Session Summaries

Biological and Integrated Control of Water Hyacinth, *Eichhornia crassipes*,
edited by M.H. Julien, M.P. Hill, T.D. Center and Ding Jianqing
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Summary of sessions 1 and 2

Session 1, which was of keynote presentations, was chaired by Martin Hill, and session 2, containing general papers on the biological control of water hyacinth, by Mic Julien. This report was prepared by Ted Center.

Sessions on Tuesday 10 October opened with three excellent keynote presentations, the first by Mr Mic Julien on 'Biological control of water hyacinth by using insects in the world', the second by Dr R. Charudattan on 'Biological control of water hyacinth by using pathogens in the world' and the third by Dr Ding Jianqing on 'Water hyacinth in China: its distribution, problems and control status'.

Mic Julien presented a review of water hyacinth biology and its status as a worldwide problem, using examples from Papua New Guinea, Thailand and Zimbabwe. This included a historical perspective on the introduction and spread of water hyacinth around the world beginning in the early 1900s and culminating in the recent widespread invasions in Africa. Mic then followed by defining 'classical' biological control and he outlined the steps in a classical biological control project. He then listed new proposed agents (as outlined by Cordo in the previous workshop) and reviewed the biology and impact of many of the agents in current use.

Perhaps most importantly, Mic explored the factors that relate to successful control, factors that accelerate success, and factors that limit control. Factors that he associated with successful control included: presence in tropical and subtropical areas; infestations manifested as monocultures in free-floating mats (which are able to sink when damaged); and mats that are stable (i.e. undisturbed) over long periods. Factors proposed that might accelerate control included wave action, reduced growth (by the actions of biocontrol agents, which allows plants to be flushed out of the systems), and high nutrient status (as it relates to the production of high quality plants thus enhancing insect population growth). Factors that limit control included removal of mats by herbicidal or mechanical means (thus disrupting agent populations), shallow water (damaged plants unable to sink), ephemeral water bodies, toxicity effects in polluted waters, low temperatures at high-altitude, temperate sites, and high nutrients at temperate sites. These observations represent important hypotheses needing further testing, but this delineation represents a first attempt to come to understand the variable nature of successful biocontrol.

Mic concluded by providing recommendations for improving water hyacinth biological control. He suggested that existing agents needed wider use, that new agents had to be identified, that better resources were needed to support projects, that stakeholders needed to be educated about biocontrol, that more collaboration with weed scientists and managers was needed, and that catchment-specific integrated weed management plans needed development.

Dr Charudattan began his presentation by stating that, in his view, pathogens would be most useful as biopesticides as opposed to 'classical' biological control agents. He

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emphasised that pathogens should be explored fully and *fairly* so as to assess their potential as biopesticides in integrated weed management systems (as opposed to 'stand alone' agents). He felt that the use of 'local' pathogens avoided the quarantine problems associated with exotic pathogens. He noted that no new pathogens had been identified in the past 20 years, despite numerous surveys. The only viable 'classical' candidate that he identified was the rust fungus *Uredo eichhorniae*. He felt that the bioherbicidal approach could produce quick and acceptable levels of control, a need generally perceived by aquatic weed managers and a prerequisite to widespread adoption.

Charu then enumerated and prioritised known water hyacinth pathogens. He considered *Cercospora piaropi* to be one of the most promising, being widespread with many virulent strains. *Acremonium zonatum* also showed some promised, as did *Alternaria eichhorniae* and *Myrothecium roridum* (although the availability of strains with different levels of virulence of the latter two species is not yet clear). *Rhizoctonia solani*, which is highly virulent, had not been considered previously, because of its lack of host specificity but Charu noted, in the present regulatory environment, its use is now possible. Many other species of less widely developed pathogens were noted.

Charu summarised by suggesting ways to make pathogens more effective by overcoming environmental constraints on their growth and efficacy. Once developed as bioherbicides, they can be: applied with low rates of herbicide or with adjuvants; multiple applications can used to increase inoculum loads; applications can be timed to maximise impact with insect agents; novel formulations may be used to provide humidity on the leaf surface, to protect the inoculum from solar radiation, or to promote hyphal penetration of the leaf; or they can be combined with other pathogens or several strains of the same pathogen to provide consistent performance. The overall objectives in these approaches should be aimed at developing a bioherbicide that can be used with existing agents and improve the overall effectiveness under different control scenarios so as to 'knock back' the weed as opposed to 'knock down'. One recommendation was to apply *Cercospora piaropi* in combination with *Myrothecium roridum* using a surfactant.

