Biological control of tropical weeds with Central and South American origin: current activities by CSIRO Entomology

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Summary CSIRO Entomology Tropical Weeds Project carries out research on the following weeds: mimosa (*Mimosa pigra*), parkinsonia (*Parkinsonia aculeata*), mesquite (*Prosopis* spp.), alligator weed (*Alternanthera philoxeroides*), bellyache bush (*Jatropha gossypiifolia*), hyptis (*Hyptis suaveolens*), and Mexican poppy (*Argemone mexicana* and *A. ochroleuca*).

The native range of these weeds is Neotropical Americas except for alligator weed that is from temperate South America. Studies on mesquite are centred in Australia, evaluating the impact of a biological control agent and developing integrated management. Studies of each of the other weeds involves one or a combination of the following activities; surveys in their native ranges, biological control agent biology, host specificity studies in Mexico and Brisbane, plant ecology, post-release monitoring and evaluation of agent populations, agent impact assessment, non-target impact assessment and integrated management that includes biological control. Activities involve a national perspective on weed management and where possible collaboration and cooperation with state departments. A number of these projects are included in the CRC for Australian Weed Management.

Keywords Biological control, weeds, integrated weed management, native range, Central America, South America.

INTRODUCTION

Many weeds in northern Australia have their origins in the tropical Central and South Americas. The CSIRO Entomology Tropical Weeds research group based in Brisbane and Darwin, concentrates much of its research effort towards weeds of this origin. To assist this effort,a field station is maintained in Mexico from which survey work is conducted in the region. Initially, in the late 1960s and early 1970s, under Dr. Ken Harley, a field station was set up in Curitiba, Brazil, to survey for potential agents on lantana (*Lantana camara* L.) and later on mimosa (*Mimosa pigra* L.), hyptis (*Hyptis suaveolens* (L.) Poit.), salvinia (*Salvinia molesta* D.S.Mitchell), and water lettuce (*Pistia stratiotes* L.). Field collections of a known agent were also made on alligator weed (*Alternanthera philoxeroides* (Martius) Grisebach). The station was closed in February 1982. In March 1984 a station was opened on the west coast of Mexico at Acapulco, where the climate was similar to Darwin, Northern Territory (NT), and surveys continued on mimosa and hyptis, and were initiated on spinyhead sida (*Sida acuta* Burhman f.), sida retusa (*S. rhombifolia* L.), and flannel weed (*S. cordifolia* L.). For improved convenience, the station was relocated to the east coast at Veracruz, Mexico, in December 1986, where it remains today. From Veracruz additional plants surveyed include: bellyache bush (*Jatropha gossypiifolia* L.), lantana, Mexican poppy (*Argemone mexicana* L. and *A. ochroleuca*), and parkinsonia (*Parkinsonia aculeata* L.). Surveys in the native ranges, and activities based from the Central and South American field stations, are the foundations of our research to develop biological control in Australia.

In addition, potential control agents have been introduced from other sources, and studied and released on mesquite (*Prosopis* spp.), and water hyacinth (*Eichhornia crassipes* (Martius) Solms-Laubach).

Current projects on temperate South American grass weeds, serrated tussock (*Nassella trichotoma* (Nees) Hack. ex Arechav.), Chilean needlegrass (*Nassella neesiana* (Trin. & Rupr.) Barkworth), and blue heliotrope (*Heliotropium amplexicaule* J.Vahl), are under study in the CSIRO Entomology Temperate Weeds Project and are not discussed here.

A precis of research activities and collaborations is presented for each of these weeds. Potential for future research is also considered.

