General News

Harvesters Get that Sinking Feeling

Just a couple of years ago, sceptics suggested that natural enemies were not up to coping on the grand scale of the water hyacinth (*Eichhornia crassipes*) disaster in Lake Victoria. They may have to eat their words, as that is just what South American *Neochetina* weevils have done to the water hyacinth. Furthermore, impatient stakeholders who favoured a supposedly speedier mechanical solution may have landed themselves with a large embarrassment. Massive harvesting machines ordered expressly (and at vast expense) to deal with the weed arrived in late 1999 to an uncertain future. There is now little weed to be seen on the surface of the lake, and there may be little left for the harvesters to do.

African Colonization

Although it reached Lake Victoria only 10 years ago, water hyacinth, a native of the Neotropics, was first recorded in Africa from the River Nile in Egypt in the 1890s. During the next century it spread from the Nile and later points of introduction in a series of expansions through the continent, until it colonized most of the major freshwater lakes and rivers of Africa. Lake Victoria was one of the last major waterways to be invaded by water hyacinth. It was reached only after the weed invaded in the 1980s the headwaters of the Kagera River in Rwanda, which empties into Lake Victoria at the Tanzania/Uganda border. However, infestations in Lake Victoria have another possible and more direct source: water hyacinth was apparently in cultivation in urban areas around the lake during the 1980s, and so could also have been introduced directly (which is how it is presumed to have reached Lake Kyoga in Uganda).

Water hyacinth has long been perceived as a problem for shipping and fishing industries, and only more recently as a threat to biodiversity. It can undergo rapid proliferation, forming dense mats of plants that cover water bodies, so reducing light and oxygen and changing the water's chemistry, fauna and flora. It poses a real risk to human activities or environmental conservation in the tropical regions of Africa, and in particular in Lake Victoria where the weed has thrived in the eutrophic conditions, notably in the shallow Ugandan coastal waters. Satellite remote sensing technology has recently allowed ICRAF (the International Centre for Research in Agroforestry, Kenya) and Future Harvest (Washington DC, USA) to confirm what many have long been suggesting: nutrients pouring into the lake fed the carpet of water hyacinth that was choking the rest of the life in the lake.

By the mid 1990s the effects of water hyacinth in Lake Victoria had become catastrophic. An unconfirmed report suggested that 12,000 ha of the lake were covered. The weed showed signs of significantly altering the ecological balance of the lake and posed an enormous threat to the region's socio-economy, health and industrial output. It choked the shorelines and created, in the stagnant water, an ideal breeding ground for malarial mosquitoes and the snail hosts of bilharzia. According to James Ogwang, NARO (National Agricultural Research Organization, Uganda), it became a common sight to see large mats of water hyacinth blocking Port Bell and, more seriously, the Owen Falls Dam. Hydroelectric production is particularly vulnerable to water hyacinth as the flow of water into the turbines tends to enhance the aggregation of the weed. Despite the best efforts of operators in four boats fitted with rakes and conveyor belts, the weed periodically clogged the dam, and the Ugandan capital, Kampala, was plunged into darkness. Ogwang points out that in addition to causing domestic inconvenience frequent power cuts had an effect ultimately on industrial output. By blocking ports and landing areas, the weed also threatened fishing industries and disrupted trade as vessels had to wait for wind to clear channels. Fishing communities all around the lake faced a complete loss of livelihood. Passenger services were cancelled and Kenya Railways, who grounded a five-vessel fleet operating between Kisumu, Port Bell and Mwanza in Tanzania, estimated that the weed had caused a 70% reduction in lake transport. At Mwanza, large tankers remained in port, blockaded by metre-high water hyacinth. Water hyacinth even became a threat to security as, for example, Kenyan police and fisheries patrol boats became trapped in weed-locked ports.

The pan-continental extent of the problem was highlighted, says Jeff Waage (CABI Bioscience), at the CAB International Triennial Review Conference in September 1999. CABI's African member countries actively raised their concerns regarding water hyacinth in the discussion of CABI's growing role in invasive species management, and formulated a recommendation encouraging CABI to expand its activities.

A History of Success

Biological control of water hyacinth is nothing new. Indeed, it has been one of biological control's resounding success stories. Initial exploration by staff from CIBC (the Commonwealth Institute of Biological Control – now part of CABI Bioscience) and the US Department of Agriculture (USDA) at Fort Lauderdale in Florida led to the discovery of natural enemies, including two *Neochetina* weevil species and the moth *Niphograpta albiguttalis* (= *Sameodes albiguttalis*) from Argentina. These species have since been distributed worldwide. Water hyacinth was first controlled in Florida using these species. Interestingly, biocontrol there is currently adversely affected by other control measures such that biocontrol cannot reach equilibrium. In Louisiana, by contrast, water hyacinth coverage has been reduced dramatically, although it took many years to reach current low population levels.

Another key player has been CSIRO (the Commonwealth Scientific and Industrial Research Organisation, Australia) who implemented successful control programmes in Australia (in the 1980s) and subsequently in Papua New Guinea (PNG) in 1993-98. The PNG project, funded by ACIAR (the Australian Centre for International Agricultural Research) involved the release of both species of *Neochetina* weevils. On the lagoon system of the Sepik River, water hyacinth covered some 27 km^2 in 1995, but this has been reduced to a fairly stable 5-10 km^2 by the action of the weevils. Weed cover in the worst-affected lagoons was reduced from 80% to less than 10% fringing cover. According to Mic Julien (CSIRO Entomology) temperatures in PNG were not limiting and best control was achieved in eutrophic situations where it took 2.5 years; in less eutrophic situations it took longer, up to 5 years.

In collaboration with USDA and PPRI (the Plant Protection Research Institute, South Africa) and recognizing that the current control agents were not suited to all habitats and may be affected by seasonal events

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such as monsoonal floods, CSIRO studied and released the moth *Xubida infusella* in Australia and PNG. This insect is established but has not yet had time to demonstrate if it will complement other agents and have a significant impact. In addition, field and laboratory studies conducted on the two *Neochetina* weevils demonstrated their different nutrient requirements; *N. eichhorniae* does better on the lower nutrient plants while *N. bruchi* performs best on higher nutrient water hyacinth. Such information has important management implications.

Death on the Nile

Biocontrol in Africa began in the 1970s with release of *Neochetina* weevils and *Niphograpta albiguttalis* on the White Nile in the Sudan. Water hyacinth first appeared there in 1955 and rapidly became a major weed throughout the Judd region, extending over 1700 km from Juba to the Jebel Aulia Dam south of Khartoum. Cooperation between the government of the Sudan and USDA led to the release of *Neochetina eichhorniae* in 1976. Under a joint project involving the British and Sudan governments and CIBC, *N. bruchi* and *Niphograpta albiguttalis* were introduced and large-scale releases were made in 1979-81. All three agents were established in 1980-81 and this led to dramatic reduction in the growth rate of the weed. Since the 1960s, the dam had suffered from annual accumulations of over 11,000 ha of water hyacinth, but since 1982 there has been no build up of floating mats. The formerly intensive chemical control programme was terminated in 1983, although some manual clearing of canals continued. Follow-up studies to evaluate the relative contributions of the three natural enemies were curtailed by civil unrest, but anecdotal evidence suggests that control has been maintained.

South Africa Fields a Strong Team

PPRI is currently conducting enterprising research into water hyacinth biocontrol. Water hyacinth has been South Africa's most damaging aquatic weed since it was first recorded there around 1900. A biocontrol programme was first launched in 1973 with the release of the weevil *Neochetina eichhorniae*, but terminated in 1977 when the authorities opted for quick solutions and resorted to incompatible chemical measures. The biocontrol project was restarted in 1985, since when four more insect natural enemies (another weevil, *N. bruchi*, the moth *Niphograpta albiguttalis*, the mite *Orthogalumna terebrantis* and the mirid *Eccritotarsus catarinenesis*) have been released and established.

PPRI have concentrated recently on investigating reasons for variability in water hyacinth biocontrol. Martin Hill (PPRI) says that they are asking why biological control of water hyacinth has worked in some areas of the world, and some areas of South Africa, but not others. He says that their results suggest that the following may be important in South Africa:

- Eutrophication of water.
- Physical reasons. Many of the affected water bodies are very small. Water hyacinth produces smaller plants and the mats do not hold together as well as elsewhere. The wind and wave action that seems to be important for breaking up mats (as happens, for example, on Lake Victoria) is absent.
- Climatic events. Seasonal flooding or drought adversely affect insect populations and periodic inoculative natural enemy releases may be necessary to overcome this.
- Other control options not compatible with biological control. It is not only pesticides that affect the insect populations. For example, mechanical removal has a negative impact on natural enemy populations, and the creation of untreated reserves as refugia for natural enemies has been shown to be a successful means of dealing with this.

PPRI have also been assessing the impact of the established agents, and assessing new potential control agents.

- The agent first released and still most widespread in South Africa, *Neochetina eichhorniae*, has had a variable impact. Excellent (80%) control was established within 3 years at a site in Eastern Cape Province, but the species has had little impact in Western Cape Province. Results suggest that *N. eichhorniae* is poorly adapted for nutrient enriched conditions or Mediterranean climates. In contrast, the congeneric *N. bruchi* has been shown to perform better in eutrophic conditions and colder climates.
- The mite *O. terebrantis* may have been under-estimated as a control agent and its potential contribution is being re-assessed. A number of new insect agents are under investigation, including a grasshopper (*Cornops aquaticum*) and a mining fly (*Thrypticus* sp.).
- The potential role of pathogens is being investigated. Three pathogens (*Alternaria eichhorniae*, *Cercospora piaropi* and *Acermonium zonatum*) have been identified from water hyacinth in South Africa, although none of them were intentionally introduced, and their provenances remain obscure.
- Climate- and niche-matching the biocontrol agent(s) to the target system means building up a suite of natural enemies to choose from. Thus, for example, PPRI scientists are assessing existing and potential agents for performance in high-altitude areas and, as most species studied/used so far attack vegetative plant parts, they suggest prioritizing for assessment a flower-feeding carabid (*Brachinus* sp.) that reduces seed production in its native range.

Help over Malawi's Airwaves

Water hyacinth has been present in the Shire River in Malawi since the early 1960s. It came from the Zambezi River and spread slowly north along the lower Shire River, colonized the upper Shire and the southern part of Lake Malawi in the mid 1990s, and is still spreading in Lake Malawi. A project funded by DFID (the Department for International Development, UK) to control the weed using biological control was implemented from 1996 to 1999 by the Fisheries Department, Malawi, with assistance from CABI Bioscience and PPRI, South Africa. It had four parts:
(1) establishment of biological control,
(2) community awareness/participation,
(3) monitoring of biodiversity impact and
(4) monitoring of socio-economic impact.

Novel aspects of this project included the active engagement of local communities in biological control implementation and the development of extension messages as radio jingles in three local languages. This is the first project in Africa to contain both socio-economic and environmental monitoring components in an attempt to quantify the effects of the weed and measure the success of control procedures.

Both the *Neochetina* spp. have been established, and they and the mite *O. terebrantis* have been widely distributed along the river, starting with the lower Shire. Large-scale impact of the biological control agents upon the abundance of the weed is not expected for another 1-2 years. However, once water hyacinth reached the upper Shire River, biological control agents were released, and since then there have been consistent reports of low incidence of water hyacinth. One feature of this programme is that it covers control of the weed from relatively oligotrophic waters, in a cooler climate at the start of the Shire River as it leaves Lake Malawi, to eutrophic waters in the hot Shire basin. Hence there is an opportunity to monitor the impact of biological control in different environments in different parts of the river which may give clear indications of how host plant nutrient status and temperature affects the impact of biological control agents.

In the early stages of the project, glyphosate was used strategically to knock down a new and heavy infestation of water hyacinth in the Lilongwe River, which flows into Lake Malawi. After spraying, biocontrol agents were released onto the weed so that the surviving weed would become infested with the biocontrol agents prior to being washed down the river during flooding. Since then, heavy infestations have not been noted on the river.

Work continues now through the water hyacinth component of the Environmental Management Project within the Environmental Support Programme with funding from the World Bank. The Fisheries Department will introduce further biological control agents, including the mirid *E. catarinensis* and the moth *Niphograpta albiguttalis*, with continuing assistance from CABI Bioscience and PPRI.

