International co-operation and linkages in the management of water hyacinth with emphasis on biological control

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Abstract. Water hyacinth remains the world’s most important aquatic weed. It is spreading at an alarming rate in Africa and Papua New Guinea and is a major problem in the Indian sub-continent and South East Asia. Successful biological control can significantly reduce weed cover 3-10 years after establishment of agents and has achieved excellent control in a number of countries. Information on biological control technology has been widely disseminated but the rate of application has been relatively slow due to a lack of experienced practitioners in some developing countries and because adequate funding has not been available. Recently, due to the rapid increase in the abundance and distribution of this weed in Africa and elsewhere, interest in the problem has widened and the number of control projects is increasing. The major organizations involved in conducting or supporting research on biological control of water hyacinth; CSIRO Australia, PPRI South Africa and USDA United States of America, are studying additional control agents. They are also investigating the integration of biological and other control techniques into efficient management strategies. This paper describes these organizations’ interactions and co-operation which promote efficient use of scarce resources and outlines their world-wide linkages with other agencies and national governments to further extend the application of this technology.

Introduction

Water hyacinth, *Eichhornia crassipes* Mart. (Salmis), originated in the Amazon Basin and since the late 1800s has spread throughout tropical, sub-tropical and some warm-temperate regions. Its free-floating habit, large dark green leaves and showy mauve flowers have made it attractive to man and so contributed to its spread. The problems caused by the weed and its biology are well documented, however studies of the impact of water hyacinth on the environment are few. Water hyacinth remains the world’s most serious aquatic weed and continues to invade new waterways and wetlands, and increase in abundance in many areas already invaded. Control is being achieved in locations where biological control, either alone or in combination with other control techniques, has been implemented for a number of years.

An important consideration in the management of water hyacinth is the assessment and dissemination of information to help avoid wastage of resources by unnecessary repetition of research and development, or by application of techniques previously shown to be ineffective. Vast resources have already been spent on research to develop, assess and implement control techniques and to investigate possible utilization of this weed.

In this paper we briefly review methods to control water hyacinth with emphasis on biological control, the only method providing sustainable, long-term control. We discuss briefly how biological control might be integrated with other methods to form economical and effective management strategies and we review the agents already widely used and those currently being studied. We outline the current international collaboration and co-operation which underpins research to improve biological control, to assist development of integrated management, to
encourage development of country and regional projects, and to provide information to scientists, policy makers and funding agencies.

Utilization

Water hyacinth can be regarded as an enormous reservoir of a raw material and for years man has been challenged to find ways to utilize it (Gopal 1987). The biggest factor mitigating against its utilization is its high water content, to gain one tonne of dry material approximately nine tonnes of fresh material must be collected, transported and processed. In low-cost labour or subsistence situations water hyacinth is used as fodder for pigs and other livestock, biogass production and mulch. It is used in cottage industries in the Philippines to make sandals and furniture and to make paper in India. However most attempts to develop industries based on the utilization of water hyacinth have not been successful.

The low demand for water hyacinth products, the scattered and inaccessible location of most water hyacinth infestations and the inverse relationship between accessibility of the raw material and the viability of an industry mitigates against utilization contributing to control of this weed. As a consequence, when it is decided that water hyacinth poses a threat to a community, country or region and should be controlled, considerations of possible utilization should not confuse the main agenda.

Physical control

Manual control
This is the most widely used form of control because most people directly affected by infestations of water hyacinth live in poor rural communities in developing countries where hand removal is often the only available option. It is practised to maintain access to water for fishing, transport or general water use or to prevent the weed from invading fish farms, fish landings or paddy fields. Removal by hand is often used in conjunction with floating booms to maintain small weed-free areas but this has no impact on the overall growth and spread of the weed.

Manual control is practised on a larger scale in a few situations, for example where labour is cheap, the value of the water is high, the infestations are smaller than a hectare, or where regrowth can be conveniently cleared after chemical control. Manual control is also used to clear weed from around pump intakes. For most large-scale management projects, manual control of water hyacinth is not a viable option.

Mechanical control

Machines to remove water hyacinth are either located on the bank with an arm and bucket used to collect the weed, or float and collect the weed for later disposal onto the bank or into barges or trucks. The disadvantages of using machinery relate to the enormous biomass of weed to be moved, the weed’s growth rate (in some situations exceeding the rate at which it can be removed), the inaccessibility of many infestations and the high capital outlay and continuous running and maintenance costs.