In conclusion, Charu felt that it was indeed a challenge to develop an effective and practical bioherbicide, but that the challenge could be met given the bio-friendly posture of modern regulatory agencies. However, newer, innovative approaches were required to meet particular needs.

Ding Jianqing provided a history of water hyacinth in China and noted that it is widely utilised as animal food so not everyone regards it as a problem. Water hyacinth was introduced in Taiwan in 1903 from Southeast Asia and then to the mainland in 1930. It was introduced into almost every province in the 1950s and 1960s for use as animal food. It became more damaging as nutrient pollution increased during the 1990s. Water hyacinth is now distributed in 17 provinces and is regarded as a problem in 10 of them, mostly in the south. China spends 100 million RMB annually to manually control water hyacinth. The problems caused by water hyacinth are generally the same as in other countries (however, one that may be unique to China was that it provided hiding places for criminals – nicely illustrated with a self portrait surrounded by the weed!). Ding presented a very interesting example of the impact of water hyacinth on the biodiversity of Dianchi Lake. The number of plant species known in the lake declined from 16 before the introduction of water hyacinth to 3 afterwards. Although invasive species are often blamed for adversely affecting biodiversity, this is rarely documented.

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Ding emphasised that utilisation does not solve the problem and should not be confused with control. Mic Julien had earlier emphatically stated this as well.

Biological control was initiated in China in 1995 and, after demonstrating the effects of the weevils in small-scale tests, *Neochetina bruchi* and *N. eichhorniae* were released in 1996. Significant control is now being realised in Zhejiang and Fujian provinces. More recently, the mirid *Eccritotarsus catarinensis* has been released and surveys for pathogens have begun. Chinese researchers have also demonstrated that integrated control, using herbicides with the weevils, provides better control than either alone. In the future they plan to introduce the weevils into new areas, to introduce new insects, and to develop bioherbicides.

One of the most profound statements of the meeting was made by Ding in his concluding remarks. He stated that control of water hyacinth is not about technology, but rather about politics.

In the general session that followed the keynote presentations, Dr Martin Hill presented the first paper, an introspective look at biological control of water hyacinth in South Africa focusing on constraining factors, success, and new courses of action. South Africa has introduced more agents (6 total) than any other country, yet water hyacinth is still a problem. He identified several of the same factors enumerated by Julien as possibly being inhibitory, plus some others: diverse climate (ranging form high altitude to coastal Mediterranean and coastal subtropical), eutrophication (at some sites 100% of inflow is treated sewage effluent), herbicide interference (direct toxic effects as well as removal of bioagent habitat), hydrological parameters (small, shallow systems), and limited releases (small, inoculative releases as opposed to mass rearing and release).

Martin then presented a case study from an oligotrophic system at New Year's Dam where biological control agents reduced water hyacinth coverage from 80% in 1990 to less than 10% in 1994. Thus, even though biological control is not universally effective everywhere, it is effective in the proper circumstances. He concluded with the feeling that water body managers expected too much from biological control, that the problem of eutrophication needed to be addressed, and that better integration with other control measures was needed. He also echoed the sentiments of almost every participant that additional biological control agents were needed.

Tom Moorehouse then provided an overview of the biological control activities in the Kagera River Headwaters in Rwanda. The Kagera River feeds into Lake Victoria on the western side and is the source of much of the water hyacinth entering the lake. In collaboration with Ugandan researchers, Clean Lakes, Inc. is setting up weevil rearing systems and training the Rwandans in the use and application of biological control.

Dr Yahia Fayad presented great news about the biological control of water hyacinth in Egypt. Although the weevils were studied in the early 1980s, the Egyptian Government refused to grant permission for their release. However, the previous working group meeting provided the stimulus for them to finally issue approval. As a result, both species were released during August 2000 when 2000 weevils were liberated at Mariout Lake and 4000 at Edko Lake.

The afternoon session concluded with another presentation by Dr Hill on the biological control of water hyacinth in Malawi. Water hyacinth was found at Lake Malawi during the late 1960s, and by 2000 it was scattered throughout the country. Rearing systems for *Neochetina* weevils have been set up at two facilities along the Shire River. About 200,000 weevils have now been reared and released, 47% in the upper Shire

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River, along with the water hyacinth mirid *Eccritotarsus catarinensis* and the moth *Niphograpta albiguttalis*. The mite *Orthogalumna terebrantis* was already present. (In contrast to Mic Julien's conclusion that these mites are ineffective, they seemed to be quite damaging in this area.) The weevils have established and monitoring is continuing. Some reductions in water hyacinth have already been noted but new infestations are appearing elsewhere. Nonetheless, Martin was optimistic.