Plain Sailing again in West Africa

Water hyacinth appeared in the coastal lagoons of West Africa in 1984-85 and quickly spread, causing serious disruption to local communities who lived on or beside the water and relied on it for their livelihood. A programme led by IITA (the International Institute of Tropical Agriculture) at Cotonou, Benin concentrated on the release of two species of *Neochetina* weevils and the moth *Niphograpta albiguttalis*, obtained from CSIRO, Australia. The first releases were made in Benin in 1989, and subsequent releases were made in other countries including Nigeria, Ghana, Côte d'Ivoire, Niger and Burkina Faso. It is still too early to assess results in many of these countries, but Peter Neuenschwander (IITA) says that in Benin the success of the programme is beginning to be recognized as some waterways are opening up to fishing again. In 1999, IITA staff were invited to a fishing festival by fisherman of one formerly covered lake that can now be fished after a gap of 7 years. This festival was shown and explained on national television. However, some of the infestations are still resisting control, and a fourth agent, the mirid *E. catarinensis*, was imported from South Africa in late 1999. In January 2000, another fishing community invited IITA to a similar festival. Economic studies show a benefit/cost ratio for this programme well in excess of 100, which is, Neuenschwander points out, in the same range as other famous biological control programmes against agricultural arthropod pests. Thus, he says, after more than 10 years of painstaking monitoring and advocacy, the successful reduction of water hyacinth is beginning to be recognized by fishing communities and politicians alike.

Lake Victoria: Steering a Way Through

Yet while biocontrol programmes in other African countries were progressing, it was not until 1997 that the problem on Lake Victoria was seriously addressed. At that point it was suggested that the severity of the infestations that had developed meant that biocontrol could take 5, or even up to 10, years to bring the weed under control. Too long, said many. Others argued that natural enemies would never succeed in controlling the weed and that mechanical and chemical methods stood a better chance of providing a much-needed solution. The World Bank made available funding to manage the weed through the Lake Victoria Environmental Management Project (LVEMP). In the first phase of a 5-year sub-regional programme involving Kenya, Uganda and Tanzania, US$77 million were allocated for research on fisheries and water quality in the lake, and management of the wetlands and the environment, and of this $8.3 million were allocated to controlling water hyacinth.

Why, with such a notorious invasive weed as water hyacinth invading the lake, did it take so long for the problem to be recognized and solutions sought? According to Hans Herren of ICIPE (the International Centre for Insect Physiology and Ecology, Kenya), the machinery of international cooperation simply ground too slowly. He argues that specialists in Africa (South Africa, Benin, Zimbabwe and Kenya) with experience of water hyacinth programmes were warning of impending disaster as early as 1991, but were ignored until the problem had reached catastrophic proportions. As a result, the cost and time needed to solve it escalated.

In June 1991, a workshop in Harare, Zimbabwe organized by the Commonwealth Science Council, UK (CSC) in collaboration with IIBC (the International Institute of Biological Control, now part of CABI Bioscience) and CSIRO discussed the control of Africa's floating water weeds. Delegates from eight African countries were joined by water hyacinth control experts and representatives of other concerned bodies. The workshop identified water hyacinth as one of Africa's three worst water weeds. It was described as increasing at an alarming rate in rivers, lakes, swamps and lagoons. The severe socio-economic and environmental impact of the weed was also recognized.

Timothy Twongo, UFRO (Uganda Fisheries Research Organization), speaking at the workshop, reported that aerial surveys of Lake Victoria the year before, in June 1990, had revealed extensive occurrence of water hyacinth in bays and inlets on the Ugandan shoreline and among offshore islands. He warned of casual reports since then suggesting that the weed was spreading rapidly, and he argued that another aerial survey would confirm an escalating picture of colonization of the lake. At the same meeting, Doug Taylor of IUCN (the International Union for Conservation of Nature and Natural Resources) described how the pattern of water hyacinth movement and colony location led IUCN to the mouth of the Kagera River. They found substantial quantities of water hyacinth in the form of large clumps and individual plants continually entering the lake and spreading, mostly northwards, from the mouth of the river. Taylor accurately identified future trouble spots on Lake Victoria: the Owen Falls Hydroelectric Dam at Jinja in Uganda (because of calm water on the lake side), the innumerable fish-landing sites of Uganda's shore and islands, and Kenya's Winam Gulf (because of wind blown weed) and thus Kenya's main lake port at Kisumu. He also noted that water hyacinth had been reported to be covering Speke Gulf east of Mwanza in Tanzania. Taylor said that control of water hyacinth in Lake Victoria would depend upon the introduction of a biological control agent, and that "No other control measure will work because the spread of the weed [in Lake Victoria] is now too wide for application of chemical or mechanical means."

The workshop was prophetic in identifying problems that would subsequently dog the implementation of water hyacinth biological control in Lake Victoria. Participants highlighted:

- Lack of awareness of dangers posed by water weeds at the highest political and bureaucratic levels. Hence, there were no budgets for routine surveillance, nor funds for crisis management, and responses tended to be reactive and delayed. To overcome this, the workshop recommended that a single organization should be responsible within each country for dealing with floating water weeds, and this should be ultimately the responsibility of a political head.
- The ease with which water weeds could move between countries in interlinked waterways, and the effects of nutrient rich water on enhancing water weed populations. The workshop recommended technical cooperation on a regional level and joint action proposals for water weed problems (and the Upper Nile Basin of eastern Africa was recognized as a priority region for this). They identified a need for legislation to address erosion and pollution issues, and suggested that

water weed control should be seen as part of larger land-use scheme for sustainable development of watersheds.

The workshop also recommended that control should be based on integrated methods, but noted that solutions were likely to be site-specific. They recommended that biological control be implemented immediately an infestation was confirmed. They noted that biological control was the only cost-effective, sustainable and environmentally friendly method of combating water weeds; although physical and/or chemical measures should be implemented if these were judged necessary for short term relief, this should not jeopardize the long-term goal of biological control.

With hindsight, the disastrous consequences of the subsequent delay in implementing control measures in Lake Victoria are all too apparent, but at the time the issues were not as clear cut. Advice and information coming in from other parts of the world with experience of water hyacinth invasions gave conflicting messages. Although to some it was a serious threat to utilization of water resources, to others it was a valuable resource for fertilizer, biogas production, fibre and other local industries. Mic Julien comments that unfortunately the decision makers had not conducted the search for information that would have shown that, of the many utilization schemes, large and small, attempted in many countries, only cottage industries have ever continued. The main problems, he points out, are that water hyacinth is about 95% water, and that it grows in inaccessible places; energy and costs for gathering and transporting it for processing are prohibitive. Localized cottage industries are unable to use sufficient weed to offset the problems it causes.

Cooperation between countries was a problem: the weed spread more easily and quickly than information across borders, and inter-country consensus was not always easy to get, despite the facilitation role of FAO (the Food and Agriculture Organization of the UN). The three countries bordering Lake Victoria's shores held divergent views on the nature of and solution to the spread of the weed. In addition, the problem facing Kenya, Tanzania and Uganda on Lake Victoria was traced back to the Kagera River in Rwanda. How could a problem for these countries be addressed by action taken in a fourth? Even within one country, water hyacinth management fell uneasily between camps: weed control is normally the remit of agriculture ministries, and impedance of shipping and ports falls outside their area of influence. New concerns about its effects on biodiversity brought in environment ministries. This meant that no single ministry was completely informed about the problem, or had responsibility for dealing with it. The result was a delay in recognizing the problem, and then in dealing with it while inter-ministry committees were set up to organize a national programme. Jeff Waage points out that some of the greatest tragedies associated in recent years with alien species have occurred when the problem fell snugly between the remits of different agencies. He says that with water hyacinth in Lake Victoria, only when this problem was resolved could real progress be made with limited national resources. Even then, the need for better inter-ministerial and inter-governmental coordination still constrained implementation.

Once the need for some form of control on Lake Victoria was agreed, there was still conflict over the best approach. Some recognized biocontrol as desirable, but others were dubious about importing an alien species to control an alien species – especially to Lake Victoria, where the legacy of Nile perch introduction looms large. And this, says Julien, was despite evidence that biological control had controlled significant water hyacinth problems in other countries without unwanted effects. Mechanical control meant the use of large pieces of equipment of questionable appropriateness and efficacy – the first delivered to Uganda sank on the day it was launched. However, harvesters were popular with aid programmes, especially if they could be sourced from the donor country. Agrochemical companies that had effective marketing and distribution networks in the countries concerned advocated chemical control.

It was several years before all these issues were resolved, and by then the water hyacinth problems on Lake Victoria had reached the catastrophic proportions described above.

Uganda's Silent Warriors

Biological control of water hyacinth in Uganda is spearheaded by the Biological Control Unit of NARO – a semi-autonomous research organization under the Ministry of Agriculture, Animal Industry and Fisheries. James Ogwang says that it is not an overstatement to say that one of the greatest scientific achievements in Uganda in recent times, which seems to have gone largely unnoticed, is the seemingly 'sudden disappearance' of water hyacinth from Ugandan waters, especially Lakes Victoria and Kyoga.

Ogwang explains that this started in 1992, when the Ugandan government, through NARO, formulated the National Task Force on the Control of Water Hyacinth. This body of Ugandan experts in various scientific fields was charged with advising the government on the best way to combat the weed. The task force recommended an integrated approach using mechanical measures, natural enemies (biological control) and, pending conclusive tests, possibly herbicides. However, says Ogwang, following a public outcry and debate about biosafety, the National Environment Management Authority of Uganda (NEMA) decided that herbicide use should be deferred. To date, Ogwang emphasizes (and a point we return to later), no herbicides have been used in Ugandan water bodies against water hyacinth other than in small area controlled trials. The control options that have been used are mechanical harvesters (mainly at Port Bell and the Owen Falls Dam, where they kept the turbines free of weed and reduced blackout time and maintenance) and biological control agents. In 1992, the National Task Force recommended the importation of the weevils *N. bruchi* and *N. eichhorniae* from IITA in Benin.

However, it took some while longer before the weevils could be released in Lake Victoria. There was initial opposition from Kenyan quarantine authorities to releasing biocontrol agents into Lake Victoria until further safety tests had been conducted. Ogwang says that despite their safety record elsewhere, NARO scientists were required to carry out safety tests on bananas (a staple food crop in Uganda), rice, onions and egg plants/aubergines to reassure doubters in both Uganda and neighbouring countries before releases were allowed in Lake Victoria.

In the meantime, a successful 'pilot' programme on Lake Kyoga was funded by the CSC and implemented by Ogwang and Ken Harley (CSIRO). Ogwang received training from IITA in Benin and brought back *Neochetina* weevils, which were reared at Namulonge Research Institute, where they subsequently adopted rearing techniques developed by CSIRO. Weevils were harvested monthly and released onto dense weed mats in Lake Kyoga, beginning in 1992. Additional rearing stations were constructed at three other sites around the lake, and fisheries staff and local fisherman were trained to manage these stations. Together, these increased the rearing capacity and numbers of weevils released, and the distribution and spread of the weevils.

Over the first 5 years of the project, the weevil populations built up progressively, reaching up to 16 weevils per plant by the end of 1997. Plant weight and other parameters of plant growth were also found to have fallen dramatically, and although no formal measurements of infestation surface area was made, it was evident that a significant reduction occurred over the 5 years since the weevils had been introduced. Regrowth and seedling growth was heavily attacked, as the weevils prefer young plants. However, the water gradient of the White Nile was also crucial. Reduced growth and weevil-damage meant that the weed was unable to form dense mats, and those that formed broke up more easily and were swept downstream. Weevil-damaged plants also appeared unable to attach to the bank and were swept away. Problems experienced by fishermen at landing sites were considerably reduced, and severe weed blockages were rare.

Following Kenya's agreement, weevils were released into Lake Victoria in December 1995. Ogwang says that since 1995, weevil rearing has continued at NARO's Biological Control Unit based at Namulonge Research Institute and at onshore rearing facilities constructed at seven sites along the shores of Lakes Victoria and the mouth of the Kagera River. He describes how the biocontrol programme again recruited and trained fisheries extension staff and local fishermen in lakeside communities for the mass rearing programme. "They were", he says, "instrumental in the fast distribution of the initial weevil population in our lakes."

Ogwang also pays tribute to the weevils: "These silent warriors have been slowly but surely causing irreversible damage by reducing leaf area, root length, petiole length and reducing plant vigour and weight". He says that the weed has been dying back at a stupendous rate in remote parts of both lakes, since 1992 in Lake Kyoga and 1995 in Lake Victoria. But, he intimates, most of the world remained in ignorance: "The only witnesses to this noble process have been fishermen themselves," and he observes that the fishermen were convinced and appreciative long before alleged 'experts'.

Tanzania Stems the Weed

Water hyacinth has been present on the Sigi and Pangani Rivers in northeastern Tanzania since the 1950s. Environmentalists did not recognize it as a threat although it had been interfering with hydroelectric power generation at Hale on the Pangani River since 1964. The Tanzanians employed control measures of manual removal and prevention of weed movement that complemented each other; 200 litre drums were used as booms to protect the water intakes from the floating weed, and these were found to be more effective when the accumulated material was manually removed.

