monitoring were maintained in the laboratory and their mortality recorded. On Mfangano and Nzenze islands the fly populations were reduced during the experimental period to 82% and 96%, respectively, of the untreated control population. The incidence of *M. anisopliae* in fly populations was low during the first 12 weeks of the experiment but increased afterwards up to the termination of the treatment. After three months following removal of the treatment, incidence of *M. anisopliae* (9%) could still be observed in tsetse populations on Mfangano Island. Correlation analysis showed that infection rates were generally negatively correlated with trap catches, suggesting that the effects of fungal infection on the tsetse population persisted for many weeks, which in turn implies that after infection, flies lived for some weeks before dying, or that infected flies passed the infection to other flies, or both.

The results of this study have shown that fungus used in a contamination device can give control comparable to the 'trap and kill' technology and offers the added advantage of fly-to-fly contamination and prolonged persistence. This technique may also be applicable to other species of tsetse flies that are readily attracted to traps. However, additional field testing is required to optimize the trap/Cd density necessary per unit area according to vegetation type and to determine appropriate fungal dosage and formulation. Further large-scale suppression trials are also required to validate this new technology.

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[2] Jordan, A.M., Trewern, M.A., Borkovec, A.B. & De Milo, A.B. (1979) Laboratory studies on the potential of three insect growth regulator for the tsetse fly, *Glossina morsitans morsitans* Westwood (Diptera: Glossinidae). *Bulletin of Entomological Research* **69,** 55–64.

[3]Maniania, N.K., Ekesi, S., Odulaja, A., Okech, M.A. & Nadel, D.J. (2006) Prospects of a fungus-contamination device for the control of tsetse fly *Glossina fuscipes fuscipes*. *Biocontrol Science and Technology* **16**(2), 129–139.
http://journalsonline.tandf.co.uk

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A New Green Control for Locusts Now Readily Available to Farmers

Australia is home to three species of locusts – the spur-throated locust (*Austracris guttulosa*), the migratory locust (*Locusta migratoria*) and the Australian plague locust (*Chortoicetes terminifera*). Of these, the most damaging is the Australian plague locust with outbreaks requiring control occurring about every 2 years. Locust plagues tend to develop when widespread areas of inland Australia receive good rainfall in successive seasons and subsequent grass growth produces ideal habitats for locusts to breed.

All three species can cause significant damage to pastures and crops in the warmer parts of Australia and outbreaks can occur across large areas, from cropping areas to arid zones (western areas of Queensland, New South Wales and Victoria, much of South Australia and southern Western Australia). In addition there are several species of grasshopper which cause damage to pastoral areas and horticultural crops in the cooler regions of the country.

Now a rare native fungus is set to help Australian and overseas farmers to battle locust plagues. Scientists at CSIRO Entomology developed a strain of the naturally occurring fungus, *Metarhizium*, to control locusts and CSIRO has signed a worldwide agreement with the agricultural biotechnology firm, Becker Underwood Ltd, to manufacture, market and distribute the end product, Green Guard®.

Green Guard® has already been used extensively against recent locust and grasshopper outbreaks in Australia, but only under special licence. Now it will be available to all as it has been granted full registration by the Australian Pesticides and Veterinary Medicines Authority (APVMA). Becker Underwood intends to make it available to farmers through the agricultural reseller network and government bodies involved in locust control such as the Australian Plague Locust Commission and the NSW Rural Lands Protection Boards. They are also involved in discussions with groups around the world such as China where Green Guard® has already been successfully field tested. Becker Underwood have specialized in the development and marketing of biopesticides since 1989.

Because it is a naturally occurring fungus, Green Guard® can be used in areas where it is not appropriate to use chemical pesticides such as on organic farms, in ecologically sensitive areas and close to water courses. Its use will help minimize the amount of chemical pesticide used for locust and grasshopper control.

There are many strains of *Metarhizium* each of which attacks different insect species. The strain used in Green Guard® is specific to locusts and grasshoppers. When it was first discovered, it did not seem a promising candidate for controlling plague locusts. Locusts like it dry and the fungus likes it moist. But the need for a 'green' alternative to insecticides for locust control made the scientists persevere. It took the research team a decade to produce a commercially viable product.