CURRENT TARGET WEEDS

Mimosa Exploration for biological control of mimosa commenced in 1979. The first agents, seed feeding beetles, were released in the NT in 1983. To date 37 species (35 insects and two fungi) have been studied and 12 (10 insects and two fungi) have been released. Four of these, the seed feeding beetle, *Acanthoscelides puniceus* Johnson, the flower feeding weevil, *Coelocephalapion pigrae* Kissinger, the tip boring moth, *Neurostrota gunniella* (Busck) and the stem boring moth, *Carmenta mimosa* Eichlin & Passoa, are widespread, abundant and damaging. Recent studies have shown that where these agents have been present for a number of years, seed production and seed soil bank have been reduced by one to two orders of magnitude and are approaching the levels found in mimosa's native range (Paynter and Flanagan

2002). In addition, sustained attack by *C. mimosa* over several years has lead to plant death. Another recently released agent, the leaf-feeding beetle *Malacorhinus irregularis* Jacoby, is increasing in the field and may have developed sustainable populations.

In 1997 the program broadened to include the development of integrated management of mimosa. The aim was to determine cost-effective management tools and integrate them with biological control. This work is nearing completion, has provided exciting and applicable results and is subject of a presentation at this conference (Paynter and Flanagan 2002).

There are about five potential biological control agents that remain to be assessed. Any one of these may contribute to future control. The management of fire and grazing to prevent reinvasion of cleared areas by mimosa also requires investigation, as does the manipulation of thickets to increase edges and so encourage population increase and damage by the important agent *C. mimosa*. This project has been supported by the Federal and NT Governments, CSIRO Entomology and The Australian Centre for International Agricultural Research (ACIAR).

Hyptis Exploration for potential agents began in Brazil with two major surveys conducted between 1979 and 1982 and several preliminary surveys in Venezuela and Mexico in 1981. When the field station was moved to Acapulco, surveys on hyptis in Mexico were carried out in conjunction with surveys on other weed species until 1986 when work ceased. Variation in hyptis plants was noted and very few natural enemies (12) were found. It was considered that the chemistry of this aromatic plant provided protection from herbivory. Several insect species were studied either in Mexico or Brisbane but none proved to be specific to hyptis (Table 1) (J.D. Gillett and K.L.S. Harley, unpublished results). A rust fungus, *Puccinia hyptidis*, also recorded from hyptis has not yet been studied.

During 2000, support increased and in the 2000–2001 and 2001–2002 growing seasons surveys were conducted in Venezuela and Mexico. The plant is highly variable morphologically and there appears to be differences in the suite of insects encountered on different forms. Molecular taxonomy is being used to check plant population differences.

The insects collected recently include the following: flower feeding beetles, including *Meibomeus* sp., the chrysomelid leaf feeder *Omorphoita* sp., several leaf and stem feeding weevils, including *Coelocephalapion* sp., a stem galling weevil, and moths, including a stem boring Sesiid, a Geometrid looper, and the Pyralid moths *Pyrausta* that are now considered to be five or six different species.

Table 1. Insect that either failed preliminary host range tests in Mexico or Brisbane or failed to survive on Australian hyptis.

Potential agent	Plant part attacked	Status
Coleoptera: Chrysomelidae		
Metriona sp.	Leaf feeder	Ex Brazil. Failed specificity tests in Brisbane in 2001
Neocharida bifida	Leaf feeder	Ex Brazil. Failed specificity test in Brisbane in 1980s
Coleoptera: Apionidae		
Coelocephalapion sp.	Leaf feeder	Ex Mexico and Venezuela. Failed specificity tests in Brisbane in 2000.
Coleoptera: Bruchinae		
Meibomeus sp.	Flower feeder	Ex Venezuela. Failed to survive on Australian hyptis in 2001.
Diptera:		
Calcomyza hyptidis Spencer	Leaf miner	Ex Mexico. Failed preliminary tests in Mexico in 1980s.
Lepidoptera: Pyralidae		
Pyrausta panopealis (Walker)	Leaf and stem feeder	Ex Mexico. Failed preliminary tests in Mexico in 1980s.
Nematoda		
Unknown species	?	Ex Mexico. Not specific. Studied in Mexico in c. 1990

Several species were imported into quarantine in Brisbane where they either failed to survive on Australian hyptis or they attacked a wide range of plant species and so were eliminated (Table 1).