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Summary of session 3

Session 3, 'Biological Control – Pathogens', was chaired by Garry Hill. This report was prepared by R. Charudattan.

Three papers were presented in this session. The first, entitled 'An International Collaborative Program to Investigate the Development of a Mycoherbicide for Use Against Water Hyacinth in Africa', was presented by Roy Bateman (CABI Bioscience, UK), on behalf of the International Mycoherbicide Programme for *Eichhornia crassipes* Control in Africa (IMPECCA) team. He gave an overview of the IMPECCA program, in which the following groups are participating: CABI Bioscience, UK; the International Centre for Research on Agro-forestry, Kenya; the International Institute for Tropical Agriculture, Benin; the Danish Institute of Agricultural Sciences, the Plant Protection Research Institute, South Africa; and the University of Mansoura, Egypt.

The project will build upon existing studies of mycoherbicides that have been carried out in Egypt and Zimbabwe. Explorations will be undertaken to find pathogens native to the African continent and the pathogens will be characterised by cultural and morphological studies. Weed biotypes will be characterised by a molecular (AFLP, amplified fragment-length polymorphism) technique. Preliminary results indicate that the water hyacinth biotypes examined to date are similar—a promising sign that host genotypic differences will not be a complicating factor in this mycoherbicide program. Formulation studies are under way with emphasis on an oil-based formulation that could be sprayed like a conventional herbicide. An application technology based on the successful locust-control program (LUBILOSA program) will be evaluated for implementation of a mycoherbicide for water hyacinth. Pathogenicity tests are also being carried out with the following fungi found in the participating countries: *Alternaria alternata, A. eichhorniae, Acremonium zonatum, Cercospora piaropi, Rhizoctonia solani,* and *Myrothecium roridum.*

The IMPECCA program will be promoted and widely publicised. The Water Hyacinth Newsletter published by CABI Bioscience will be continued under this program. A technical bulletin, edited by Roy Bateman, will be made available to interested individuals and agencies. A web site (http://www.impecca.net) has been set up and is running. Another key output will be the strengthening of technical capability and linkages within African national programs to undertake biological control of weeds.

Harry Evans (CABI Bioscience, UK) then presented a paper (by Evans and Robert H. Reeder) on the fungi associated with water hyacinth in the upper Amazon basin, and the prospects for their use in biological control. He pointed out that few fungi have been reported on water hyacinth in South America, most of the fungal taxa reported coming from the Palaeotropics rather than the Neotropics. He detailed his observations from surveys he undertook in 1998 and 1999 in the upper Amazon basin of Ecuador and Peru. The objective of the surveys was to document both the distribution of water hyacinth and its associated microbial pathogens. Ecuador and Peru are within the purported center of

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origin or diversity of water hyacinth and no surveys had previously been made in this area.

Three groups of fungi were collected: biotrophs, colonising green tissues without significant external symptoms; necrotrophs, causing prominent leaf lesions; and those associated with tissues damaged by insects (*Taosa* spp., *Thrypticus* spp.), typically on the petioles. Several fungi that belong to known plant pathogenic genera were isolated or recorded on the collected specimens. These remain to be tested. These surveys have yielded several interesting fungi, including some that appear to be new species. In my view, this collection represents an important resource and it would be very worthwhile to test and evaluate these fungi.

Yasser Shabana (Mansoura University, Egypt; currently and temporarily at University of Hohenheim, Stuttgart, Germany) reviewed his work on *Alternaria eichhorniae* conducted during the past 16 years. This work (by Shabana, Elwakil and Charudattan) has covered a large area of the subject, including the initial surveys in the Nile Delta (Egypt), host-range and safety tests of *A. eichhorniae,* investigations on several aspects for improving the efficacy of this mycoherbicidal agent i.e. sporulation, phytotoxin production, bioherbicide formulations, determination of optimum epidemiological conditions for disease incidence and disease severity, and physiological and ultrastructural studies. This work has clearly established this fungus as a leading candidate for mycoherbicide development in the African continent. Shabana presented results from his most recent work on formulation and field-testing of this fungus, concluding that, for best results, spore or mycelial inoculum of this fungus should be formulated in an invert oil emulsion, along with phytotoxic metabolites produced in culture. The phytotoxic fractions promote disease development, while the invert emulsion protects the fungal inoculum from dehydration.