Initially the infectious spores were mixed with water for spraying but this was not successful. Not only were the waxy spores difficult to suspend in water but they quickly dried out and died. The solution was to suspend the spores in oil for spraying. The spores form a suspension in the oil which protects them from the sun and from drying. It also aids the infection process.

However before this could be commercialized several major hurdles had to be overcome by detailed research – the spores did not persist well, they settled out quickly and were difficult to resuspend, and they clogged spray nozzles. Changes to the manufacturing process and the formulation have now enabled an effective product to be launched.

The oil suspension can be sprayed under very hot conditions and will not dry out. In fact, the fungus will infect and kill locusts in conditions where it would not normally be expected to be active. The fungus in the oil suspension will survive for several years in storage but does not persist in the environment for more than about 4 weeks.

Metarhizium is most effective against locusts and grasshoppers while they are in the young, or hopper, stage and it takes 10–14 days to kill them. It costs a little more than chemicals but for those who prefer not to use chemical pesticides, it is the ideal solution. While the fungus is effective against a wide range of grasshoppers and locusts it does not affect even close relatives like crickets. Aquatic life and birds are also safe.

Metarhizium spores literally bore into the locust's cuticle. Once inside they use up water and nutrients and grow little tubes that burrow further eventually killing the insect. There are 40,000 million spores per gram but as few as 500 on one locust is enough to kill it.

The initial research on locusts and grasshoppers was funded by the Rural Industries Research and Development Fund and conducted by Dr Richard Milner from CSIRO Entomology. The subsequent commercial development was by CSIRO Entomology undertaken in collaboration with the Australian Plague Locust Commission, the Queensland Department of Natural Resources, the then New South Wales Agriculture and industry.

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Announcements

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

BNI Rings the Changes

The eagle-eyed amongst you may have spotted our new web address in recent issues, and found *BNI*'s new virtual home at: www.pestscience.com
This site includes all the news and reviews formerly on Pest.CABWeb. New issues of news are being loaded as a PDF of the printed version, which we hope you will find easier to navigate and read.

Many of you, however, will have been mystified by *BNI*'s apparent absence from the Internet in recent months, and to you we apologise. It proved impractical to provide a redirect from old to new sites.

The review section has also changed. From the end of 2005, *BNI* reviews are part of *Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources* (*PAVSNNR*). This new online review journal from CABI Publishing offers a rapid route to publishing quality reviews – and access to the CAB Abstracts database to help with preparing them.

Web:
www.cababstractsplus.org/cabreviews/index.asp

Reviews with content relevant to *BNI* will be published first online in *PAVSNNR*, and then reprinted in *BNI*. The editors of *BNI* will continue to welcome correspondence and suggestions about reviews, and suitable manuscripts, or you can contact the *PAVSNNR* Commissioning Editor. Full author instructions will be given on the website.

Contact: David Hemming, Commissioning Editor, *Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources*
Email: d.hemming@cabi.org

Weed Biocontrol Symposium Returns to Europe

The XII International Symposium on Biological Control of Weeds (ISBCW) will be held in Montpellier, France on 22–27 April 2007. The ISBCW series provides an international, quadrennial forum for research related to biological control of weeds and the logistics surrounding its implementation.

ISBCW returns to Montpellier after a gap of nine symposia and 34 years. Much has happened in weed biological control in Europe since the last symposium here in 1988, and Montpellier has become an international multi-agency biocontrol centre (CILBA – Complexe Internationale de Lutte Biologique Agropolis). Nevertheless, biological control of weeds is still in its infancy in Europe, with the first release of a classical biological control agent yet to happen. The return of this international forum coincides with a European public awakening to the extent and impacts of alien plant invasions. The XII ISBCW can provide a window to show the public and policy makers in Europe and around the world that biological control of weeds uses internationally accepted scientific rigour and analysis to provide permanent and non-chemical weed control benefits, far outweighing any risks or costs. Proposed topics include:

- Strategic ecology and modelling
- Evolutionary theory and applications
- Cost-benefit/risk analysis
- Regulations and public awareness
- Biological control opportunities in Europe
- Target and agent selection
- Pre-release specificity and efficacy testing
- Post-release evaluation/monitoring
- Retrospective studies/assessment of predictions
- Novel approaches and technologies
- Release practices and strategies

English will be the official language and no translation services will be provided. Other important dates to remember are: 6 October 2006 – abstracts due; 17 November 2006 – notification of accepted papers/posters; 15 December 2006 – close of registration.