Surveys are planned in new areas of Central America in Guatemala, Nicaragua and Costa Rica in conjunction with surveys on other weeds. Depending on field availability and likely impact one or more of the unstudied insects will be collected and attempts to rear and assess host ranges will be made either in Mexico or Brisbane. This work is supported by NT DBIRD and CSIRO Entomology.

Bellyache bush A project supported by NT DBIRD began in 1997. Eight Caribbean and Central and South American countries have been surveyed to date and 61 insect and pathogen natural enemies recorded (Heard and Chan 2002). In the last four years QDNRM have supported host range testing of agents in quarantine.

Four insects have been studied in Brisbane, three were rejected through lack of acceptable specificity, and one, the seed feeding bug *Agonosoma trilineatum* Fabricius, appears to be specific to bellyache bush. An application for its release will be submitted soon. Several other insects have been imported but due to difficulties with rearing the colonies failed or host range testing has stalled. The fungus, *Phakopsora jatrophicola* (Artt.) Cumm., was sent to CABI Biosciences, UK, to determine if growing it on bellyache bush was feasible. This was successful and funds are required to proceed with further biological and host range assessments. A number of other agents await importation and testing and permits are or have been obtained (Heard and Chan 2002).

Parkinsonia Ecological studies in Australia on parkinsonia began in 2000 in collaboration with QDNRM, NT DBIRD, CSIRO Sustainable Ecosystems and the WA Department of Agriculture. The aim being to quantify reproduction, growth, seed banks, germination and population dynamics over a range of landscapes to assist selection of potential biological control agents and development of sustainable management strategies. In addition, the impact of the widely established seed feeding bruchid, *Penthobruchus germaini* (Pic), which was released by QDNRM in 1995 (Julien and Griffiths 1998), is being assessed.

Surveys had previously been conducted in southern USA and northern Mexico with a single short survey into Costa Rica in 1984 (Woods 1988). As a result three insects were released and are established in Australia (Donnelly 1998, 2000). Two are not causing useful damage and the impact of the third, *P. germaini*, is being studied. Recent information suggests that the centre of origin of parkinsonia is likely to be southern Mexico to Costa Rica (C.E. Hughes unpublished report 1989), including areas not previously surveyed. With funding through the National Weed Program, surveys for new potential agents began February 2002 in southern Mexico, Guatemala, Costa Rica and Nicaragua.

Mesquite While studies on seed feeding bruchids were underway in the 1990s by QDNRM, we developed a project focusing on agents that attacked other parts of this weed. Between 1996 and 1998, four insects were selected from known lists of natural enemies of mesquite and tested in quarantine. As a result two were released, the moth *Evippe* sp., a leaf tier, and the sap sucking psyllid, *Prosopidopsylla flava* Burckhardt, and two were rejected.

The psyllid is tenuously established at a few locations. However, the moth is well established at all release sites across rangeland Australia. It is most abundant in the Pilbara Region, WA, where high levels of prolonged defoliation are likely to be having a significant impact on reproduction, growth and survival (van Klinken *et al*. 2002, van Klinken *et al*. in press). Impact, and possible implications for integrated management, is currently being monitored in the Pilbara.

With NWP funding, an integrated management strategy will be developed over the next few years based on the large infestation in the Pilbara Region. The outcomes may be applicable to mesquite management elsewhere and for other woody weeds.

Mexican poppy Studies in the native range of Mexican poppy commenced in the summer (dry season) of 1998–1999 in Mexico and continued over the following two summers. The plant appears to have a relatively depauperate fauna.

Two weevil species have potential as biological control agents. One breeds and feeds on the flowers, seeds and fruits, and the other breeds on the roots and the adults eat all plant parts. Preliminary host range studies are limited in Mexico due to the very few species of Papaveraceae growing there. A small field study indicated that adult feeding may be restricted to Mexican poppy. There are no native Papaveraceae in Australia and this improves the chances of finding suitable biological control agents.