Overall, this was an interesting and informative session highlighting the importance of pathogens as biological control agents of water hyacinth.

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Summary of session 4

Session 4, 'General', was chaired by Ding Jianqing. This report was prepared by Harry Evans.

Two talks were presented in this session, both covering information technology relating to water hyacinth. Firstly, Garry Hill introduced the idea of a multifunctional Water Hyacinth Resource Manual which, as well as being an information source, could also be used both as a training tool and as a guide to decision-makers. The manual would be focused specifically on developing countries in Africa and would be prepared in the form of a comprehensive, practical and authoritative directory, by an editorial team under a professional editor. It was envisaged that there would be a workshop around mid-2002 to finalise the contents of the document.

The session participants considered this to be an excellent initiative and a potentially valuable and much-needed resource, although the ambitious subject area could mean that the manual may run into several volumes. It was further suggested that the document could be in a loose-leaf format and that the initial drafts should be presented on a web site.

A lively discussion ensued over the costs involved and the potential donor sources.

Luis Navarro then presented a proposal to aid decision-making through the establishment of a Water Hyacinth Information Partnership (WHIP). While WHIP would be aimed at presenting information to African and Middle Eastern countries, its principal mission would be to link this information rather than to create it, facilitated by an Information Exchange and Networking Mechanism (IENM).

Thus, the partnership could be employed for the early detection of water hyacinth infestations and thereby stimulate decision-makers to respond more rapidly to their control or eradication. In the past, such decisions have not been taken until weed levels have become critical and this has been the experience in 21 countries since the 1980s. Thus, there are political reasons for WHIP: to raise donor awareness of the problem and to serve as an information source to decision-makers; as well as technical reasons—to provide data on the spread, socioeconomic costs and integrated control strategies.

It was proposed that this concept could be extended to other invasive weeds and that a conference should be organised to present the initiative, particularly to potential donors. The general view of the session participants was that the projected budget (US$1.5 million) was excessive for the envisaged outputs.

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Summary of session 5

This session, 'Biological Control – Insects', was chaired by Dr Lu Qingguang. This report was prepared by Mic Julien.

Ted Center presented thought-provoking ideas and early studies that assess the changes in competitiveness of water hyacinth when attacked by biological control agents. This is work prepared by Center, Van and Hill. He suggested that this technique could be used to select the most damaging agents for release. The idea has considerable merit, especially if it improves our predictive capacity and thus saves time and resources. The experimental design may need to pay attention to nutrient levels. Changes in nutrition may alter agent impacts or the plant's ability to withstand or compensate for damage. The experimental design is already large, and adding nutrients as a treatment will increase its size considerably.

The Oberholzer and Hill paper, presented by Martin Hill, reported the results of studies on *Cornops aquaticum*, a potential control agent that has long been waiting in the background. It appears that this insect is specific to Pontederiaceae. That *C. aquaticum* took a bite of banana during testing is undoubtedly an aberration. Because of the importance of bananas, the South African Plant Protection Research Institute will study this phenomenon further. Even if later studies show that banana is not a suitable host, the original results should be reported and decision-makers may misconstrue this. In this respect we are all obliged to educate the people who sit on committees and make decisions about what is and is not safe to import and release.

Andrew Mailu described the impacts of water hyacinth on life on, in and around Lake Victoria. He indicated the importance of prior experience in decision-making. Kenya moved quickly to embrace biological control of water hyacinth following experience with salvinia. He indicated that the project on water hyacinth was bigger than just water hyacinth and embraced the whole of catchment management, and that the success of biological control of water hyacinth will have far-reaching effects in the area. He discussed the importance of obtaining reliable scientific and socioeconomic data to describe the costs of problems and the benefits of solutions.

John Wilson, PhD student, outlined progress with modelling the water hyacinth and the impact of controls. His study attempts to bring together data and ideas worldwide, and to investigate some areas of plant–insect interactions. The broad aims are to identify areas needing research, identify the factors that limit control and to help make area-specific predictions about control.