Email: weeds2007@ars-ebcl.org
Web: www.cilba.agropolis.fr/weeds2007.html

Biological Control – the Journal

It is worth looking out a copy of the December 2005 issue of *Biological Control* (**35**:3, 181–388), unless you have already read it from cover to cover. The contents are devoted to 'Science and decision making in biological control of weeds: benefits and risks of biological control', edited by Raymond I. Carruthers and Carla M. D'Antonio. Following an editorial by the two editors, papers include:

- Ecological, practical, and political inputs into selection of weed targets: What makes a good biological control target? Raghavan Charudattan
- The role of pre-release efficacy assessment in selecting classical biological control agents for weeds – applying the Anna Karenina principle. Alec S. McClay and Joseph K. Balciunas
- Translating host-specificity test results into the real world: The need to harmonize the yin and yang of current testing procedures. D. T. Briese
- Scientific advances in the analysis of direct risks of weed biological control agents to nontarget plants. A. W. Sheppard, R. D. van Klinken and T. A. Heard
- Microevolution in biological control: mechanisms, patterns, and processes. Ruth A. Hufbauer and George K. Roderick
- Melding ecology, classical weed biocontrol, and plant microbial ecology can inform improved practices in controlling invasive plant species. Anthony Caesar
- Environmental safety of biological control: policy and practice in New Zealand. B. I. P. Barratt and A. Moeed
- Assessment of ecological risks in weed biocontrol: input from retrospective ecological analyses. Svata M. Louda, Tatyana A. Rand, F. Leland Russell and Amy E. Arnett
- Field assessment of the risk posed by *Diorhabda elongata*, a biocontrol agent for control of saltcedar (*Tamarix* spp.), to a nontarget plant, *Frankenia salina*. Tom L. Dudley and David J. Kazmer
- A retrospective analysis of known and potential risks associated with exotic toadflax-feeding insects. Sharlene E. Sing, Robert K.D. Peterson, David K. Weaver, Richard W. Hansen and George P. Markin
- Indirect nontarget effects of host-specific biological control agents: implications for biological control. Dean E. Pearson and Ragan M. Callaway
- The potential for indirect effects between a weed, one of its biocontrol agents and native herbivores: a food web approach. A. J. Willis and J. Memmott
- After biocontrol: assessing indirect effects of insect releases. Julie S. Denslow and Carla M. D'Antonio
- Risk and ethics in biological control. Ernest S. Delfosse
- Risk analysis and management decisions for weed biological control agents: ecological theory and modeling results. Mark C. Andersen, Megan Ewald and Jason Northcott
- Evaluating risks of biological control introductions: a probabilistic risk-assessment approach. Mark G. Wright, Michael P. Hoffmann, Thomas P. Kuhar, Jeffery Gardner and Sylvie A. Pitcher
- Economic framework for decision making in biological control. Karen Jetter
- Applying legal sunshine to the hidden regulation of biological control. Marc L. Miller and Gregory H. Aplet
- Integration of biological control agents with other weed management technologies: successes from the leafy spurge (*Euphorbia esula*) IPM program. Rodney G. Lym

Available online from: www.sciencedirect.com

Chromolaena and Mikania Workshop

With two articles in this issue on chromolaena, this is a good time for a reminder that the 7th International Workshop on Biological Control and Management of Chromolaena and Mikania is being held at National Pingtung University of Science and Technology, Taiwan on 11–14 September 2006.

Chromolaena odorata and *Mikania micrantha* are neotropical plants that have become invasive weeds in the Old World. They invade pastures, vacant land, roadsides, plantation crops and disturbed forests. They suppress local fauna, restrict wildlife movement, and interfere with cultivation. The workshop will include presentations on taxonomy, ecology, biology, and different methods of control of chromolaena and mikania, and a field trip to invasive weed infested areas in southern Taiwan.

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Intractable Weeds and Plant Invaders Symposium

The International Symposium on Intractable Weeds and Plant Invaders will be held at Ponta Delgada, Azores, Portugal on 17–21 July 2006, organized by the EWRS (European Weed Research Society) Working Groups on Invasive Plants, Biological Control of Weeds, and Optimisation of Herbicide Dose, and the IBG (International Bracken Group), in cooperation with the local organizers, Serviço de Desenvolvimento Agrário de São Miguel and CCPA (Departamento de Biologia, Universidade dos Açores).