This research has been supported by NT DBIRD and CSIRO.

Alligator weed Successful biological control of alligator weed growing as floating mats in central coastal NSW was achieved in 1979 following the release of the flea beetle *Agasicles hygrophila* Selman & Vogt (Julien 1979, 1995). However this aquatic insect was unable to control growth on banks, in swamps, and in terrestrial areas and is not suited to cooler climates (Julien *et al*. 1995).

Recent spread of the weed and the limited options for effective management have lead to a renewed effort in biological control. The original surveys, conducted in the 1960s by Vogt (1973), identified three agents that have been used for biological control in USA. Two of these were released and are established in Australia; *A. hygrophila* and the moth *Arcola malloi* (Pastrana). Another, the flea beetle *Disonycha argentinensis* Jacoby, was later studied and released in Australia and New Zealand but did not establish. Other species were also collected by Vogt but were not considered further, and many were not identified. Vogt *et al*. (1979) estimated that 39% of the native range of the weed had yet to be surveyed.

In October 2002 surveys began in the north and central sections of eastern Argentina, south-eastern Paraguay and southern Uruguay. A range of interesting insect and fungi natural enemies have been collected and submitted for identification but little or nothing is known of their biology or host ranges.

Morphological variation of alligator weed has been noted in the native range of the weed (Pedersen 1999) and insect diversity, particularly among chrysomelid leaf feeders, appears to differ on the various plant forms. This is consistent with plant biotype differences and variation in attack by *A. hygrophila* between two biotypes of the weed observed in USA (Kay and Haller 1982).

In addition, viable seeds and seedlings have been found for the first time, and only in southern populations in Argentina (Sosa, Julien and Cordo unpublished information). Morphological and molecular taxonomy is underway to determine variation within native populations and compare these with Australian populations. This may assist our interpretation of native range survey data, help direct future surveys and alert Australian quarantine authorities to the presence of a fertile taxon of alligator weed that should not enter Australia.

HOW SUCCESSFUL HAVE WE BEEN?

CSIRO Entomology Tropical Weed Project with its collaborators have researched biological control for 13 weeds species of Central or South American origin since the late 1960s when the group was developed. Agents have been released on eight species: no appreciable control was achieved for one, lantana; the prognosis for control of mesquite in the Pilbara and for mimosa is very good but not yet achieved; good control of water hyacinth and alligator weed has been achieved in some situations or habitats, and sida, salvinia and pistia have been successfully controlled.

Of the remaining five species, agents have not been released against flannel weed and Mexican poppy, due to lack of funds to undertake detailed studies. However, we believe that there are host specific species available. Suitably host specific agents have not yet been identified for hyptis. The release of the first insect for bellyache bush is expected this year. Surveys for parkinsonia have just begun.

THE FUTURE

The investment in developing suitable controls for mimosa appears to be paying off. This is undoubtedly due to adequate levels of long-term support and excellent collaboration. It is important that this project be taken to its logical conclusion, i.e. the known small suite of remaining potential agents should be processed and the suitable ones released and established widely in the field. In biological control we are good at predicting which agents are safe for release, but we cannot predict which agents will provide successful control. Therefore we need to consider all potential species with equivalent weighting. History suggests that at least one of those remaining species will contribute to control of mimosa.

We are utilising the mimosa experience to assist in more efficient management of other weeds. Through the CRC AWM the past and present selection of agents for a number of projects will be assessed and tested to determine how we might improve our ability to pick winners.

Survey work will continue on hyptis, bellyache bush, parkinsonia and alligator weed to ensure that we know the fauna with potential as control agents. Selected species will then be studied and hopefully released. Ecological work on bellyache bush and parkinsonia will allow assessment of impact of control agents, and assist the development of integrated strategies. We anticipate that current ecological studies of parkinsonia in Australia will contribute to the selection of suitable agents once the range of potential natural enemies is known. Ecological work is needed for hyptis and alligator weed.