The two *Neochetina* weevil species were imported into Tanzania in April 1995 from IITA. The national programme team, led by Gaspar Mallya, was given training in rearing and monitoring techniques by CSIRO. Rearing units were established at the National Biological Control Centre at Kibaha, near Dar es Salaam. Harvesting of the biological control agents started in August 1995 and 2000 weevils were released on the Sigi and Pangani Rivers. By June 1996, 9460 weevils had been released and their establishment and impact on the weed has since been confirmed. Manual removal of the weed at Pangani Falls water intake has not been required since late 1997. (However, as a consequence, the local community has been deprived of their previous employment of manually removing the weed.)

Water hyacinth was first reported from Tanzanian Lake Victoria in 1991. Mobile weed mats were less of a problem here than in the northern part of the lake. The main infestation was a ribbon of weed along the shore. By 1998 an estimated 2000 ha of lakeshore was covered with the weed, which impeded landing sites and access to the lake. Manual removal was extensively employed. In the Mara and Mwanza regions, regional and district authorities organized village communities into self-help groups, and over 200 tonnes of the weed were removed from the landing beaches in one year in the Mara region. Where manual removal was not organized, fishermen occasionally employed casual labour to clear the landing sites and fish was often used as payment. Equipment used in manual removal included rakes, hoes, wheelbarrows, forks, etc. These tools, and protective gear, were made available by LVEMP to the communities involved. Prior to this, manual removal was carried out barehanded.

The most likely source has been confirmed as the Kagera River. Large clumps of the weed are today seen drifting downstream some 50 km above the mouth of the Kagera, but these are largely dismembered as the river goes over two waterfalls *en route* to the lake. Surviving stem fragments anchor to the banks and grow into plants, and then mats, which break away to drift into Lake Victoria.

Since August 1997 *Neochetina* weevils have been released in Tanzania at 20 points around Lake Victoria and along the Kagera River. More than half of the weevils released was harvested from the Sigi and Pangani Rivers where many weevils were present on the severely damaged water hyacinth. The number of weevils so far released in Lake Victoria has been small in comparison with the magnitude of the problem, so the Water Hyacinth Control Component of the LVEMP has developed simple techniques for increasing redistribution. The Mobile Rearing Unit uses plastic buckets and basins that are moved from one site to another along the shoreline. Mated females are allowed to lay eggs in water hyacinth plants in buckets, after which adult weevils are harvested from the plants. The plants with eggs and larvae are placed in the field amongst water hyacinth and adults are placed on new plants in buckets to lay more eggs. In addition, Adult Weevil Multiplication Centres have been constructed around the lake for rearing and harvesting of weevils. Using these methods many thousands of adult weevils and plants containing immature stages have been released in the lake.

The establishment of biocontrol agents released on the lake was confirmed, and aided by water currents and waves the infested plants were found to have taken the agents far from release points.

Kenya Beating the Colonizer

The Kenyan biocontrol programme is being conducted by KARI (the Kenya Agricultural Research Institute) and training has been provided by CSIRO Entomology. *Neochetina* weevils imported from Benin (IITA), Uganda, South Africa (PPRI) and Australia (CSIRO) were released directly into the field or reared in quarantine facilities at the National Agricultural Research Centre at Muguga, where host specificity testing was completed. Subsequently, they were reared for mass release at a newly constructed facility at the National Fibre Research Centre at Kibos, close to Lake Victoria, by a team led by Gerald Ochiel (KARI). A combination of container and pool rearing methods allowed a monthly production of some 2000 weevils. Infested plants and a total of some 36,000 adult weevils were released at 27 sites around the Kenyan shoreline of the lake between January 1997 and August 1998. Releases were made more than 50 m from the shore on stationary and floating mats; the latter helped disperse the weevils to non-release sites. Releases by canoe reached some otherwise-inaccessible sites.

Preliminary monitoring surveys conducted in 1998 indicated that the weevils had established at release sites, and they were also recovered at non-release sites up to 50 km from the nearest release site. Sampling indicated that they were reducing leaf size and weight, and that larval mining and feeding and adult weevil densities were generally increasing.

What Weed Mats?

To biological control experts such as Mic Julien, the initial results of all three country programmes were not surprising and were immensely encouraging, with the weevils established in all the countries. However, and in line with predictions, there was no obvious early evidence of the weed mats retreating on Lake Victoria. Julien says that although he had deliberately given a conservative time frame of 5+ years for achieving control, the expectations of people unfamiliar with biocontrol and those agitating for other methods to be used were still that instant changes should be seen. Biological control was on track, he says, but people ignorant of plant–insect interactions or with other agendas could not understand, or did not want to know. Other methods were argued by them to be the only option for at least short-term alleviation. Under the World Bank project, $1.3 million was awarded to an American firm to supply machines to Kenya that would chop the hyacinth into small pieces, a move opposed by environmentalists and lakeside residents concerned about leaving the chopped weed in the lake as another source of pollution.

The first 'Swamp Devil' harvester, costing $300,000, arrived in September 1999. But as it was being unloaded on the shore at Kisumu in Kenya, something had happened out on the lake. While the machines were in cumbersome transit, the water hyacinth began to turn brown and shrivel – not in fear of the harvesters, but because the accumulated effects of the introduced weevils had taken their toll over the previous few years. The changes becoming visible in the water hyacinth populations did not come as a surprise to Julien, who had predicted such an outcome a year before.

During a mid term assessment of the biological control component of LVEMP in November 1998 in Uganda, Julien and James Ogwang had found very little water hyacinth remaining in bays that previously had been clogged. The weed, says Julien, had sunk during the preceeding few months. An assessment was made of data collected by Ogwang and Richard Molo (NARO) and chronologies of activities and changes provided by a wide range of people (fishermen to recreational boaters to scientists). The results indicated that the activities of the weevils had contributed to the demise of the weed, and this, Julien points out, within 2.5 years of the release of the first weevils on the lake by Ogwang. Julien had also visited Kenya as part of the same assessment. He and Gerald Ochiel had found that although the surface area covered in that part of the lake remained unchanged, the entire floating mats were severely damaged and were showing signs of water logging (floating lower in the water as a result of larval tunnelling in the crown and in the lower portions of the petioles which reduces flotation through water logging). Every plant they looked at had a number of adult weevils, larvae and eggs. Julien predicted then that the mats would sink within the following 12 months.

Julien says that the results in Uganda and the impending control in Kenya were relayed to the LVEMP secretariat in Kenya and the World Bank, but the decision to import mechanical harvesters was upheld. Yet while the harvesters were on the high seas to Mombasa, being transported to Kisumu and made ready for their task, the mats of water hyacinth were sinking.

A survey of Uganda by Timothy Twongo in November 1999 found very little water hyacinth along the Ugandan mainland coast and around the islands. Peter Neuenschwander, who visited the area with Ogwang in late 1999, said that the impact of the released weevils was much faster than they had experienced in West Africa. He says that the results from Uganda now are absolutely spectacular. Around Jinja, where until recently bays were clogged with the weed, the waterways are clear. He and Ogwang found only a few clumps of water hyacinth and these were heavily infested with the weevils. Even the Owen Falls dam was clear, and Neuenschwander says that this was an unexpected bonus, as remaining weed could have been expected to accumulate here. Ogwang says that at one time there were massive dry mats of dead weed with millions of stranded weevils at the Owen Falls Dam, and that it was common to see many birds, especially the cattle egret, on the dry dead mats, feeding on the stranded weevils. He likens the weevils to gallant soldiers who have successfully accomplished their assignment, and says that many have since perished because there is simply no water hyacinth left to feed on.

In Kenya, Julien and Ochiel inspected the water hyacinth in December 1999, and confirmed that at least 75% of the weed had sunk. Bays that had been locked in with water hyacinth for years (and in some cases abandoned by the fishing communities) were now essentially clear of the weed, and fishing activities had recommenced. The remaining fringing mats were heavily damaged and harboured many weevils. The remaining floating material consisted of small (up to 3 m × 3 m but mostly much smaller) mats of water hyacinth held together and prevented from sinking by hippo grass (*Vossia* species) that had broken away from fringing mixed species mats. Julien anticipates that as the water hyacinth dies, from insect damage and/or competition from the hippo grass riding on its back, the hippo grass will be deposited in the lake to sink to the bottom.

Neuenschwander reports a similar story from the southern side of the lake at Mwanza, which he visited in late 1999. Steamers are no longer port-bound by the weed in Mwanza Bay and the remaining fringe of water hyacinth around the shore is heavily infested by both species of *Neochetina* weevil.

Doubting Thomases

It still remains to convince some, both that water hyacinth has been brought under biological control, and that the weevils are responsible. At Kisumu, for example, where the mats have floated out into the lake, the reduction in weed cover is widely attributed to the wind. At Mwanza, fishery authorities were reportedly mystified as to the cause of the sudden clear waterways. These views are perhaps understandable, given the seasonal changes and movements of water hyacinth mats on the lake in previous years.

However, James Ogwang is irritated by a sudden plethora of alternative explanations for the disappearance of the weed, which he said are being proffered by alleged 'experts' on biocontrol. He dismisses these as ill-informed, describing their purveyors as "prophets of doom" and he is keen to see any apparent mystery cleared up. The most scurrilous explanation currently propounded is that herbicides were used to control water hyacinth in Uganda. Ogwang explains that this belief originated because of the practice of unscrupulous fishermen who used poison to increase the harvest of fish from the lake, for what he describes as their selfish economic gains. This led to the European Union (EU) slamming a ban on fish imports from the East African region, but he points out that herbicide residues were never detected in EU fish samples, and two different stories became confused. In truth, he says, no herbicides were used to reduce the water hyacinth biomass in Uganda. Ogwang points out that: (1) Herbicides such as 2,- 4-D and glyphosate do not kill fish instantly and were not used by fishermen. (At most, given the low dosage commonly used in aquatic systems, there might be some long-term cumulative effect.) (2) In Uganda there are many other aquatic plants such as papyrus, hippo grass, Nile cabbage, etc., in the water bodies. If herbicides had been used at all against water hyacinth, all these other aquatic plants would have perished as well – but they are still healthy and flourishing. (3) It would require a massive operation, possibly involving aerial sprays, to rapidly kill the weed and therefore it would virtually be impossible to spray the weeds secretly, even at night, without being detected. Mic Julien also points out that experience elsewhere has shown that for large infestations repeat spraying is required for the initial kill and rapid regrowth requires repeated applications to maintain control. Control on the lake is being maintained and there is no evidence that herbicides are being applied on any scale let alone on the scale that would be needed.

Ogwang is equally dismissive of those who have ascribed the disappearance of weed to *El Nino*. Perpetrators of this explanation argued that the abnormally high amounts of rain during the *El Nino* added so much water to the lake that it became diluted to the extent that the water hyacinth could not get enough nutrients, and hence it disappeared. But, as Ogwang puts it, this explanation holds little or no water. He points out that high rainfall would lead to more rather than less nutrient being washed into the lakes, owing to increased erosion, in which case the weed growth would have been, if anything, enhanced rather than decreased. Elsewhere in Africa and the world water hyacinth grows prolifically in waterways less polluted than Lake Victoria.

Harvesters Left High and Dry

Harvesters have been in use in Uganda for a number of years, where they did sterling work in keeping the Owen Falls Dam turbines largely free of the water hyacinth. They were also used to remove weed from Port Bell, although with probably less impact. They have been idle since late 1999.

In Kenya, the 'Swamp Devils' were launched in late 1999, and did some clearing of weed at Homa Bay. Then the weed moved, but it did not settle in Kisumu Bay, as expected, or indeed anywhere else. This, says Mic Julien, was because a lot of it sank due to biological control, leaving just small mats of water hyacinth supporting other species. Julien suggests that although these will sink eventually (when the water hyacinth becomes sufficiently damaged), the harvesters are meanwhile doing a useful job around Kisumu, chopping these mixed mats and also papyrus mats. However, the future employment prospects of the Swamp Devils are uncertain: they are not capable of chasing around Winam Gulf looking for remaining water hyacinth.

The harvester contract, to chop 1500 ha of water hyacinth and leave it in the lake, cannot be fulfilled, says Julien, and this is also good news for those concerned about the environmental impact of such an activity. He estimates that there is not one third of that amount of water hyacinth left and the amount is decreasing daily as the weed succumbs to the weevils. Julien says that on his recent flights to and from Kampala's Entebbe Airport and Kisumu he saw no mats in Ugandan waters and a few limited mats off the Kenya coast, and they are in the process of disintegration.

Julien is surprised only by the speed at which the control of water hyacinth has been achieved. Successful control using solely these weevils has been achieved in a number of other countries, and based on that knowledge and experience, he fully expected biocontrol to be useful in Lake Victoria. He indicated a time span of at least 5 years so as to be realistic and not oversell biocontrol. Julien says that such good results after 2.5-3 years suggest that temperature and nutrition have not been limiting, and the results are similar to those achieved in nutrient-rich waters in PNG.

Julien is in the process of determining the feasibility of using remote sensing to verify the change in surface area of the weed mats. However, ground-level assessments to check on the weevil presence and plant density have already been conducted by Gerald Ochiel and Julien in Kenya in November 1998 and December 1999 and by James Ogwang in Uganda in December 1999. Their results provide solid evidence for the key role of the weevils in the disappearance of the weed.