Agricultural weeds and plant invaders are research subjects generally studied in isolation. However, intractable weeds and plant invaders raise similar questions regarding their understanding and control. This symposium aims to gather researchers from the fields of weed biology and plant invasions to facilitate a broader discussion and a transfer of knowledge between these two complementary fields.

Symposium topics will include: biology and genetics, ecology, toxicology, environmental impact, economic impact, modelling, surveys, databases, regulations, management, mechanical control, physical control, chemical control and biological control. The deadline for application and submission of abstracts is 30 April 2006.

Email: ccpa@notes.uac.pt
Web: www.uac.pt/~isiwpi/

Bridal Creeper News

The publication in December 2005 of the third issue saw the completion of the first volume of the 'The Bridal Creeper', a colour four-page newsletter of the Australian National Asparagus Weeds Management Committee. The newsletters, which give the latest news of the biocontrol programme, are online at: www.weeds.org.au/WoNS/bridalcreeper

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Hogweed Manual

The Giant Alien project, which was funded under the 5th Framework Programme of the European Union from January 2002 to April 2005, involved the collaboration of scientists from the Czech Republic, Denmark, Germany, Latvia, Russia, Switzerland and the UK. The objective of the project was to develop an integrated management strategy comprising effective, practicable and sustainable means of controlling the alien non-agricultural plant, giant hogweed (*Heracleum mantegazzianum*). The project has published a best practice manual, available in eight languages, providing guidelines for giant hogweed management and control.

Wide-ranging studies conducted on the biology and ecology of giant hogweed in the invaded area in Europe and its native area in the Caucasus covered taxonomy and genetics, development and phenology, population dynamics, pathology, herbivorous insects and their impacts, and interactions with soil, nutrients, vegetation cover and land use changes. The manual synthesizes these into an accessible form, summarizing the following aspects of current knowledge:

- Place of origin and historical background
- Identification
- Biology and ecology of the plant
- Seed dispersal
- Effects on surrounding flora
- Public health hazards and safety instructions
- Preventative measures, early detection and eradication
- Evaluation of control methods
- Revegetation
- Planning a management programme

The publication refers specifically to *H. mantegazzianum*, but could be applied to the closely related species *H. sosnowskyi* and *H. persicum*. It also serves as a model for how other exotic species could be controlled or prevented from reaching the invasive phase.

The manual is available in Czech, Danish, Dutch, English, French, German, Latvian and Russian, all of which can be downloaded or ordered from the website: www.giant-alien.dk/

Nielsen, C., Ravn, H.P. Nentwig, W. & Wade, M. (eds) (2005) *The giant hogweed best practice manual. Guidelines for the management and control of an invasive weed in Europe*. Forest & Landscape Denmark, Hoersholm, 44 pp.

Golden Apple Snail Information Online

The NBII (National Biological Information Infrastructure) Invasive Species Information Node now has pages on the golden apple snail (*Pomacea canaliculata*; GAS) with a link to the downloadable global information database on GAS.

Web:
http://invasivespecies.nbii.govgoldenapplesnail.html

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European Invasive Species Website

The new North European and Baltic Network on Invasive Alien Species (NOBANIS) website is a gateway to information on invasive alien species (IAS) in North and Central Europe, covering marine, freshwater and terrestrial environments.

For each country, information on the status, invasiveness and impact of the IAS is neatly presented. Maps covering the entire region show the distribution of species that are particularly problematic. Country searches can be conducted by name, habitat, group, natural distribution (by region), type of introduction, pathway of introduction, current status and potential threat. There are also databases for literature and regional experts. National regulations pertaining to invasive alien species are included. It is planned to add information on management and control of the most invasive species.

NOBANIS is a network of environmental administrators from Northern, Baltic and Central European countries working with invasive alien species. Current members are Denmark, Estonia, Faroe Islands, Finland, Germany, Greenland, Iceland, Latvia, Lithuania, Norway, Poland and Sweden. Finance is provided by the Nordic Council of Ministers and the participating countries' environmental authorities.