Abandoned water-weed harvesters exist throughout the developing world, having been ineffective or lacking adequate resource backup. Considering the diverse habitats invaded by water hyacinth, it is difficult to imagine that a universal machine could be developed to remove water hyacinth at an acceptable cost. Weed harvesting machines are useful but only in particular situations. For example, a machine is used to remove weed mats that approach the water intake tower at Barekese Impoundment, Ghana. If left alone the weed would block intakes and foul pumps, requiring shut-down of the already severely restricted water supply to Ghana’s second largest city. Mechanical harvesting is unlikely to provide a long-term solution to most infestations because of reinvansion and regrowth by the weed.

Booms and barriers

Booms are mostly used to keep areas free of floating aquatic weeds. They are often of timber or bamboo or steel cable with floats and sometimes hinged, allowing weeds to float out with water outflow but not back, when water direction changes. Plants accumulated against booms may be sprayed or manually removed. Smaller barriers, often made of wire mesh, are used to protect pump intakes.

Chemical control

The treatment of water hyacinth with herbicides can be very useful in specific situations where fast removal in small areas is essential and other methods are not practical. Unfortunately chemical control is often used
without considering the population dynamics of the weed (fast growth-rate, capacity to reinstate, long-lived seeds) and the limitations to applying chemical controls (accessibility to the weed, equipment, rate of application and costs). In many instances considerable resources have been used on chemical control to reduce water hyacinth in the short term. However, with no long-term follow-up because of insufficient resources or commitment to counter regrowth or reinvasion, problems return and the resources previously applied are wasted. Large-scale chemical control requires huge infrastructural investments (equipment, trained personnel, etc.) to ensure that regular maintenance can be undertaken. In many situations the application of chemicals will not be cost-neutralised due to concerns about contamination of the environment or contamination of water supplies and fisheries.

Chemical control can best be justified to remove small areas of invading plants thereby preventing development of larger problems, that is, a relatively small input can prevent a future expensive problem. However to justify the expense, the potential, long-term impact of the weed must be considerable.

**Integrated management**

Integrated weed management (IWM) requires a holistic understanding of the problem, knowledge of the various control methods and the ability to apply the methods in a flexible, yet properly integrated manner to achieve the best result. The ideal result is short-term alleviation of the problem as required for continued social, economic and conservation purposes, and long-term control over the full range of the weed with as little environmental and financial cost as possible.

In some instances it is not appropriate to use more than one control technique at a particular location. For example, in Papua New Guinea (PNG) small, isolated infestations are removed by hand whereas biological control is used for larger infestations. It is neither desirable nor practical to use mechanical or chemical control methods. However in many locations where biological control is being instigated, the inhabitants use manual removal and exclusion with booms to maintain access to water and navigable channels and limit the amount of water hyacinth entering lagoons.

Where an IWM strategy is desirable, it is important to recognize the strengths and limitations of each control technique and to integrate the appropriate techniques in time and space to achieve the best result. In general, chemical and physical controls can be used to reduce the weed in critical areas while biological control is being instigated. Once biological control has reduced the population of the weed, additional controls should not be required in most areas. However, at some locations, management may be required ad infinitum because water hyacinth will never be eradicated and wind or currents may move some of the remaining weed into critical areas, such as docking sites or water intakes.

Water hyacinth is capable of infesting pristine, relatively low-nutrient waterways, e.g., many river systems in PNG. However, it flourishes in eutrophic conditions commonly brought about by deforestation of catchments, run-off from agricultural and urban land and discharge of industrial and human waste. Strategies for long-term management of this and other aquatic weeds should address the issue of reducing water body eutrophication.

**Application of biological control**

Biological control should be the preferred method of control either on its own or in conjunction with other
techniques in an IWM strategy. A survey of the infestation will determine critical areas where immediate control using physical and, or, chemical methods is required. Implementation of biological control should be the first step in any management project to control water hyacinth. This may avoid considerable hardship and expense incurred by applying biological control as a last resort, particularly considering that the latter is the technique that takes longest to provide results.