Mic Julien and Hans Herren are agreed that there is a good chance that the harvesting could be abandoned and the weevils left to reduce the weed to mere decorative matter. Herren adds that it is time urgently to review the project and decide on the best follow-up, both for what is now being confirmed as the successful biological control of water hyacinth on Lake Victoria and for the associated problem of eutrophication of the lake waters. However, Herren is anxious that people should not see biological control as a cheap last resort, to be turned to after large sums of money have been spent ineffectively on other methods. He points out that biological control, if done well, costs money, and not least for monitoring activities, for which funding is all-too-often cancelled once a problem seems to have gone away. On the other hand, because biological control, in the classical sense of the term, provides a permanent solution, it offers huge savings over recurrently needed methods, such as pesticides or mechanical removal.

Ogwang is quick to point out that although most of the mats of water hyacinth and their weevil populations have all but disintegrated, there is a real possibility that remnants of the weed and young plants that sprout will re-grow and pose some threat. The plants would be growing in an environment with few or no weevils. Additionally, fresh massive amounts of the weed are daily being fed into Lake Victoria from the Rwanda highlands via the River Kagera. "In effect," he says, "we have won the battle but the war is still much around." Future activities planned by the Uganda programme include: the construction of more weevil rearing facilities for maintenance of weevil releases; Rwandese and Burundian nationals trained by Uganda to initiate weevil release so that weeds that enter Lake Victoria would carry weevil infested water hyacinth; research on other potential natural enemies including pathogens; and monitoring any changes in weed biomass to determine appropriate action.

Good Groundwork

The water hyacinth biocontrol experts who argued back in 1997 that giant harvesters were not the answer were not Luddites lying down in the path of progress. They really did know better, and there was already plenty of evidence of their better judgement in the clear waterways around the world where natural enemies had been allowed to feast in peace. As the British *Guardian* newspaper put it, "Forces of Weevil Trump World Bank" [16 January 2000]. Will rusting harvesters be left to line the shores of Lake Victoria as manifest evidence of international development's continuing folly? Or will someone somewhere see sense, send the monsters home, and put the money to better use? Herren suggests that the enormous and probably unneeded funding for mechanical harvesting would be better directed towards more biological control training. Julien says it should be used to develop better integrated and sustainable strategies for other weeds and pests, including training and infrastructure based on catchment and regional approaches. This idea is supported by Herren who advocates the establishment of a permanent regional facility, and also suggests that publicizing the success of water hyacinth biocontrol can assist with prevention activities in the lake's watershed.

Organizations involved in international programmes often disagree over the finer points of who did what, and history tends to be treated as a creative subject when it comes to apportioning credit for success. However, it is clear in this instance that most credit for the success of biocontrol of water hyacinth on Lake Victoria is due to the national programme staff who persevered, on occasion in the face of indifference and even outright opposition, against what they were told by so many alleged experts were hopelessly overwhelming odds. With the vital support of experts in water hyacinth biocontrol from around the world (CABI, CSIRO, ICIPE, IITA and PPRI), yet with often little money and inadequate resources, they succeeded in rearing and releasing the weevils, albeit not always in enormous numbers, and in training and mobilizing local communities. The exciting results now being reported are their vindication.

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Riparian Weed Invades Concrete Jungle

Japanese knotweed (*Fallopia japonica* syn. *Reynoutria japonica*) is an unwelcome intruder in the UK, not least because it is capable of bringing down walls and gravestones, and pushing through concrete paving. It has even been found growing through the foundations of a house in Wales and sprouting up from behind a sofa. Its main threat, however, is to riparian habitats. Its formidable strength is attributable to a mass of rhizome that can extend to a depth of over 15 m from which the plant can grow at a peak rate of more than 40 mm per day to reach well over 3 m in height. This otherwise handsome perennial is a classic example of the escape of a 'desirable' garden plant into a new environment in which it has spread exponentially. Remarkably, research has shown that the whole UK infestation originates from one 'mother plant' and, since knotweed is currently restricted to asexual reproduction, the whole population could be considered one organism – a fact that has led to one national newspaper headline, "Largest female on earth could strangle Britain".

Knotweed is extremely difficult to control since herbicide use is restricted on its favoured riparian habitats and a fragment of rhizome weighing just 0.7 g left in cleared land can regenerate a new plant. Its ability to push through tarmac and concrete means that infested land earmarked for development must be cleared of all knotweed remnants and the soil disposed of at specialist landfill sites. The cost of this process is considerable and can add 10% to a developer's overall budget. Knotweed also disrupts river protection works, increases the risk of flooding, and restricts access to waterways whilst excluding native vegetation under its dense canopy. Although estimates are hard to come by, Japanese knotweed control costs are likely to measure in the millions of pounds per year in the UK alone.

In its native range of Japan, south China and Korea, Japanese knotweed exists as a component species in the succession process. For example, it acts as a colonizer on the inhospitable volcanic fumaroles of Japan where it is soon outcompeted by other vegetation. The scientific literature shows a considerable range of natural enemies inflicting damage, in some cases severe, to Asian populations including a promising chrysomelid beetle and two primary pathogens whose specificity is likely to be high.

Steps are underway to implement classical biological control programmes against Japanese knotweed in the UK and the United States. CABI Bioscience has been developing biological control programmes against this, and other introduced riparian weeds, for over a decade. This groundwork, along with a scoping study funded by the UK Environment Agency, has resulted in biological control being identified as the only sustainable solution to this 'knotty problem'. A meeting was recently held at CABI Bioscience's Ascot site in order to present the proposal, and to clarify the principles and safety of weed biocontrol to potential funding organizations in the UK including the Welsh Development Agency, the South West Development Agency and the Environment Agency. The proposal is also under consideration by concerned parties in the eastern United States where biological control is increasingly the first line of defence. This situation contrasts sharply with the UK where classical biocontrol is considered 'novel and controversial' since there has never been a complete programme against a weed target in the UK.

A collection of over 50 newspaper articles on the subject of Japanese knotweed in Britain stands testament to public opinion on this unwelcome invader, and only funding stands in the way of this plant being faced with the old enemies it has done so well without.

A website entitled the Japanese Knotweed Alliance will shortly be coming on line and will be accessible through the CABI Bioscience website at www.cabi/bioscience

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Fungal Solution for Crop Pests?

American scientists have been looking into the possibility of harnessing the fungi *Beauveria bassiana* and *Paecilomyces fumosoroseus* for control of two major crop pests: diamondback moth (DBM) (*Plutella xylostella*) and Russian wheat aphid (*Diuraphis noxia*). USDA Agricultural Research Service (ARS) scientist John Vandenberg says that fungi are a promising alternative for pests developing resistance to *Bacillus thuringiensis* (*Bt*). A significant feature of the research has been extending laboratory work into the field, and assessing the commercial and large-scale efficacy of fungal preparations.

Diamondback Moth

This lepidopteran pest of brassica crops has become problematic in recent years because of the development of resistance to insecticides, including the microbial pesticide *Bt*. Because of this, a significant proportion of the control treatments applied worldwide, which in total cost some US$1 billion annually, is of limited efficacy.

In laboratory studies, Vandenberg's team working with Cornell University scientists found dramatic differences between strains of *P. fumosoroseus* in their ability to infect and kill DBM. There were some highly virulent strains, and these were characterized by having large spores that attached easily to the insect cuticle and germinated quickly. They were thus able to penetrate the cuticle and initiate infection more quickly. All larval stages were susceptible to infection by *B. bassiana* in laboratory tests, but those that were exposed shortly before moulting avoided infection because the contaminated cuticle was shed before the fungus could penetrate it.

Moving into a farm-based setting, Vandenberg and his collaborators looked at the efficacy of *B. bassiana* for DBM control on cabbage seedlings in screenhouses (the conventional way of raising plants for the field in the USA), using a commercial formulation of *B. bassiana*, Mycotrol (Mycotech; Butte, MT, USA). Weekly or twice-weekly applications significantly reduced insect populations and seedling damage compared with water-sprayed controls. The control achieved was as effective as conventional insecticide treatments, and persisted for more than two weeks. Mycotrol as a wettable powder and an emulsifiable concentrate also reduced DBM populations when applied to larger plants in the field, and multiple applications improved performance.

Further field trials investigated the potential for *B. bassiana* in the season-long control of DBM and other lepidopteran pests *(Pieris rapae,* the imported cabbage worm and *Trichoplusia ni,* cabbage looper) in fresh market cabbage. Treatments assessed included *B. bassiana* strain GHA (Mycotrol ES) at $1.25\text{-}5 \times 10^{13}$ spores/ha, *Bt* var. *kurstaki* (Javelin WG) at 0.3 and 1.2 kg/ha, and simultaneous or sequential combinations of the *B. bassiana* and *Bt* treatments. Six applications were made between 4 August and 15 September 1998, insects were sampled five times during the season, and damage and marketability were assessed at harvest. The use of *B. bassiana* alone reduced DBM numbers at all rates used, and *P. rapae* and *T. ni* numbers were reduced at higher rates. Both rates of *Bt* reduced numbers of all three pests. Four applications of *B. bassiana* followed by two late-season *Bt* treatments reduced larval counts of all three pests also. However, the results of these sequential treatments, and simultaneous treatments in which *B. bassiana* and *Bt* were applied simultaneously as tank-mixes, indicated that combined treatments were no better at reducing larval counts than *Bt* alone at either rate. Laboratory tests of the efficacy of *B. bassiana*-treated leaved for DBM indicated about 80% efficacy for freshly treated leaves, but this dropped to about 40% for samples taken three days after treatment. There were no differences in cabbage head weights between treated and untreated plots, but cabbage head marketability was best among *Bt*-treated plots and reduced in plots treated with *B. bassiana*.

In conclusion, although *B. bassiana* worked well alone against DBM and provided some control of other pests, reliable control of this complex of cabbage pests may require the development of other *B. bassiana* strains with better activity against Lepidoptera. However, just one or a few large larvae can inflict late-season damage to cabbage heads, and therefore late-season application of a highly toxic faster-acting insecticide may remain necessary to preserve marketability. However, combining early season *B. bassiana* with late applications of *Bt* or chemical insecticides may help to slow or limit the development of insecticide resistance.

Russian Wheat Aphid

Russian wheat aphid invaded the USA in about 1986 and since then has cost some US$850 billion in lost yields and control and other costs. It spends the winter primarily on wheat and barley throughout its North America range, which now extends through 16 American states and two Canadian Provinces.

In field studies run over three seasons, Vandenberg together with University of Idaho scientists tested the ability of spores of *B. bassiana* and *P. fumosoroseus* to control the pest on artificially infested spring-planted wheat. They found significant reductions in aphid populations in all three years in plots sprayed with *B. bassiana* as Mycotrol. Sampling four days after spraying revealed that 52% of aphids on wheat tillers were infected. In 1997-98, Mycotrol was applied to larger (0.4 ha) plots using a moveable pipe irrigation system. Aphid populations dropped significantly within 2-3 weeks of spraying. It has thus been proved that the treatment works on a large scale and has commercial potential, and this is the first time that the efficacy of Mycotrol against Russian wheat aphid has been demonstrated.

Tests with *P. fumosoroseus* proved inconclusive, however. The fungus reduced aphid populations in 1995 but not 1996 after one or two applications. The team is now looking at ways of improving the field stability of this fungus in collaboration with an ARS microbiologist.

Source: *Agricultural News,*
September 1999.
http://www.ars.usda.gov/is/AR/archive/sep99/fungi0999.htm

Impact on Nontargets

Before *P. fumosoroseus* can be deployed for Russian wheat aphid control, its effects on nontarget organisms need to be evaluated. Preliminary studies have been carried out by Vandenberg in collaboration with Judith Pell from IACR-Rothamsted, UK. They have examined the impact of *P. fumosoroseus* on convergent ladybirds, *Hippodamia convergens*.

Laboratory studies have shown that under certain conditions ladybirds may become infected with the fungus, but how far this physiological susceptibility in the laboratory might translate into ecological susceptibility in the field remains to be determined. Laboratory bioassays found some individuals succumbed following *P. fumosoroseus* sprays, and this was thought to be related to the degree of pre-trial stress to which they had been exposed. In a relatively unstressed batch of ladybirds, no mortality was observed following exposure to *P. fumosoroseus*, apart from a low (6.7%) level where ladybirds were exposed to 10× the field concentration and incubated for 72 h at 100% RH.

In general, the ladybirds avoided feeding on aphids showing signs of fungal infection. Starved ladybirds ate recently killed cadavers, but only when these were still green and showed no visual sign of infection. However, ladybirds became contaminated with conidia while foraging in the proximity of sporulating aphid cadavers, and were found to be able to vector the conidia to healthy aphids. Infection was initiated in an average of 53.1% of aphids exposed to contaminated ladybirds, whilst four out of seven contaminated ladybirds also became infected. Ladybirds foraging in the environment of sporulating cadavers are therefore most at risk from infection.