Web: www.artportalen.se/nobanis

Contact: Inger R. Weidema, Rural Division, Danish Forest and Nature Agency, Ministry of the Environment
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IUFRO Working Group for Invasives

A new IUFRO (The Global Network for Forest Science Cooperation) Working Party on Alien Invasive Species and International Trade will hold its inaugural meeting in Random, Poland on 3–7 July 2006. The working group has been established to focus specifically on global forestry issues related to the unwanted international movement of all invasive alien species (IAS). The increasing emphasis on pathways for movement of IAS, especially those associated with packaging wood and nursery stock will provide a broad focus for the work of the WP. This emphasis provides an opportunity to integrate across a range of invasive organisms so that links to other IUFRO Working Parties dealing with insects, pathogens and invasive plants will be a priority, as will forming close relations with the International Forestry Quarantine Research Group (IFQRG) affiliated with the UN Food and Agriculture Organization, International Plant Protection Convention (IPPC). Proposed sessions include:

- Relying on inspection systems: new methods and measuring reliability
- Developing clean stock programmes
- Effects of introducing genetic variation into existing pest populations
- Post-entry quarantine systems
- Predicting invasiveness of plant imports
- Wood packing materials: presence of bark
- Wood packing materials: alternative treatments and schedules
- Ecological and economical impacts of invasive species

The meeting will be held in the European Forest Training Centre, Regional Directorate of State Forests.

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Leszek Orlikowski [lorlikow@insad.pl]

British Columbia's Web Tool for Invasives

A web-based tool developed by the Canadian Province of British Columbia is aimed at improving management of invasive alien species by making it easy for stakeholders to share information. The Invasive Alien Plant Program (IAPP) is a web-based data entry system and mapping tool. It will allow about 200 people working in government, industry and local weed committees to quickly and efficiently share information about where invasive plants are located, and what weed control treatments have been used. By sharing data, the agencies involved in invasive plant management will be able to prioritize work across the province, prevent duplicated efforts and measure progress.

The public may also access the application to produce maps showing the location of various weed species in British Columbia.

Web: www.for.gov.bc.ca/hfp/invasive/

Caribbean Food Crops Meeting

The 42nd Annual Caribbean Food Crops Society Meeting will be held in Puerto Rico on 10–16 July 2006, with the theme: 'Food safety and value added production and marketing of tropical crops'. It will be held jointly with the Biannual Meeting of the Caribbean Agro Economic Society (CAES).

In addition to the presentations related to the theme of the Meeting, and topics covered by the CAES, there will be:

- An Invasive Alien Species Workshop, sponsored by the Tropical/Subtropical Agricultural Research (T-STAR) Program of the Universities of Florida, Virgin Islands and Puerto Rico; coordinators Dr Waldemar Klassen and Dr William Brown, University of Florida
- A Workshop on Water Quality in the Caribbean; coordinator Dr David Sotomayor, University of Puerto Rico
- A half-day session on tropical root and tuber crops; coordinator Dr Alberto J. Beale (alberto_beale@cca.uprm.edu)
- A Puerto Rico farmers' forum
- The 2nd Meeting of Director of Agricultural Research Programs (Experiment Stations) of the Caribbean Region
- Presentations from CFCS members on their areas of expertise, such as horticulture, agronomy, crop protection, animal science, and others.

The participation of over 300 CFCS Members is expected at the meeting, and poster presentations are encouraged; a 2–3 hour session and reception will be devoted exclusively to them.

Contact: Dr. Wilfredo Colón-Guasp (English and Spanish language presentations)
Email: ue_wcolon@suagm.edu

Dr. Guy Anais, (French language presentations)
Email: guy.anais@wanadoo.fr

Novel Biotechnologies in Biocontrol

NATO is holding an Advanced Study Institute (ASI) on 'Novel biotechnologies for biocontrol agent enhancement and management' at Gualdo Tadino, Perugia, Italy on 8–19 September 2006.

A NATO ASI is a high-level teaching activity where a carefully defined subject is treated in depth by lecturers of international standing, and new advances in a subject, not taught elsewhere, are reported in tutorial form. It takes the form of a short course contributing to the dissemination of knowledge and the formation of international scientific contacts, and is aimed at scientists at the postdoctoral level. In this case, the ASI offers to participants a concentrated overview of the rapidly developing advanced biotechnological knowledge and tools to enhance and manage biological control agents so that they will be effective in modern agriculture.