Preliminary host range studies will be conducted in Mexico on several potential agents for Mexican poppy. Detailed studies will have to wait until the relative importance of this weed increases in Australia or eastern Africa. There is potential here for international coinvestment.

Community and government interests are such that surveys for natural enemies of cabomba (*Cabomba caroliniana* A.Gray), are likely to begin within the next year or so. This will be a challenging activity working with a weed that grows in tussock form, rooted over two metres below the surface of South American water bodies. Compared to other habitats, the diversity of fauna is likely to be limited, but the degree of specialisation may be greater: interesting questions to deal with during the pursuit of applied ecology.

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The successful biological control of a weed presents a special problem, seldom shared by the control of an insect pest, namely that some other plant, perhaps even a weed that is more difficult to control by other means, will spread to occupy the space vacated. Reduction to the greatest possible extent of the density of a weed is desirable in situations such as pastures or national parks.Â Surveys in Tropical America would be necessary to provide data on which prospects for its biological control could be evaluated. 12 Biological Control of Weeds: Southeast Asian Prospects.Â (1977) as a weed in some crops in Central and South America, it is significant that nowhere in that region (unlike the rest of the tropical world) is it regarded as a serious or a principal weed. Published by: CSIRO Entomology, GPO Box 1700, Canberra ACT 2601, Australia Â© CSIRO 2004 National Library of Australia Cataloguing-in-Publication International Symposium on Biological Control of Weeds (11th : 2003 : Canberra, A.C.T.). Proceedings of the XI International Symposium on Biological Control of Weeds Canberra, Australia, 27 April-2 May 2003.Â Biological control of saffron thistle with fungi: limited prospects. In: Proceedings of the XI International Symposium on Biological Control of Weeds (eds Cullen, J.M., Briese, D.T. Kriticos, D.J., Lonsdale, W.M., Morin, L. and Scott, J.K.), pp. 351â€“352. CSIRO Entomology, Canberra, Australia. Biological control of tropical weeds with Central and South American origin: current activities by CSIRO Entomology. 13th Australian Weeds Conference: weeds "threats now and forever?", Sheraton Perth Hotel, Perth, Western Australia, 8-13 September 2002: papers and proceedings, 361-365. Julien M; McFadyen R; Cullen J, 2012. Biological control of weeds in Australia [ed. by Julien, M.\McFadyen, R.\Cullen, J.]. Collingwood, Australia: CSIRO Publishing, 620 pp. Karihaloo JL; Wakhlu AK; Irshad A, 1981. Argemone ochroleuca Sweet a New Record for Jammu and Kashmir State.Â Antimicrobial activity of Agromone ochroleuca Sweet (Chicalote). BoletÃn Latinoamericano y del Caribe de Plantas Medicinales y AromÃ¡ticas, 10(2):139 - 146. Schwarzbach AE; Kadereit JW, 1999. Alligator weed is a South American species that has invaded all continents except Africa and Europe and is spreading in Australia where it grows in both aquatic and ter-restrial habitats. A climate matching program, CLIMEX, and the known distribution of the weed in South and North America were used to infer areas suitable for its growth else-where in the world.Â Again, to assist with weed management it would be useful to use current knowledge to predict where this biological control agent could be successful. J. Aquat. Plant Manage.Â Climatic associations and establishment of biological control of weed insects. In Center et al. (eds), Proceedings of the Symposium on Exotic Pest Plants, November 1988, Miami, Florida. Weed control is the botanical component of pest control, which attempts to stop weeds, especially noxious weeds, from competing with desired flora and fauna including domesticated plants and livestock, and in natural settings preventing non native species competing with native species. Weed control is important in agriculture. Methods include hand cultivation with hoes, powered cultivation with cultivators, smothering with mulch, lethal wilting with high heat, burning, and chemical control with...