Information: Bulletin IOBC /OILB 1998,
Insect Pathogens and Insect Parasitic
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LUBILOSA: the Stewardship Phase

Over the last nine years, the biological control of locusts in Africa has become a reality with the development of Green Muscle® by the LUBILOSA (LUtte BIologique contre les LOcustes et les SAuteriaux) programme. Green Muscle® consists of a virulent strain of *Metarhizium anisopliae* that specifically infects and kills locusts and grasshoppers, and it can do this within 6-12 days of application. Locust feeding is markedly reduced within 3 days of infection, and over a 3-week period, the biopesticide's killing power is greater than that of conventional knock-down insecticides. It can be applied using conventional ULV spray equipment and has exceptionally good storage characteristics for a biological agent. Infected locusts can also provide a source of inocula for re-infection. It has been extensively tested and shown to be effective against all the major locust and grasshopper pests of Africa, but has no adverse effects on non-target organisms. Green Muscle® is recommended by an FAO panel of experts for operational use to control locusts in conservation and environmentally sensitive areas, and the product was registered in South Africa in December 1998 [See *BNI* **20(1)**, 5N (March 1999)] where it is manufactured by Biological Control Products SA Pty in Durban. The product is also expected to be registered in West Africa in early 2000.

Phase 3 of LUBILOSA was concerned with completing the process of taking research findings and developing from them a viable product, and this was achieved by the end of 1998. Phase 4 of the programme, which began in January 1999, has a different brief. It is concerned with Product Stewardship – the process by which sufficient support is provided to complete the commercialization of Green Muscle® and ensure its sustained purchase, uptake and use for locust and grasshopper control in Africa. LUBILOSA is committed to ensuring that Green Muscle® eventually becomes the first choice for the strategic control of locusts and grasshoppers in Africa.

The outlook is promising, with NGOs in West Africa increasingly turning to the product. SECAMA (Société Catholique du Mali) in Mali have purchased Green Muscle® and sprayed it on 200 ha – the first time that Green Muscle® has been purchased for operational use without technical or financial support of LUBILOSA. In Maradi, Niger, CARE International has trained their extension personnel in the use of Green Muscle®, and PROSOPAS (Projet d'Aménagement de Zone Pastorale) have taken part in demonstration trials in Taouah. In Benin, an extension programme is being developed by CRDB (Centre de Recherche pour un Développement Intégré à la Base) in collaboration with IITA (the International Institute of Tropical Agriculture).

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Training News

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

Vietnam Showcase

The Vietnam national IPM programme is well on the road to becoming a showcase for vegetable disease management Participatory Action Research (PAR) from which other countries can learn. Since 1996, IPM trainers have been organizing farmer field schools on vegetable IPM. Farmer trainers have emerged from these field schools, and have gone on to train other farmers in formally organized farmer-to-farmer field schools, and as a result some 14,500 farmers have been trained in vegetable IPM since 1996. In addition, some farmers conduct field studies, either in groups or individually, and others organize themselves into IPM clubs and meet regularly to discuss agriculture and related issues. Field schools and follow-up activities have shown that a major reduction in pesticide use in vegetables can be obtained by better understanding of biological control, crop compensation and different cultural practices.

The project to pilot vegetable disease management PAR began in January 1999 with a workshop held in Hai Phong Province. The workshop brought together Training of Trainers (TOT) graduates from three provinces (Hai Phong, Ha Tay and Lam Dong), Plant Protection Department, Regional Plant Protection Centre and National Institute of Plant Protection (NIPP) personnel and representatives from the FAO IPM office in Hanoi and CABI Bioscience.

The workshop aimed at identifying a rough plan-of-action for the trainers to study disease management with farmers. Important diseases were listed, and from these were selected those that cause major yield losses in important crops (tomato, bean, cabbage, cucumber and onion). Each province prioritized the crops for study, and an agreement was reached to focus on soil-related diseases: bacterial wilt in tomato, root rot (fungal disease) in bean, bottom rot (fungal disease) in cabbage and bacterial wilt in cucumber. However, as it became clear that not all diseases had been properly identified, the urgent need for this to happen was agreed.

During the workshop, practical disease exercises were done as refreshers for the trainers, such as characterization of disease, disease 'zoos'/infection studies, and preparation of disease triangles. A session on composting and the use of compost was also held, as it became clear that the term 'compost' created confusion. In Vietnam, a mixture of manure and crop residues is called compost even before it is fully composted. Leaflets describing what compost is and how to go about making it are available in Vietnamese. Much attention was given to the design of PAR and observation and evaluation methods, and drawing up action plans for each province.

After the workshop, the provincial participants, now the facilitators of the PAR, returned to their respective provinces and organized farmer workshops to go through the steps described above and finalize the details of the PAR, with farmers choosing the specific diseases to be studied, and farmers deciding on the various treatments as well as the design of the study.

A second workshop was held in September 1999 as an evaluation and planning forum for IPM trainers and farmers from each of the three provinces and resource personnel from the National Institute of Plant Protection, FAO and CABI. Although the weather during this first season of the project was largely unfavourable for the diseases chosen for study, and some mistakes were made in some experimental designs, farmers and trainers were enthusiastic about the results and what they had learned, and were determined to continue.

For example, the participating farmers in Hai Phong Province focused on compost – how to make it and its impact on cucumber wilt (identification still not clear) and bacterial wilt in tomato (*Ralstonia solanacearum*). They also evaluated the effects of using pesticides only after weekly agro-ecosystem analysis (AESA) judged them to be necessary, rather than following local pesticide practice. In both crops, the incidence of the disease under study was too low to reach any conclusions in this first season, but farmers were encouraged by what they did experience, and in particular at how IPM practices could make their crops more profitable.

In cucumbers, it was found that adding manure to the planting hole at about 19 t/ha led to better cucumber plant growth and yield, and lower disease ('blight') incidence. The yield was 80% higher than for the farmers' practice treatment and this, together with a reduction of pesticide applications from nine to five per season, led to an almost astronomical increase in profits, from VND 14,000/sao in the farmers' practice treatment to VND 255,000 in the IPM treatment. [1 sao ≈ 360 m²; US$1 ≈ VND 13,500.]

In the tomato trial, seedlings for the IPM treatments were raised in banana leaf pots filled with clean soil and compost, whereas farmers traditionally raise them in flat field seed beds. At transplanting, the IPM treatments added manure to the planting hole at about 15 t/ha ± crushed lime. Farmers found that there was less damping off in seedlings, and less seed was needed, when plants were raised in clean conditions in pots rather than in traditional seed beds. Results indicated that pest and blossom end rot incidence were similar in all treatments, but AESA led to pesticide applications being reduced from 11 in farmers' practice plots to seven in the two IPM treatments. Yields were also higher by 37% and 50% for treatments with and without lime, respectively. Profits increased from VND 558,000 in the farmers' practice treatment to VND 787,000 in the plus-lime IPM treatment, and VND 1,007,00 in the no-lime IPM treatment.

The farmers also conducted pot experiments to study the effect of clean soil and/or irrigation water on disease spread and infection. They concluded that disease can be harboured in crop residues, soil or water, and that a combined approach to disease management has to be taken, including field sanitation, roguing of diseased plants and using them for composting, and crop rotation (rice-rice-cucumber).

The enthusiasm of the farmers at the workshop was striking. It was clear that the lead was now coming from the farmers and trainers, who had already made plans for the next season and were inviting the resource personnel to come back and help. The first steps in the PAR process have been well documented in this programme, and the national programme intends to make information and results available for exchange after another season of activity.

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Practical Scouting in Zimbabwean Horticulture

Scouting for pests is widely practised in Zimbabwean agriculture, on cotton, tobacco and coffee. For the last ten years, flower, vegetable and fruit exports have been expanding greatly in the country and scouting is being used on these new crops to great benefit. In horticultural crops, pesticides usage is high as the growers must produce a cosmetically near-perfect product. The markets for Zimbabwean horticultural produce are primarily in the European Union but also in Australia, the Far East and South Africa. These markets demand that pesticide usage is reduced whilst still demanding a blemish- and pest-free product. For the Zimbabwean grower it also makes good economic sense to reduce pesticides as these account for a high proportion of the production costs. However, pests and diseases must be managed.

Scouting is proving to be a powerful tool to the Zimbabwean horticultural manager and is axiomatic to successful reduction in pesticide usage whilst still managing pests and diseases. It has a range of benefits:

- Timely discovery of a pest or disease allows for easier control. In many cases, insect pests become more hidden as they grow older making them more difficult to reach with sprays. As they grow they also become decreasingly susceptible to the sprays, as the lethal dose of pesticide increases with body weight.
- Scouting allows management to monitor the effects of applied pest and disease control methods, be they chemical or biological. In Zimbabwe, as in many African countries, non-performance of pesticides is often associated with poor application.
- Scouting allows the application of biological control methods at an early stage. The introduction of biological control agents is most successful when the levels of the pest are low, but sufficiently high to feed the beneficial organisms. It is especially important to apply the beneficials before any deleterious pesticides, such as pyrethroids or sulphur, have been applied in response to economic pressure.
- Much of horticulture is based on the production of edible fresh crops. Early detection of pests and diseases allows the usage of pesticides within accepted harvest interval periods and hence reduces the risk of exceeding maximum residue levels(MRLs).
- Strategically, scouting allows the producer to inform the market of problems, and allows the market time to source product elsewhere if there are production problems. This creates goodwill.
- There is less chance of resistant organisms being present in significant numbers if the pest is discovered early, while the population is still small.

Scouts Get 'Phyto-serious'

Scouts can be used for tasks other than straight pest and disease monitoring. One of their most useful functions has been in the development of biological control programmes.

A notable success story has been the use of the predatory mite *Phytoseiulus persimilis* against tetranychid mites on strawberries and hops in Zimbabwe. These two crops suffered severe economic damage from attacks of *Tetranychus cinnabarinus* (and possibly *Tetranychus urticae*) every year in spring. The infections started in August and increased into spring (October), which is hot and dry. The two crops differ greatly in shape and size, being one of the lowest and one of the tallest crops in Zimbabwe. Strangely, this led to the same problem: poor under-leaf cover with acaricides. The hops were difficult to spray up to the full 6 m in height, and the strawberries were difficult to spray as the leaves are close to the ground. *P. persimilis* was imported from five countries: South Africa, Israel, the UK, Belgium and the Netherlands.

At the start of the growing period, the scouts' role was to advise the manager, as early as possible, that mites were present. This allowed the manager time to draw the licence from the Ministry of Agriculture, order and pay for the consignment of natural enemies, and clear it through customs before the pest had done much damage.

From the time of the scout finding mites to the time of release was typically two weeks. During this period scouting was increased and every plant was inspected. Plants with tetranychid mites were marked using thatching grass (*Hyparrhenia* sp.) straws. Once the predators arrived they were taken directly from Harare International Airport and released under the supervision of the Ministry of Agriculture. Only those plants marked by straws were treated. The scouts were taught how to release the predators. This is relatively skilled as the predators must be warmed up just prior to release (they arrive refrigerated), they must be evenly spread throughout the vermiculite carrier in the bottles and the carrier–insect mixture must be shaken onto the plants gently to minimize injury to the predators.

After four days, the scouts checked every plant for predators as well as for tetranychid mites. Plants with tetranychid mites alone were marked with *Hyparrhenia* sp. straws. Those found with predators were marked with sticks from a feral weed, *Tagetes minuta*, a tall South American marigold species, which is recognized as having certain beneficial (nematicidal) qualities. After the scouting exercise the scouts moved leaves from the *Tagetes*-marked strawberries or hops to the *Hyparrhenia*-marked plants.

The predators proved to be extremely effective, and their numbers reached very high levels, to the point where they would swarm to the tips of the plants and blow away in the wind. The scouts, in typical Zimbabwean fashion, invented a nickname for the predators, 'Phyto-serious'.

The predatory mites are reasonably cost effective if produced close to the usage area, but become very costly if imported by air, refrigerated, to the middle of Africa. However, the scouts facilitated control of the tetranychid mites in the two crops with one introduction of predatory mites per season. The number of predators used was hence smaller, and proved to be more successful, than for similar applications overseas. This made biological control economically viable in these crops in Zimbabwe.

Scouts can also be used for checking equipment, such as the plastic covers in green houses, irrigation equipment and application, harvest and crop destruction requirements. They should also scout for physiological problems, watering and weeds.

Good Scouts

Scouts are the eyes of management and as such must have certain attributes:

- Obviously they need to have good eyesight. Women generally make better scouts then men because they are almost never colour blind whilst colour blindness amongst Zimbabwean men is common.
- They should be literate. Peg board methods have been developed which illiterate scouts can use. However, when the records are transferred or portrayed graphically, it is most useful to have a scout who is literate.
- They must be trustworthy and trusted. If the manager cannot trust his scouts then he is better off without them.