Web: www.ispa.cnr.it/NATO-ASI

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Conference Reports

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

Florida Meeting Ground for Biocontrol Workers

The Entomological Society of America (ESA) 53rd Annual Meeting held in Fort Lauderdale, Florida, USA on 15–18 December 2005 (postponed from November owing to Hurricane Wilma) provided a forum for entomologists of all persuasions. Thus it also provided an opportunity for biocontrol scientists to discover what fellow workers have been doing. The reports below focus on two aspects of the large and varied programme.

Symposium on Weed Biological Control in Natural Areas

One symposium was on biological control in natural areas. Invited speakers included state and federal researchers conducting classical biological control projects of invasive plants in diverse rangeland, aquatic, and upland habitats. Topics included retrospective analyses of successful projects on purple loosestrife (*Lythrum salicaria*), giant salvina (*Salvinia molesta*) and melaleuca (*Melaleuca quinquenervia*), and the progress made in on-going projects on Brazilian peppertree (*Schinus terebinthifolius*), mile-a-minute weed (*Polygonum perfoliatum*), kudzu (*Pueraria montana*) and yellowstar thistle (*Centaurea solstitialis*). Additionally, two talks discussed the importance of hybridization in plant invasions. The symposium was a valuable opportunity for researchers to exchange ideas on classical biological control projects at all stages of development.

The goals of the symposium were to: (i) include projects from diverse natural ecosystems that are being threatened by invasive plants; (ii) include both temperate and subtropical systems; and (iii) highlight different approaches to solving the problem and limitations of the research. Presentations included:

- Biological control of purple loosestrife in Illinois wetlands (R. N. Wiedenmann)
- Biocontrol of Brazilian peppertree in Florida: a retrospective and prospective analysis (J. P. Cuda)
- Genetic diversity of Brazilian peppertree and its implications for biological control (W. A. Overholt)
- New prospects for biocontrol of Brazilian peppertree in the USA (D. Gandolfo)
- Biological control of mile-a-minute weed and kudzu (J. A. Hough-Goldstein)
- Hybridization in plant invasions: saltcedar (*Tamarix ramosissima*) and other examples (J. F. Gaskin)
- Successful biological control of giant salvinia in the United States (P. Tipping)
- Biological control of yellowstar thistle (L. Smith)
- Area-wide management of melaleuca in Florida (P. D. Pratt & S. Blackwood)
- The characteristics of a great weed biological control agent; *Oxyops vitiosa* on *Melaleuca quinquenervia* (G. S. Wheeler)

By: Gregory S. Wheeler, Invasive Plant Research Laboratory, USDA/ARS, Fort Lauderdale, Florida, USA, and William A. Overholt, Biological Control Research and Containment Laboratory, University of Florida, Fort Pierce, Florida, USA.

A Biopesticides Perspective

The ESA conference was excellent as a morale booster to counteract the impression that biopesticides are the new phlogiston and to meet up with other normal human beings who also believe that biopesticide work is valid. From a personal perspective it was satisfying that there is still significant regard for the achievements of the project LUBILOSA, which developed Green Muscle® based on *Metarhizium anisopliae* var. *acridum*, effective against locusts and grasshoppers. However, that very regard for LUBILOSA also demonstrates that there have been fewer technical advances in biopesticides over the past few years than required to maintain momentum. Once again, regulatory affairs appear to be a major limiting factor in the adoption of biopesticides.

Because the conference is so vast only a taste of the topics is possible but, with biopesticides in mind:

- On invasive tick and mite species, Mike Burridge suggested that the USA appears to be ignoring the threat posed by, especially, *Amblyomma* ticks, which carry serious livestock diseases. Recent work in Trinidad and elsewhere is indicating that mycopesticides could play a role in their regulation.
- Thaddeus Graczyk gave a talk highlighting the role of flies in vectoring pathogens resulting in gastro-intestinal problems. Some 2.3 million children under 5 years of age die of diarrhoeal diseases each year. Flies appeared again with Phillip Kaufman, Chris Geden and Wes Watson, this time in relation to flies in livestock and poultry units. Flies appear quite susceptible to entomopathogenic fungi and although most interest appears to be with veterinary targets, the medical field may be of great potential in relation to diseases including, for example, trachoma.
- Jeff Lord gave an excellent presentation on stored product pest control using *Beauveria bassiana*.
- Jarrold Leland talked about his work on *B. bassiana* and the lygus bug. Hemipteran pests could form the basis of a new LUBILOSA; there is a lot of separate activity on a range of these pests worldwide, which would be more efficiently conducted under the umbrella of a large project. *Beauveria bassiana* was also featured in talks by Melanie Filotas (against aphids) and Todd Ugine (thrips).
- A symposium on 'Augmentation in Biological Control' included a talk prepared by Roy Bateman on enabling technologies for biopesticides and was based around the LUBILOSA experience. I presented on insect pathogens and their potential to regulate pest populations, rather than using them as biopesticides against a pest outbreak.