Despite the widely-known benefits of biological control and the often extreme urgency to instigate controls immediately, some agencies continue to support expensive and time-consuming preliminary studies to confirm the growth and extent of infestations and to consider management strategies. Surveys, for example, may be undertaken while biological control efforts are commencing. After 18 months of study costing US$2 million, the Economic Community of West African States (ECOWAS) is currently formulating control strategies for its member countries (Pieterse personal communication). Meanwhile in Benin, an ECOWAS member country, biological control was initiated in 1991 with assistance from the International Institute for Tropical Agriculture (IITA). There, populations of control agents are increasing and can soon be expected to provide control (Van Thielen et al. 1994). During the same period in yet another project in western Africa, agents were released in Ghana in an integrated management project funded by the European Union (EU) and implemented by the Food and Agriculture Organisation (FAO).

**Biological control agents**

Biological control research began in the early 1960s when surveys for natural enemies of water hyacinth were conducted in South America by scientists working for the USDA (Center 1994). Since then, numerous natural enemies have been considered as potential agents, three are widely established, another has been released but is of lesser importance, several fungi appear unimportant and three other potential agents are undergoing pre-releases studies.

**Agents in general use**

Three insects have been widely released (Table 1) (Julien 1992) and are providing good control where their populations have been permitted to develop unperturbed (Harley 1989).

*Neochetina eichhorniae* Warner (Coleoptera: Curculionidae), the water hyacinth weevil, has a relatively long life-cycle and has its most obvious impact on the tall phenotype of water hyacinth that grows in crowded situations. It takes several years for populations to increase and significantly reduce weed populations. Attack causes a slow attrition of plant vigour resulting from larvae tunnelling in the crown, lower petioles and in the upper root. This reduces plant growth and reproduction, promotes rotting and may cause plant death.

*Neochetina bruchi* Hustache (Coleoptera: Curculionidae), the chevroned water hyacinth weevil, has a similar life history and mode of feeding to *N. eichhorniae*. There may be some niche competition between the two *Neochetina* species but the combined effects of both weevils appears to provide better control than either by itself. There is mounting evidence that this species develops larger populations on plants with relatively little damage, whereas *N. eichhorniae* can continue to develop on poor-quality plants that are already heavily damaged (Wright and Julien personal observations). The biology and host-specificity test results for both of *Neochetina* species are reviewed in Harley (1989).

*Samedes albifutalis* (Warren) (Lepidoptera: Pyralidae) prefers the smaller, fast growing, bulbous phenotype characteristic of water hyacinth invading open water. The moth's life cycle is relatively short. Larvae tunnel inside the petioles causing the plant to become water-logged and to rot. The effects of *S. albifutalis* are important because they can reduce the rate of invasion by the weed.

**Other agents released but not considered effective**

Several other natural enemies have been studied and released but have not greatly contributed to control.

A mite, *Orthogalumna terebrantis* Wallwork (Acarina: Galumnidae), was assessed by the International Institute for Biological Control (IIBC) and released in Zambia, during 1971, where it is widespread but its effect on the weed is uncertain, and in India, during 1986, where it is established but has not contributed to control. Although not released, it has been found in Cuba, Jamaica, Malawi (almost certainly spread from Zambia), Mexico, South Africa and the United States of America (Julien 1992). Observations in Malawi and Zambia suggest that closer attention ought to be given to the potential of *O. terebrantis* as a control agent (Harley personal observations). In
tropical areas of South Africa, this mite is regarded as a useful addition to the suite of control agents because the peak period of mite activity differs slightly from the peak period for weevil activity.

Two very closely-related species of fungi, *Cercospora rodmani* Conway and *Cercospora piaopii* Tharp (Hyphomycetes), are specific to water hyacinth but have not contributed to control. *Cercospora piaopii* was found in South Africa in 1987 and has been redistributed within that country (Julien 1992). *Cercospora piaopii* occurs in Australia and lesions similar to those caused by this fungus are common in South East Asia and PNG although positive identifications have not been made.

**Potential agents under study**

Three agents are currently under study and are expected to be released in the near future.

A moth, *Achiga infusella* (Walker) (Lepidoptera: Pyralidae), was considered to be one of the most damaging natural enemies by early explorers (DeLoach 1975). After studies by the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the moth was released in Australia in 1981. The two release sites suffered from drought and urban development and field populations failed to persist after 13 months. Shortage of funds prevented further attempts to establish the moth. In a collaborative project between the United States Department of Agriculture (USDA) and CSIRO which began in 1994, *A. infusella* was again imported into Australia. A disease-free colony has been reared and host-specificity studies, involving three *Monochoria* spp., are underway, which so far indicate that this insect will develop on *M. vaginalis* (Burman f.) C. Presl ex Kunth.