There are two extremes of scouts, the 'includers' and the 'excluders'. The includers will mark a pest present if they suspect it is there or feel it should be. They seem to want to impress management with their conscientious scouting skills or wish to insure against missing a problem. Excluders, conversely, leave problems out, as they seem to feel that the presence of pests or diseases are their responsibility. It often seems to come from a 'kill the messenger of bad news' attitude of managers who, even at best, will not greet bad news with enthusiasm.

Training and Beyond

Zimbabwe is fortunate in having a scout training school. The Cotton Training Centre*, which trains people to be cotton scouts, is based in Kadoma, two hours drive west of Harare. This institution, which has received much donor funding from USAID amongst others, has a full-time professional staff who prepare courses and train the scouts. Candidates come from commercial and small-scale farming backgrounds. The courses are conducted in the local language, Shona, but there is one course a year in English for non-Shona speakers. The facility offers the course, food and accommodation.

Cotton scouts emerge after two working weeks with a knowledge of cotton pests. They cover most of the pests or beneficials they are likely to encounter on horticultural crops. But for them to become proficient as horticultural scouts, it is important to train them on diseases specific to the crops they will work on and any special pests or beneficials they might encounter.

Scouts need to be re-trained on refresher courses frequently, and at least just before each new season or when a new pest or disease emerges.

It is important to have more than one scout. This allows for leave and sickness, but also for individual variability: a scout should never check the same field more than twice in a row. Many growers get together and swap scouts for a day every month so that they can compare scouts' proficiencies.

Scouts have a responsible place in management and should be rewarded appropriately.

Practical Methods of Scouting in Horticultural Crops

There are a number of patterns which ensure that statistically correct data are derived from scouting. These are based on random selection of sites or plants in a field. However the methods have three major faults: (a) It is often necessary to go back to a particular position to identify a problem a scout has found or to check if the scout has made a correct diagnosis. (b) 'Random selection' is seldom random. The includers include plants that have problems, the excluders exclude them. (c) Handling a crop whilst looking for pests and diseases spreads diseases, notably viruses.

Many growers have found that it is a better strategy to place 25 poles, high enough to be easily visible, spread evenly throughout the crop. No unit must be bigger than 10 ha. The scouts visit the poles at least twice a week, more often if there is a problem. The procedure should be:

- scout: discover a problem
- report: action taken
- scout: check if action effective and if other problems have arisen

Scouts inspect an 'arms length' of the crop, to the left and right of the pole. They search the crop in a specific order:

1. Look under leaf for whitefly (which fly away if disturbed) and for spider mites, leaf diseases and leaf feeding insects.
2. Inspect the flowers or fruit for thrips and for aphids and diseases.
3. Check the whole plant for general well being.
4. Check for root diseases but with minimal root disturbance.
5. Check other factors such as weeds and irrigation.

The scouts record presence or absence of a pest only, and not numbers. Checking for numbers takes too long and is not as important as trends over a period of time. Economic thresholds are impossible to determine in a horticultural crop as the prices in the market are very fluid. Hence absolute numbers of a pest or disease are less important then their increase or decrease with time. Although economic thresholds are difficult to establish, it is useful to place arbitrary thresholds on different pests and diseases based on previous experience.

In addition to the above, the manager must use all other methods to determine whether a pest or disease is likely to develop. Weather forecasts and laboratory testing, such as pre- planting nematode screening, play major roles in pest and disease management.

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Internet Round-up

By: Tony Little, Technical Support Group to the Global IPM Facility, CABI Bioscience.

A few issues ago, I think I indulged in some rather tedious bleating about the usefulness (or lack of) of Internet search engines for tracking down technical biocontrol information. While you should not ever admit you are plain wrong, at least not in so many words and certainly not in print, I am prepared to make an exception for water hyacinth. Typing 'water hyacinth into the engine (I usually use Yahoo or Altavista), brings up about 60 or 70 relevant sites. If you can pick your way around the sites extolling the virtues of water hyacinth as an ornamental, you should be able to find what you are looking for. These are just a few of the most informative and useful that I found, but it's by no means an exhaustive list:

The University of Florida has a Center for Aquatic and Invasive Plants and its web page can be found at:

http://aquat1.ifas.ufl.edu/welcome.html

This is a great site. From here you can get easy, free access to masses of information on aquatic weeds in general, including water hyacinth and notes on biology, infestation levels and loads of photographs. There is also a page on biological control agents with links to pictures. You can also access the Aquatic, Wetland and Invasive Plant Database:

http://aquat1.ifas.ufl.edu/database.html

This has over 50,000 citations, 1140 or so of which are related to water hyacinth. You have to go through Telnet which hails from the computing Stone Age (some where in the early 1990s) and is therefore slow and cumbersome. But once you get in it's a great resource.

The Northern Plains Agricultural Research Laboratory at:

http://www.sidney.ars.usda.gov/index.html

is a USDA-funded lab in Montana, and has a page on biological control of water hyacinth at:

http://www.sidney.ars.usda.gov/scientists/nspencer/water_h/index.html

From here the Proceedings of the International Water Hyacinth Consortium in 1997, which I understand was a fairly key meeting, are available. There are a few other bits and pieces including a couple of satellite snaps of a suspected infestation on Lake Victoria.

Washington State Department of Ecology at:

http://www.wa.gov/ecology/wq/plants/weeds/aqua010.html

gives a nice little summary of technical information on water hyacinth and other aquatic weeds.

Quite few organizations have put up brief one-pagers for a bit of light reading, including CABI Bioscience:

http://pest.cabweb.org/pest9704.htm

CSIRO:

http://www.csiro.au/promos/ozadvances/Series1Hyacinth.html

Southern Africa environment project:

http://www.saep.org/subject/water/water2_1.html

and the University of Florida (again):

http://gnv.ifas.ufl.edu/%7EFAIRSWEB/IPM/ipmfl/v2n4/hyacinth.htm

As I say, there are many more news items, bulletins and newsletters available. It's just a case of tapping into the search engine and taking your pick.

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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.

Whitefly Symposium

The First European Whitefly Symposium will be held in Sicily on 24 February – 4 March 2001, and will be organized by the European Whitefly Studies Network (EWSN) and hosted by the University of Catania.

The symposium will cover the following disciplines: Faunistic & Systematics, Virology, Epidemiology, Natural Enemies and Pest Management.

Although the symposium will have a European focus, it will also incorporate complementary work from elsewhere in the world. It is also proposed that a comprehensive poster session is incorporated within the symposium.

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Michigan Short Course

An international short course on 'Agroecology, Integrated Pest Management (IPM) and Sustainable Agriculture will be held at Michigan State University on 18-30 June 2000. This multi-disciplinary course will cover: concepts and principles of agroecology, IPM and sustainable agriculture; ecological opportunities in agricultural productivity: insects, pathogens, weeds, nutrients, soil and water; agronomic opportunities in agricultural productivity: agroecosystem design and systems integration, and environmental consequences of various systems; new horizons in agriculture: biotechnological approaches to agricultural production, ecologically based pest and nutrient management, and social concepts; integrated natural resource management, including soil, water and biodiversity management; extension strategies, and the adoption and acceptance of new technology; information and training resources in agroecology, IPM and sustainable agriculture; and field visits to agricultural research stations and innovative farmers' sites.

Registration is US$250 and the course fee (includes instruction fee, information packages, local travel, meals and lodging) is $2750. The application deadline is 15 May 2000.

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Publications from India

A Year of Progress

The sixth annual report of the Project Directorate of Biological Control in Bangalore[1] (PDBC) provides information on biological research work done by PDBC and its 16 coordinating centres spread over different parts of India during the period April 1998 – March 1999.

In a busy year for the insect rearing staff, 63 cultures of host insect and 108 cultures of natural enemies were sent to coordinating centres for trials. The subabul psyllid predator *Curinus coeruleus* was multiplied using the mealybug *Ferrisia virgata* as host in addition to the psyllid, *Heteropsylla cubana*. Similarly, the mealybug predator *Brumoides suturalis* was also reared on *F. virgata* in the laboratory. Progress was made with developing artificial diets for natural enemies: a de-fatted soyabean diet proved effective for rearing *Chrysoperla carnea* and *Cardiastethus exiguus*, and a liver-based diet was successful for *Cryptolaemus montrouzieri*.

A wheat bran-based formulation of *Trichoderma harzianum* PDBCTH 10 was found effective against chickpea root rot and wilt, *Rhizoctonia solani*, in both greenhouse and field trials. Seed treatment with *Gliocladium virens* alone or in combination with Vitavax was found highly effective against damping off and seedling rot of soyabean. *Pseudomonas putida* PDBCAB 19 and *P. fluorescens* PDBCAB2, PDBCAB29 and PDBCAB30 were identified as potential antagonists of *Macrophomina, Sclerotium, Rhizoctonia, Botrytis cinerea* and *Fusarium oxysporum.*

Different media were evaluated for mass production of the entomophilic nematodes *Steinernema* spp. and *Heterorhabditis* spp. Larvae reared on artificial diet yielded more infective juveniles in *Spodoptera litura* than larvae reared on castor and tomato.

Surveys were undertaken for *Parthenium* diseases in Bangalore. *Fusarium pallidoroseum*, a leaf spotting pathogen, showed most potential for development as a mycoherbicide against *Parthenium*; all growth stages of *Parthenium* were susceptible to the fungus, and preliminary host testing found that a number of crops, including sunflower cultivars, were not susceptible..

PDBC has developed an extensive portfolio of biocontrol-based technologies for pest management in a wide variety of crops including sugarcane, cotton, maize, tobacco, vegetables and fruit.

The information system, PDBC-INFOBASE has been developed to help a wide range of people including farmers, extension workers, those in industry, entomologists, biocontrol experts, students, teachers, research managers and planners. The user-friendly, menu-driven self-explanatory software gives information on biological control resources in the country.

Another useful title in PDBC's series of checklists, an annotated checklist of the coccinellid fauna of India was produced. The checklist (excluding Epilachninae) includes the faunal composition, valid name + synonyms, type depository, distribution and selected bibliography for all taxa. In all, 65 species from 29 genera, nine tribes and five subfamilies are dealt with.

Biocontrol Consultants

The adoption of biocontrol technologies for a pollution-free environment requires the development of a critical mass of trained scientific manpower in different agricultural universities, ICAR (Indian Council of Agricultural Research) institutes, other scientific organizations and private industry. With this objective, the Directorate has attempted to compile a directory of experts[2] who could promote guidance on different aspects of biological control, particularly for setting up biofactories, educational facilities, research initiatives, and management of pest and diseases by incorporating biocontrol into a viable green alternative to pest control. This is a beginning and efforts shall further be made to involve many other agencies for a broader consensus for the coming millennium.

[1]Project Directorate of Biological Control (1999) Annual Report 1998-99. Bangalore, India; PDBC, 218 pp.

[2]Hussaini, S.S. (*ed*) (1999) Biocontrol Consultants. Bangalore, India; PDBC, Dr S.P. Singh, 59 pp. Free of charge.

These publications are available from:
Dr S. P. Singh, Director,
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By: Dr S. P. Singh.

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Scarab Biocontrol Network

Scarab beetles provide us with some of our most intractable insect pest problems as soil-inhabiting root or stem feeders. This diverse group can be a threat to agriculture, horticulture and forestry in tropical and temperate regions.

Research groups from around the world have developed non-chemical control measures currently ranging from hand-collecting and soil cultivation to microbial control. The Scarab Biocontrol Network has the objective of facilitating cooperation between scarab biocontrol researchers to meet the increasing threat posed by scarab pests. The network aims to identify and link science teams working in this area, provide information on biocontrol projects and identify background resources to underpin this research.

One of the functions of the Network is production of Scarab Biocontrol News, edited by Trevor Jackson. SBN is an informative bi-annual newsletter, with substantial news stories from around the world, as well as traditional newsletter items of meeting reports, an events calendar and a list of recent scarab-related publications.

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Conference Reports

Indirect and Non-Target Effects of Biological Control

Recently, the potential for negative, indirect, environmental effects of biological control has received increasing attention in the scientific and popular press. In response to this, the International Organization for Biological Control (IOBC) convened an international symposium on 'Evaluating indirect ecological effects of biological control' in Montpellier, France on 17-20 October 1999. The aim of this meeting was first, to summarize what is known about indirect and non-target effects of biological control agents, and second, to identify the key research questions and appropriate methodologies to increase the safety and predictability of biological control. The symposium comprised over 70 presentations (either oral or poster) together with two workshop sessions in which the participants broke up into 12 working groups before reporting back for discussion and recommendations.