The above gives a taste of the biopesticide work presented at the conference, although there were many other interesting presentations and posters. These included an assessment of the positive value of insects to the American economy at US$ 58 billion per year. Biocontrol, pollination and dung breakdown came to $8 billion, with the rest from recreation, consisting largely of the value of insects to the hunting and fishing industries in supporting wildlife in the pre-sport stage of their lives, e.g. before being blown to pieces (ornithology, hiking, etc., did not feature, possibly because of less tangible links).

Invasive arthropod species which seemed of most interest included brown marmorated stink bug (*Halyomorpha halys*), emerald ash borer (*Agrilus planipennis*), sirex woodwasp (*Sirex noctilio*), viburnum leaf beetle (*Pyrrhalta viburni*) and a mite attacking palms in the Caribbean (*Raoiella indica*), while Asian longhorned beetle (*Anoplophora glabripennis*) remains a priority. Plant invasives included *Lepidum draba* (brassica) and swallow-wort, *Vincetoxicum* spp.

By: Dave Moore, CABI Bioscience (UK Centre).

New Books

Methods for Arthropod Biocontrol Environmental Impact Assessment

This book* provides a comprehensive review of the current methodologies used for assessing the environmental impacts of invertebrate biological agents used to control pests in agriculture and forestry.

The content of the chapters was first discussed in June 2004, when 25 sages of the world arthropod biological control community met at a workshop in the Swiss town of Engelberg. The workshop was convened in response to growing calls for a more structured and detailed approach to environmental risk assessment for the use of invertebrates for biological control. CABI Bioscience Switzerland Centre, in collaboration with Agroscope FAL Reckenholz, Switzerland organized the intensive one-week workshop with funding from the Swiss Agency for the Environment, Forests and Landscape and Agroscope. The workshop's aim was to compile a summary of current knowledge and to provide recommendations for further research and regulatory guidance in environmental risk assessment. The participants reviewed the existing methods for evaluation of non-target effects, and produced science-based guidance to those charged with assessing and evaluating environmental risks of biological control introductions. The draft papers presented at the workshop were revised for this book in light of discussions at the workshop and subsequent suggestions. Additional material was commissioned to fill gaps identified at the workshop, so that the book is now a comprehensive presentation of the current state of the art.

The book explores methods to evaluate post-release effects and the environmental impact of dispersal, displacement and establishment of invertebrate biological control agents. It covers methodology on screening for contaminants, the use of molecular methods for species identification and the determination of interbreeding. It also discusses the use and application of information on zoogeographical zones, statistical methods and risk-benefit analysis. It gives practical advice on how to perform science-based risk assessments and on how to use new technology and information. Content includes:

- Current status and constraints in the assessment of non-target effects, D. Babendreier, F. Bigler and U. Kuhlmann
- Selection of non-target species for host specificity testing, U. Kuhlmann, U. Schaffner and P. G. Mason
- Host specificity in arthropod biological control, methods for testing and interpretation of the data, J. C. van Lenteren, M. J. W. Cock, T. S. Hoffmeister and D. P. A. Sands
- Measuring and predicting indirect impacts of biological control: competition, displacement, and secondary interactions, R. Messing, B. Roitberg and J. Brodeur
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Erratum Notice

The paper 'Guidelines on information requirements for import and release of invertebrate biological control agents in European countries' by F. Bigler, J. S. Bale, M. J. W. Cock, H. Dreyer, R. GreatRex, U. Kuhlmann, A. J. M. Loomans & J. C. van Lenteren, which appeared in the December 2005 issue of *Biocontrol News and Information,* should have indicated that its correct citation was:
Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 2005; **1**: No. 001, 10 pp., and that it was being republished in *Biocontrol News and Information.*