Another moth, *Bellura densa* (Walker) (Lepidoptera: Noctuidae), has been reared and released in trial plots within its native range in the USA. This insect has not been released outside its native range. However, as suggested by Baer and Quinby (1980), we believe that this very damaging insect could contribute significantly to control of water hyacinth provided it is sufficiently host specific. Pre-release studies confirm that it will develop on taro, *Colocasia esculenta* Scott, as recorded by Habeck (1974) and also on pickerel weed, *Pontederia cordata* L. It has not yet been determined if females will oviposit on taro.

The biology and host specificity of a bug, *Eccitator tus catarinensis* Carvalho (Hemiptera: Miridae), has recently been studied in South Africa. The adults and nymphs feed gregariously on both phenotypes of water hyacinth causing chlorosis and premature leaf death. It is anticipated that this agent will be released during 1996 in South Africa.

**Limits to biological control**

Where control has been achieved it has taken 3-10 years after release (Harley 1989) and the degree of control varies with location. When designing a management strategy for water hyacinth, consideration must be given to the time necessary to achieve results, the likely equilibrium level and the location of the infestation.

Many water bodies are intensively used, highly visible, often managed by engineers, with no biological experience and whose management plans may be politically motivated. The urgency for control often means that what is perceived as the ‘quick-fix’ often over-rides decisions for long-term control that may have included biological control. The ‘quick fix’ methods disrupt developing populations of control agents, preventing control and reinforce misconceptions that biological control does not work. For example, Center (1994) showed that areas subject to chemical control in Florida compare unfavourably with those where biological control alone has been used. In other situations, the delay between the release of agents and the achievement of control is perceived by managers to be unacceptably long, especially when compared to herbicidal or mechanical methods. In time, however, with continued failures of alternative control methods and with a better understanding of the costs of other control methods, the use of biological control is often reconsidered. Meanwhile valuable time has been lost and the infested area has increased substantially.

Since biological control involves interactions between organisms (the weed and the agents) and the environment, results vary with location. Water bodies with different nutrient levels support different growth rates and biomass of water hyacinth. In turn, the nutrients available to the insects in the host weed affect the rate of agent population increase and hence damage to the weed. Temperatures experienced by the weed and the insects affect rates of growth and development, uptake or ingestion of nutrients, rate of reproduction and hence the time taken for agent populations to reduce the weed infestation. Hydrology, timing and degree of flooding and the amounts of weed and resident-control-agents flushed from the system affect
levels of control achieved. Annual flushing prevents the development of damaging populations of the weevils on water hyacinth that grows on the edges of the fast flowing Sepik River, PNG, while nearby oxbow lagoons support stable mats of water hyacinth and increasing populations of weevils that have developed over several years.

In the well studied cases of biological control of salvinia, the weed was brought under control more rapidly in high-nutrient waters than in low-nutrient waters and control was faster in warm (tropical) than in cool (elevated or temperate) areas. There was also an interaction between temperature and nutrient levels, i.e. high temperature and high nutrients provided faster control (Room et al. 1989). Studies on water hyacinth and its control agents suggest similar responses, although there is a plant-form preference between the moth and the two weevils (Center and Dray 1992) and a nutrient response difference between the two weevils (S. Winterton unpublished). These differences will be exploited to enhance control of the weed.

Field observations suggest that the agents can reduce the level of cover of water hyacinth on small water bodies to 20-30% cover in Australia (Wright personal observations), 20-50% in PNG (Julien personal observations) and to 10-40% in the USA (Center personal observations). When attacked by the insects, the water hyacinth is shorter, with lower biomass and is less able to form dense interlocking mats. These plants, with reduced vigour, are less able to reproduce at the rate required to maintain the area covered prior to the release of biological control agents.