In opening the meeting, Jeff Waage (CABI Bioscience and President of IOBC) listed three factors that have led to the recent debate about biological control: increased numbers of stake holders, increased interest in conservation and biodiversity, and increased commercial biological control, particularly in greenhouse production. The effect is that the public is now more aware that biological control programmes can involve effects both on the target pest and on non-target organisms such as closely related plants or prey species. Three cited examples of indirect (non-target) effects of introduced biological control agents were: (i) the attack of rare, native species of cacti in the southeastern USA by one of biocontrol's 'citation classics', *Cactoblastis*, which spread accidentally from the Caribbean (Don Strong, University of California, Davis and Bob Pemberton, US Department of Agriculture – Agricultural Research Service (USDA-ARS), Ft. Lauderdale, Florida); (ii) the impacts of the seed feeding weevil, *Rhinocyllus conicus*, originally introduced to North America to control nodding thistle, but now reducing seed production of several native thistles and influencing a native picture winged fly that feeds on the thistle seeds (Svata Louda and Amy Arnett, University of Nebraska, USA); and (iii) the decline of *Aphidoletes aphidimyza*, an important, early season dipteran predator of aphids in apple orchards in the eastern USA following the introduction of the Asian ladybird, *Harmonia axyridis*, (Mark Brown, USDA, Kearneysville, West Virginia).

Moving on from the fact that important indirect and nontarget effects can and do exist, Mark Lonsdale, David Briese and Jim Cullen (Commonwealth Scientific and Industrial Research Organisation (CSIRO), Canberra, Australia) pointed out that risk assessment must involve both determining the potential hazards or unwanted events, and the probability of the hazards occurring. They stressed that for appropriate evaluation, benefit assessment must accompany risk assessment; while an introduced control agent may attack a native species, the impact of the target pest on other native species such as rare species living in the same environment must also be evaluated. Don Strong, among other speakers, pointed out that for many introduced pests, biological control is the only feasible solution. Peter Neuenschwander (International Institute of Tropical Agriculture (IITA), Cotonou, Benin) and Richard Markham (IITA, Ibadan, Nigeria) reinforced this message and highlighted the serious consequences of imposing too many restrictions on and over regulating biocontrol. But Strong and Pemberton also cited the apparent lack of restraint in recent biological control programmes as demonstrated by the introduction of 31 species of natural enemies between 1986 and 1993 in the Russian wheat aphid control programme in North America. Given that with each biological control agent comes the possibility of non-target impacts, what emerged from this was that a better understanding of the characteristics of successful agents is a necessary prerequisite to reducing the number of unsuccessful species that are introduced.

In terms of other practical considerations, determining host specificity was the most widely mentioned approach to avoiding non-target effects. Various reports showed how host specificity testing has been widely used in the biological control of weeds but much less so for biological control of insects. Phylogenetic, trophic, geographical, habitat, climatic and phenological similarities were suggested as characteristics to be considered in host range testing. What also emerged was that interpreting host range is difficult because the physiological host range demonstrated in the laboratory is not necessarily the same as the ecological host range observed in the field. This is particularly a problem for pathogens (Mark Goettel, Agriculture Canada, Lethbridge, Alberta and Ann Hajek University of Cornell, USA). To test the effectiveness of protocols for predicting the host range of parasitoids, Elizabeth De Nardo (Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA), Jaguariúna, Brazil) and Keith Hopper (USDA-ARS, Newark, Delaware) used a retrospective case study of parasitoids introduced for corn borer control. This work is still in progress but was an innovative approach to a very difficult problem of designing appropriate and safe protocols for biological control.

As an additional dimension to this, the risk of evolutionary host range expansion is always of concern in biological control programmes. However, Rieks Van Klinken (CSIRO, Indooroopilly, Australia) found no evidence of such shifts having occurred thus far, but suggested that increased use of a host that was in the fundamental host range of a species was possible as density of the target host changed. Similarly, Bob Pemberton (USDA-ARS, Ft. Lauderdale, Florida) showed, through an analysis of weed control projects in the USA, the Caribbean and Hawaii, that risks of non-target attacks are not associated with host changes but with the existence of native relatives and target plants in the same locations. Michael Hochberg (Université Paris VI, France) addressed this issue from a theoretical perspective using insect parasitoids as his model system. He concurred that there was no evidence for host range evolution, and proposed that this related to a range of genetic barriers to parasitoid adaptation as well as weak selection pressure on the parasitoids to adapt.

Beyond this, as a general observation, few studies attempted to link empirical investigations with theoretical models. Two notable exceptions were presentations from Bob Holt (University of Kansas, USA) and Liam Lynch and colleagues (the latter working as part of the ERBIC project, which comprises a consortium of European Union partners looking at evaluating risks of biocontrol introductions, led by Heikki Hokkanen from the University of Helsinki, Finland). Both these studies identified the need to investigate transient population dynamic effects, in addition to the traditional equilibrium states of agent-host interactions. This work showed that in the short term, overflow of the control agent is likely if the carrying capacity of the target population is high, possibly resulting in local extinction. Thus absolute, rather than relative, attack rates on different host species are important, underlining the need for no choice in addition to choice experiments in host range studies.

By way of closing, there was clear agreement that biological control is, and can remain, an effective tool for combating agricultural, environmental and green house pests. There was also a consensus across a very international and diverse group of scientists that techniques are available for improving the safety and effectiveness of biological control. Host range testing, pre-release experimentation in the native habitat, and post-release monitoring for direct and indirect impacts were emphasized as being necessary for future programmes. Additionally, in order for the pros and cons to be considered more fully, the public needs to be better educated and more involved in the decision making process; a challenge to which biocontrol practitioners must themselves rise. However, in order for real progress to be made, funding agencies must recognize that biological control is a discipline built on solid ecological principles, and that safe and effective biological control requires more than just collecting agents from one area, releasing them in another and then hoping things will work out for the best.

By: Matt Thomas[1], Jenny Cory[2], Judy Myers[3] and Liam Lynch[1]

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Organic Banana Workshop

Many small-scale banana farmers who are facing increasing difficulty in competing in a free market economy desperately need production and diversification alternatives. One possibility, the organic production of bananas, has attracted considerable interest in both producer and consumer countries. As a result, INIBAP (International Network for the Improvement of Banana and Plantain), CAB International, and CTA (the Technical Centre for Agricultural and Rural Cooperation, Netherlands) jointly organized an international workshop on the production and marketing of organic bananas produced by smallholder farmers, and this was held in the Dominican Republic on 31 October – 4 November 1999 by kind invitation of the Executive Director, Centro Para el Desarrollo Agropecuario y Forestal, Inc. (CEDAF).

The workshop had a specific focus on production and marketing requirements and constraints for organic bananas produced by small-scale farmers in the Caribbean region. Key players in the farmer-to-table chain were participants, and these included representatives of farmers and producers (mainly from the Caribbean and Latin America regions, but also from Africa), European and North American organic certification organizations, importers and retailers. Other participants included representatives of governments, donor agencies and a number of regional and international bodies.

The main aim of the meeting was to provide an impartial forum for discussion and information exchange, with the objective of establishing a nucleus to take organic banana initiatives further. It was recognized at the outset that organic banana production would not provide a solution to all the problems facing the banana industry in the Caribbean, but that it does have the potential to provide a stable source of income for some smallholder producers, and a continuous, guaranteed supply of organic bananas is required for the market.

The meeting consisted largely of working group meetings, with discussions focusing on five major issues, and these are summarized below.

Technical Constraints to Production

Black Sigatoka and lack of soil fertility are the key production constraints. Site selection is crucial in any organic initiative and it was recommended that organic production should be based on an entire watershed with a sufficiently large area. This requires a co-ordinated approach and a critical mass of farmers. A systems-based approach to production was also recommended with participatory research methodologies used to address the key constraints. It is extremely difficult to produce Cavendish varieties organically where there is a heavy presence of black Sigatoka. However, other varieties with potential for organic production are available, either as Cavendish replacements or as speciality bananas for niche markets.

Main research needs were identified as:

- Guidelines for site selection
- Strategies for black Sigatoka management – including biocontrol; methods to reduce impact such as replanting, shade/mixed cropping; organic spray applications
- Integrated pest management
- Banana breeding, focusing on resistance to black Sigatoka and nematodes and dwarfness
- Field selection and evaluation of varieties
- Delivery mechanisms for beneficial micro-organisms such as mycorrhizae
- Post-harvest research on crown rot and latex stain and the post-harvest handling of new varieties
- Improvement of soil fertility

It was recommended that demonstration farms be set up to facilitate the training of farmers in the application of new technology packages. In addition the need for information sharing, creation of linkages and exchange of experiences was highlighted.

Mechanisms to Support Conversion

For individual smallholders, the financial and human time and resources investment necessary for conversion to organic production may be difficult without some external support. There is an urgent need for training and information for farmers who are considering converting to organic production. It was recommended that 'leader farmers' should be specifically targeted for training, not only in technical issues, but also in record keeping and skills associated with team building and negotiating. Farmer groups or co-operatives provide the ideal fora for discussion and provide the framework through which support services can be provided.

Some possibilities for financial support during conversion exist within the framework of linkages with 'Fair Trade' or 'Pesticide-free' labels. An enabling environment, in terms of local institutional support for organic farmers and a favourable policy framework, is also essential in encouraging farmers to convert. In the longer term, public awareness and education at all levels will be a major element in maintaining organic production and reducing the risks of 'contamination' from outside sources and abuse of organic systems.

Specific research needs were identified as:

- Socio-economic/technical aspects of conversion in tropical agroecosystems to identify locally appropriate approaches
- Local adaptation of participatory research and training techniques, such as farmer field schools
- Market research for diversification systems to help plan diversification associated with conversion
- Potential impacts of organic farming on the national scale to help support investments.

Certification

The certification of organic production is an extremely important issue for small holder producers. At the present time most certification is carried out by international certifiers using national inspectors. This process is costly, and there is a need to develop the capacity for certification at the national level. The advantages of carrying out certification nationally include the reduced administrative and management costs and the greater understanding that would develop between producers and certifiers. However, national certification has to overcome problems of credibility on the side of the importer, increased possibilities for conflicts of interest, financial limitations, the need for accreditation and the lack of human resources.

The market benefits of linking organic and fair trade certification are clear, even though fair trade does not embrace all the standards of organic products. It would be particularly desirable to have the same certifiers for both fair trade and organic certification.

The appropriateness of standards developed for European agriculture being imposed on tropical production systems was also discussed, and it was recommended that producer representatives from tropical countries should be involved in this process. Issues such as the initial cost and ownership of certification must also be addressed. These issues are common for all organic production, not just bananas.

Marketing

There is currently some confusion regarding the market for organic bananas. From the demand side, it is felt that organic bananas are presently far from meeting the market potential, whereas on the production side there is a conception that organic bananas cannot be sold. Members of this working group agreed to form a task force to collect relevant information and to assess the real demand and supply situation. More solid price information is also needed, and realistic price premiums need to be worked out for organic bananas by country. There is a clear need for transparency in such information and the establishment of a global monitoring system was recommended.

There is a market for different types of bananas, so long as they meet basic criteria with respect to appearance, taste, shelf-life and ripening characteristics. The market for organic bananas is no longer considered to be a niche market but, rather, a mainstream market with similar quality demands. One important aspect is the need to create consumer-producer solidarity, through which consumers can be educated to understand the limitations and constraints of producers. Products with both fair trade and organic labels stand the best chance of market entry. It was recommended that fair trade organizations be engaged to create more general access for smallholders, including organic growers. Consistency of supply is key. Present experience indicates that the minimum block size to produce homogenous container loads is 25-30 ha.

Total Quality Assurance and Exporting

The goal of total quality assurance was defined as the development of a well-flavoured banana, without progressive defects and with attractive appearance to consumers, wherever and whenever they wish to purchase it.

Quality criteria for Cavendish and for other varieties need to be defined according to stakeholders' demands. (Such stakeholders would include consumers, regulatory bodies and distributors/retailers.) It is also necessary to understand how these criteria relate to the quality aspects of the fruit. Research is therefore needed to understand the factors determining quality and to develop guidelines and minimum standards for producers and ripeners.

There is a need to define smallholder production system protocols, which will ensure that a quality product, meeting the identified criteria is achieved. In addition, it was recommended that smallholder audit trails be put in place and an audit trail manual be developed.

Specific areas for research include methods for controlling crown rot in organic systems and for minimizing latex stains on fruit.

Conclusions and Action Needed

The meeting recognized that a growing market for organic bananas does exist, particularly in Europe and North America. In contrast, local markets have a low awareness of organic issues, but have the potential for growth. Organic banana initiatives are in place, particularly in the Dominican Republic, and have been shown to work well with organized groups of small-scale producers. It is clear that organic production methods are more sustainable than traditional methods and could provide an alternative market opportunity for smallholders.

In general the meeting acknowledged the importance of information sharing and dialogue between all the stakeholders, and the desirability of partnerships between the producers and the market. In addition, a coordinated approach and collective commitment are essential, particularly in the case of small-scale producers. Other important issues include the need for further research in a number of areas, the need for training of new organic farmers and the need for greater efforts in public awareness, both amongst producers and consumers.