Martin Hill gave an outline of activities in Benin and Zambia, and indicated that a biological control project was starting in Burkina Faso. Excellent control has been achieved in several locations in Benin, with the weed infestations less than 5% of their former sizes. The project included community involvement with very beneficial results. The problems in the Kafue River (95 km infested) in Zambia remain. The weevils were released in the 1990s and are established. *Niphograpta* and *Eccritotarsus* were recently

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released. Nutrient levels are being sampled. Insufficient work is being conducted to assess progress. However, the continued presence of the weed suggests that the weevils and the mite are insufficient. This infestation presents itself as an ideal location to undertake a large-scale integrated management trial.

Godfrey Chikwenhere outlined the status of biological control of water hyacinth in Zimbabwe and the continued involvement of politics in the decision-making processes. Regardless, and this has been shown in other situations, he indicated that once the weevils were widely established they were able to contribute to control despite other antagonistic controls that were imposed. He also indicated the importance of considering other aquatic weeds at the same time, so that weeds such as water lettuce did not immediately take up space made available after water hyacinth was controlled.

Finally, Eric Gutiérrez outlined biomass and productivity studies he had conducted in Mexico with Gomez and Franco, preparatory to determining appropriate control methods for each site. Such studies have rarely been carried out before purchasing mechanical removal machines and hence the tropics are littered with expensive and largely useless machinery. He outlined successful mechanical removal operations conducted at a number of impoundments and described the current ongoing efforts of releasing 4000 adult weevils per month into other locations. It would be instructive to know the costs of the mechanical removal procedures.

This session of seven presentations was varied and very stimulating. We enjoyed talks including assessment of potential agents, development of predictive capacity, reports of successful control (biological and mechanical), reports of apparent failure of agents to control the weed, the need for total catchment management and to collect sound data that describe the costs of weeds and benefits resulting from control. I thank the presenters and the audience for the lively discussions.

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Summary of session 6

Session 6, 'Integrated management', was chaired by Roy Bateman. Martin Hill prepared this summary.

There were two talks and one video in this last session of the workshop. In the first paper, Gasper Mallya presented an update of the water hyacinth biological control program in Tanzania. As with elsewhere on Lake Victoria, fantastic results have been achieved with the release of *Neochetina eichhorniae* and *N. bruchi*. Much of the success has been ascribed to having dedicated staff and enlisting participation of the local fishing communities. This has resulted in the release of large numbers of the weevils and has ensured that collection and redistribution of the weevils to other localities has occurred. Currently, as a result of biological control, water hyacinth is not considered a problem on the Tanzanian shores of Lake Victoria.

Several initiatives have been put in place in Tanzania to ensure sustainable control of water hyacinth. Firstly, utilisation of the weed has been prohibited, thus preventing the potential spread of water hyacinth to other freshwater bodies in Tanzania. Secondly, fishermen are required to report basic information on water hyacinth infestations on the lake to the relevant authorities. This includes general observations on the size of the plants, but more importantly the occurrence of any new infestations to aid in the early detection of the spread of the weed to new sites. Thirdly, releases of the weevils in the Kagera River, where it runs through Tanzania, will facilitate the biological control of water hyacinth on Lake Victoria.

The water hyacinth program in Tanzania, as with the programs in Kenya and Uganda, has been extremely successful in reducing the environmental and socioeconomic threat posed by water hyacinth on Lake Victoria.

In the second presentation, Roy Jones showed a video and then presented a paper on the integrated control of water hyacinth on the Nseleni River and Lake Nsezi in northern Kwa Zulu–Natal, South Africa. This program was inexpensive and highly successful and has resulted in the return of a number of endangered waterfowl species to this conservation area. Roy stressed that having realistic expectations of what can be achieved was the first step. The second step was to obtain commitment from the communities along the system. Without this commitment, the program was likely to fail. The third step was to divide the system into manageable units from the top of the system, downstream. However, follow-up in units after initial clearing of the weed, to control regrowth, was vital. This single most important factor in the success of this project appeared to be having a dedicated manager who spent considerable time on the system and who could coordinate the control efforts.

This Nseleni River program was well planned from the start. It relies on biological control but uses herbicidal control and mechanical intervention (the use of cables across the river to prevent the movement of water hyacinth into previously cleared areas) in a coordinated manner. In addition, nutrient control through the upgrading of a wastewater treatment plant in the upper catchment has facilitated the control efforts. Furthermore, the

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public awareness campaign through the production of a video, the involvement of the local community around the system and the fact that the program has been well documented has ensured that this is possibly the best example of integrated management of water hyacinth that we have.