**International collaboration**

**Technology transfer**

International collaboration on biological control of water hyacinth has continued since the 1970s (Tables 1 and 2). The Plant Protection Research Institute (PPRI) in South Africa received colonies of *N. eichhorniae* from USDA in 1974 and CSIRO received colonies of *N. eichhorniae* from USDA in 1975. Prior to this, in 1971, IIBC had supplied *O. terebrantis* to Zambia, *N. eichhorniae* to Zambia and Zimbabwe and *S. albiquetalis* to Zambia. Unfortunately, probably because of inadequate support and follow up, the African releases of the weevil and the moth failed (Julien 1992; Julien et al. 1984). Between 1974 and 1990, colonies of biological control agents were shipped to 15 countries either by USDA, CSIRO or the National Biological Control Research Centre (NBCRC), Thailand. These were generally supplied in response to informal requests and resulted in one or more agents becoming established in 13 countries, while the status of releases in Egypt and Myanmar remain unknown (Julien 1992). Since 1990, agents have been shipped to a further 11 countries by the Queensland Department of Lands (QDL), CSIRO, IIBC, IITA, PPRI and USDA, many under more formal arrangements such as consultancies, regional assistance programmes or specific projects. Three of those countries have not yet made releases and agents are established in the others. The countries that have imported and released agents and the status of the agents are given in Table 1.

Water hyacinth continues to spread and the need for biological control is increasing, not only in new areas but also in older infestations where other techniques have proved unsatisfactory. Currently, various organizations, including the Commonwealth Science Council (CSC) in the United Kingdom and the CSIRO, IIBC, IITA and PPRI, are providing technical and managerial assistance and can continue to do so as demand increases. It is recognized that such assistance should be modified, as appropriate, to each problem area to ensure that mass rearing, distribution, establishment and monitoring of control agents is carried out in the most effective manner and in the shortest possible time. Levels of assistance may depend on infestation sizes and numbers, accessibility, work base facilities, expertise, and whether an IWM project is involved.

**Research to improve biological control**

At the VIII International Symposium on Biological Control of Weeds held in New Zealand during 1992, an informal group met to consider current and future research for control of water hyacinth and how and where to conduct new work for mutual benefit and efficient use of resources. Partly as a result of this meeting, collaborative research has been undertaken by the CSIRO, PPRI, United States Army Corps of Engineers (USACE) and USDA. (Participating organizations reviewed progress during the IX Symposium.)

CSIRO, in co-operation with USDA, has cleared a microsporidian disease from a colony of the moth *A. infusella* imported from Argentina. This moth had previously been released in Australia in 1981 but after
### Table 1. Countries where biological control of water hyacinth has been instigated and the research, collaborating and funding agencies (see text for abbreviations of organizations). N.e. - *Neochetina eichhorniae*; N.b. - *Neochetina bruchi*, S.a. - *Saneodes albigularis*; O.t. - *Oreoscculunna terrestris*. *i* imported not yet released; (i) imported but lack of information suggests that colonies did not survive; y released and established; n released but not confirmed established; ? probably released but not confirmed; p present but not deliberately imported and released; - not imported or released.

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13 months failed to survive. It is considered that a combination of limited releases and catastrophes at the release sites may have contributed to its failure. USDA are interested in this moth, pending an assessment of its impact on the North American native plant pickerel weed, *P. cordata* L. This assessment is being conducted in Australia where pickerel weed is an exotic and of no consequence. In South Africa pickerel weed is exotic.
Table 2. The major collaborating organizations (and the scope of their involvement) and organizations supporting international projects in research and management of water hyacinth.

**Major organizations collaborating in research**

- Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
  - Exploration
  - Host specificity testing
  - Implementation
  - Technology transfer
  - Supply of agents

- International Institute for Tropical Agriculture (IITA), Benin
  - Implementation
  - Technology transfer
  - Supply of agents

- International Institute of Biological Control (IIBC), United Kingdom
  - Exploration
  - Host specificity testing
  - Implementation
  - Technology transfer

- Plant Protection Research Institute (PPRI), South Africa
  - Exploration
  - Host specificity testing
  - Implementation
  - Technology transfer
  - Supply of agents

- United States Department of Agriculture (USDA), USA
  - Exploration
  - Host specificity testing
  - Implementation
  - Technology transfer
  - Supply of agents

**Organizations supporting international projects**

- Australian Centre for International Agricultural Research (ACIAR)
- Australian Agency for International Development (AusAID)
- Commonwealth Science Council (CSC)
- European Community (EC)
- International Institute for Tropical Agriculture (IITA)
- German Agency for Technical Cooperation (GTZ)
- South Pacific Commission (SPC)
- United Nations Environmental Project (UNEP)
- United Nations Food and Agriculture Organisation (FAO)
- United States Army Corps of Engineers (USCE)
- United States Department of Agriculture (USDA)
- World Bank (WB)

and becoming invasive (Cilliers personal observations) so attack on pickerel weed is unlikely to restrict release there. A disease-free colony will be shipped to South Africa in the future. Studies are also underway that aim to assess the interaction of the moth with *Monochoria* spp.