Looking specifically at the Windward Islands, it was noted that there are several factors in favour of organic banana production there. These include the absence of black Sigatoka, the existence of a 'banana culture' and farmer associations, the possibility of linking organic production to tourism, especially eco-tourism, the existence of a market demand and the interest of younger farmers. On the down side, adverse factors include the topography of the islands, the large numbers of small-scale farmers, a lack of organic materials for improving soil fertility, the high labour cost, an ageing farming community, problems of land tenure (especially for younger farmers) and lack of technical knowledge.

A number of specific immediate action points were identified during the meeting:

- To carry out, in the short term, feasibility studies with farmers on the socio-economic and agronomic potential for organic banana production in the Windward Islands
- To put in place further variety evaluation trials (these are already planned for FHIA-23 in the Dominican Republic)
- To initiate research on organic banana management systems and particularly the management of black Sigatoka and soil fertility for smallholder organic farms
- Follow-up on standard setting mechanisms (ISO 14000 and 9000, FAO-CODEX, IFOAM)
- The marketing task force established through the meeting to carry out a supply-and-demand study and provide a report by March 2000
- The World Organic Supermarkets Consortium to set up a forum for discussion between producers and retailers
- INIBAP to put in place a website for relevant producer/market information regarding organic banana production
- Interested parties to approach donors/regional organizations for support to move forward on this initiative
- To produce the proceedings of the meeting including a research agenda

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Cocoa–Coffee Research Meeting

A USDA/CABI/ACRI Collaborative Cocoa–Coffee Research Meeting was held in London in December 1999 under the auspices of ICO/ICCO (the International Coffee Organization/the International Cocoa Organization). The meeting was organized by Julie Flood, Julius Jackson and Iratxe Rodriguez for CABI, Eric Rosenquist (USDA, United States Department of Agriculture) and Carol Knight (ACRI, American Cocoa Research Institute). All three organizations are working together on many common research programme areas pertinent to coffee and cocoa.

During the last two years there have been some considerable developments in the biocontrol of pests and diseases of cocoa and coffee, some of which have attracted significant international donor interest. This conference provided a timely venue for researchers to present scientific papers and hold discussions regarding future research directions and areas of emphasis.

On the first day, Julie Flood chaired a session of six presentations on biocontrol methodology involved in cocoa diseases. The first presentation was by Prakash Hebber (USDA-ARS, Agricultural Research Service) on the biocontrol of cocoa diseases. He described activities to resolve the problems associated with the mass production of biocontrol agents; a major constraint to conducting large scale field trials with biocontrol agents. This was followed by Bob Lumsden (USDA-ARS) who concentrated on the biocontrol of *Phytophthora,* and described a simple bioassay using cocoa leaf discs or pod discs for screening for biocontrol efficacy. Ulrike Krauss (CABI/CATIE, Centro Agronómico Tropical de Investigación i Educación, Costa Rica) described work on biocontrol of frosty pod disease and concluded that in Costa Rica, Panama and Peru, the most promising approach to disease management appears to be a combination of cultural and biological control; weekly pod removal and applications of mixed mycoparasite inocula. UV tolerant strains that can reduce frosty pod disease in the absence of shade have also been identified. Ulrike's presentation was followed by a paper on research and extension, with particular reference to biocontrol of cocoa in Peru, was given by Enrique Arévalo Gardini (CICAD/ICT, Comisión Interamericana para el Control del Abuso de Drogas/Instituto del Cultivos Tropicales) and Alberto Hart (CICAD/OAS, Organization of American States). This project aims to overcome some phyto-sanitary limitations with an integrated approach to tropical crops which form part of the agricultural production system of the Huallaga Valley in Peru. Harry Evans (CABI) gave an exciting talk on the exploration for potential biocontrol agents of cocoa diseases. He described two distinct strategies in the search for potential biocontrol agents for witches' broom and frosty pod diseases. The classical approach involves exploration of co-evolved mycoparasites in the purported centres of origin of the diseases, namely coastal Ecuador (frosty pod) and Amazonas (witches' broom). An additional strategy involves assessing endophytic fungal isolates from woody tissues of wild *Theobroma* and *Herrania* spp. These isolates are being screened *in vitro* and *in vivo* (callus system). In the last presentation on cocoa, Smilja Lambert described biocontrol research at the Mars farm at Almirante in Brazil, and in particular described the antagonistic effects of *Trichoderma stromatcium*. A 99% reduction in basidiocarp production by the witches' broom pathogen and a 31% pod infection were reported in laboratory and small field trials using this antagonist.

After tea, Jeff Waage took over to chair the session, which concentrated on biocontrol methodology associated with insects, and especially with regard to coffee berry borer (CBB) (*Hypothenemus hampei*). There were four presentations. The first paper was by Don Nordlund (USDA-ARS) on biocontrol of CBB (the major insect pest of coffee) who reported that classical importation has given no satisfactory control to this pest. Thus, there is increasing interest in augmentative biocontrol such as releases of parasitoids or predators as a way of control. However, our inability to rear large number of these agents is impeding our ability to evaluate these agents. Peter Baker (CABI) described the limitations of parasitoids as a control for CBB. *Cephalonomia stephanoderis* and *Prorops nasuta* (two bethylid parasitoids) have been introduced to many coffee growing countries in Latin America, but there is considerable evidence that *C. stephanoderis* is ineffective. The paper argued that research on bethylid wasps should be wound up for the time being and all available resources devoted to *Phymastichus coffea*. Fernando Vega (USDA-ARS) described the exploration and characterization of natural enemies of CBB. Many fungi are pathogenic to the pest, with *Paecilomyces farinosus* outperforming all other entomopathogens tested. *Phymastichus coffea* was again noted as a very useful parasitoid of CBB. In the last presentation, Roy Bateman (CABI) described the application and testing of biopesticides for perennial crops. Experience has shown that consideration of formulation and application together, i.e. the complete 'delivery system', is vital. Additionally, testing in the field situation should be done as soon as possible after laboratory screening trials.

If you would like electronic copies of the papers mentioned above, please send an e-mail to coffee-cocoa@cabi.org with 'December Conference Paper' as the subject header. We can currently supply versions of the following presentations:

1. Ulrike Krauss: Biological control of moniliasis (*Moniliophthora roreri*) in cocoa.
2. Alberto Hart & Enrique Arévalo Gardini: Research and extension in tropical crops, with emphasis on biological control of cocoa diseases in Peru.
3. Harry Evans: Exploration for potential biocontrol agents of cocoa diseases.
4. Smilja Lambert: Biocontrol research at Almirante.
5. Don Nordlund: Biological control of coffee berry borer.
6. Peter Baker: Limitations of parasitoids as a control technology in Colombia.
7. Fernando Vega: Exploration and characterization for natural enemies of coffee berry borer.

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New Books

Natural Enemies Handbook

The Natural Enemies Handbook was produced under the auspices of the University of California Statewide IPM Project and focuses strongly on biological control practices in the USA in general and California in particular.

The first paragraph of the opening chapter contains the following mini-review: "An illustrated guide to the identification and biology of beneficial organisms that control pests. Growers, pest control adviser, landscape professionals, home gardeners, pest management teachers and students, and anyone fascinated by natural enemies and their prey will find this book useful. It is meant to be a practical guide focusing on common natural enemies that growers and gardeners are likely to be able to find, identify, and use on almost any crop or in the garden and landscape."

That it lives up to this succinct and modest outline is beyond doubt. But the book offers much more than this. The major part of the book – seven of its nine chapters – has comprehensive reviews of groups of natural enemies with superb photographs, line drawings and illustrations. The first two chapters outline the principles of biological control in all its forms, along with descriptions of other crop protection practices and their integration in IPM. It provides nice examples of most forms of control and informs the reader of when they are most likely to be used alone or in combination with other control measures.

Throughout, the text is clear, concise, and instructive. It has an excellent glossary and goes to great lengths to explain technical terms and to introduce the reader to concepts and current issues in crop protection and biological control. For example, it provides a simple and effective explanation of the current debate on non-target effects, and has a box to explain what the difference is between a parasite and parasitoid.

The description and illustration of the taxonomic groups of parasitoids and predators is superb and probably more than the average interested home gardener will need, but excellent material for biocontrol course and student training. Another strength of this book is that it refers the reader frequently to scientific literature and major texts for more detail. The reference list at the end of the book is very comprehensive – if heavily biased towards the US literature. The book also contains a list of suggested further reading, and a list of resources.

In spite of its heavy bias towards crops and biological control in California, this book should have wide appeal to biological control trainers and students everywhere. I know of no other comparably well illustrated, comprehensive and readable account of natural enemies, and as such it could be widely used for training and implementation in developed and developing countries. I have only one quibble. In focusing on California they have totally ignored other sources of information on biological control – for example the Koppert and IOBC web sites, to name but two.

*Flint, M.L.; Dreistadt, S.H. (1998) Natural enemies handbook - the illustrated guide to biological pest control. Berkeley, CA, USA; University of California Press, 154 pp. ISBN 0 520 21801 9. Price: US$35.00 or UK£21.95.

By: Garry Hill, CABI Bioscience.

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Proceedings

Soil Dwelling Pests

Control of soil dwelling pests is one of the most difficult problems in pest management today, and development of environmentally friendly, sustainable control measures for these pests has become a major challenge for researchers in recent years. Microbial control using insect pathogens provides a promising approach.

These proceedings* contain 23 papers presented at the 4th International Workshop on Microbial Control of Soil Dwelling Pests, which was held in Lincoln, New Zealand in February 1998. There is a series of three papers on prospects for microbial control of scarabs, and one each on prospects for microbial control of *Vespula* wasps and soil pests in oil-seed rape, respectively. Three papers consider synergistic interactions between insecticides and pathogens, and between different pathogens. There was a paper describing a national survey for diseases of a grass pest, and another on epidemiological models. A major theme to emerge from the workshop was the increasing use of biotechnology in the management of soil dwelling pests. The uses of molecular biology in microbial control ranged from techniques for identifying and monitoring pathogen populations in the environment (three papers) to inserting microbial genes into plants (four papers). The use of attractants in microbial control was covered in three papers. A number of issues were addressed in single papers: how entomopathogens evade insect defence mechanisms, soil moisture effects, and microbial agents as part of integrated control.

It became clear during the workshop that the development of microbial controls is a complex process, and success is likely to be most easily achieved through interaction between research groups. The purpose of this volume is to stimulate multidisciplinary research and international cooperation to advance the use of microbes for the control of this important group of insect pests.

*O'Callaghan, M.; Jackson, T.A. (1999) Proceedings of the 4th International Workshop on Microbial Control of Soil Dwelling Pests, Lincoln, New Zealand, 17-19 February 1998.

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Water Hyacinth Workshop

The First IOBC (International Organization of Biological Control) Working Group Meeting for the Biological and Integrated Control of Water Hyacinth was held at St Lucia Park, Harare, Zimbabwe on 16-19 November 1998 [see *BNI* **20(1)**, 14N (March 1999)].The proceedings of this meeting, which brought together 47 delegates from 20 countries and included the key figures and organizations in water hyacinth research and biological control, have now been published*.

The proceedings comprise 27 refereed papers and three abstracts. Reports from different countries at different stages in the process of implementing biological control mean that the proceedings provides the complete picture of how water hyacinth is brought under biological control. There are papers from countries who have recently initiated programmes, from those monitoring the progress of releases, from those with established programmes where new agents or integrated options for better or faster control are being assessed, and finally from those where biological control is considered successful and only long-term monitoring is being conducted.

In amongst the country reports, many broader topics are covered. Techniques for release and post release evaluation of natural enemies, and mass production and inundative release are described. Research on new natural enemies is highlighted, including both insects and pathogens, and work to integrate them with other natural enemies and other management techniques is described. Progress on identifying agents attacking different growth stages is summarized, and there is a discussion on how to evaluate acceptable levels for host specificity. Environmental effects, including the impact of eutrophic waters, are dealt with. The need for an integrated approach to the control of the weed is highlighted, and the results of some herbicide screening research are summarized. A role for an information network is discussed. Finally, the key questions of how best to structure and manage water hyacinth biological control programmes, and how long biological control of water hyacinth takes are considered.

Biological control of water hyacinth is progressing quickly, as highlighted recently by results from Lake Victoria [see 'Harvesters Get That Sinking Feeling', this issue]. These proceedings are an invaluable synthesis of the worldwide status of water hyacinth biological control at the end of the twentieth century.

*Hill, M.P.; Julien, M.H.; Center, T.D. (*eds*) (2000) Proceedings of the First IOBC Global Working Group Meeting for the Biological and Integrated Control of Water Hyacinth, Harare, Zimbabwe, 16-19 November 1998, 208pp.
Obtainable from: Martin Hill, PPRI, Private Bag X 134, Pretoria, South Africa, 0001. Price: US$15.00 including postage.
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