The CSIRO in conjunction with the Centre for Tropical Pest Management, Brisbane, is conducting research to assess the interaction between the two *Neochetina* spp. weevils and levels of nutrients in the water and in the host plant. This information will help determine the appropriate control agents to use in waterways with different levels of eutrophication and particularly whether high nutrient levels lower the level of biological control.

PPRI is conducting host-specificity tests on *B. densa*. The test results are of particular interest to CSIRO which regard this insect as having considerable potential. Acceptance of this insect as a control agent will probably be determined by its interaction with taro, *Colocasia* spp. and *Monochoria* spp.

PPRI has completed host-specificity studies on
E. catarinensis and anticipates releases in early 1996. This insect severely damages water hyacinth under insectary conditions and will be considered for study and release in Australia and USA.

PPRI is assessing the practical aspects of integrating biological and other control methods (especially chemical control) in an IWM strategy for large infestations. A particular application is in high-elevation areas, where the time to achieve biological control may be prolonged and immediate relief from the problems caused by the weed is required.

Several natural enemies of water hyacinth will be assessed in their native range in northern Argentina by USDA and the Centro de Ecologia Agropecuaria del Litoral (CECOAL), including a thrips, Thripicus spp., a gasshopper, Cornops aquaticum Bruner, and, if present in the study area, a bug E. catarinensis and a moth, Palustra spp.

Wide-ranging surveys will also be conducted by USDA staff based in Argentina to search for additional potential control agents.

**Discussion**

Manual removal will continue to be important in providing access to water, particularly in developing countries where inhabitants have no option but to maintain access to their water sources, fishing and gardening areas. Chemical and physical control methods make important but limited contributions to the world-wide management of water hyacinth. Their roles will mostly be in keeping critical sites clear of the weed until biological control is effective and then in removing mobile, floating mats that threaten essential activities. The use of biological control will continue to increase through improved understanding of the problems caused by water hyacinth, development of IWM strategies, recognition of economical considerations and protection of biodiversity inherent in applying a sustainable, environmentally-friendly methods of control. Application of best-management-practices will result in implementation of biological control projects immediately or a decision is reached to undertake infestation control.

The current limitations of biological control are well recognized, but despite these, biological control can provide substantial relief from problems associated with water hyacinth. Current and future research is aimed at improving the levels of control by achieving a greater reduction at equilibrium in a shorter time. We plan to achieve this by adding additional agents to the existing arsenal and we hope to understand more clearly the circumstances under which each agent may best contribute to control, e.g., which agents perform best in low-nutrient water bodies, which in high.

The organizations that have developed current knowledge in biological control are able to provide expertise and control agents in the development and implementation of biological control and its integration with other control methods. This provides a unique opportunity for funding agencies to commit resources to solving problems, since the immediate underlying research is complete and effective control projects can be mounted quickly and economically. A large research component is not usually required.

**Acknowledgements**

We would like to thank Michael Day for assisting in the design and preparation of the poster display and Mike Morris for providing a slide of fungi used for the poster.

**Abbreviations, relevant to water hyacinth, not explained in text or tables**

ARC (Agricultural Research Council, South Africa), DNRC (Department of Natural Resources Commonwealth, Puerto Rico), DWAF (Department of Water Affairs and Forestry, South Africa), EAP (Escuela Agricola Panamericana, Honduras), ECZ (Environmental Council of Zambia), EPA (Environmental Protection Agency, Ghana), GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit, Germany), HRRI (Horticulture Research Institute, Nigeria), IIA (Inst. Invest. Agro., Mozambique), IIHR (Indian Institute for Horticultural Research), IMTA (Instituto Mexicano de Tecnología de Agua), ISA (Instituto Superior de Agronomia, Portugal), KARI (Kenya Agricultural Research Institute), KRS (Korovia Research Station, Fiji), MARDI (Malaysian Agricultural Research and Development Institute), NARO (National Agricultural Research Organisation, Uganda), PCC (Panama Canal Commission), PPRIZ (Plant Protection Research Institute, Zimbabwe), SEAMEO (BIOTROP: Southeast Asian Regional Centre for Tropical Biology, Indonesia), SPC (South Pacific Commission, Fiji), UG (University of Ghana), UKS (University of Khartoum, Sudan), NVBCRC (Vietnam Biological Control Research Centre).
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