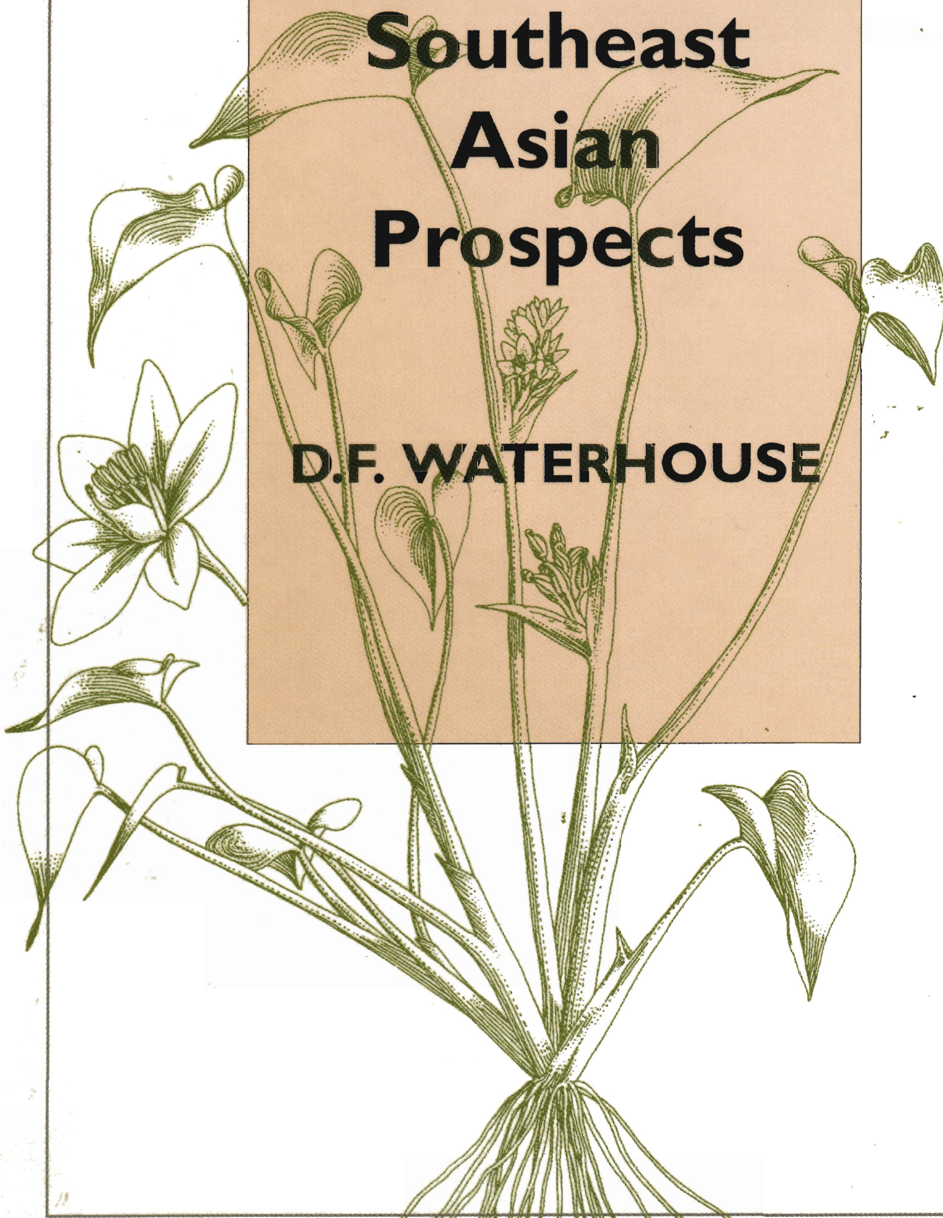
Biological Control of Weeds: Southeast Asian Prospects

D.F. WATERHOUSE



Biological Control of Weeds: Southeast Asian Prospects

D.F. Waterhouse

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ACIAR
(Australian Centre for International Agricultural Research)

Canberra
AUSTRALIA
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Foreword

From its very beginning in 1982 ACIAR has been a strong supporter of biological control as a sustainable and environmentally friendly alternative to the steadily growing use of pesticides. This alternative has achieved great success in regions of the world (e.g. Australia, New Zealand, Oceania, California) where many of the major insect pests and weeds have been introduced from outside the region. Although a smaller proportion of the major weeds in Southeast Asia are introduced than in many other regions, a recent survey commissioned by ACIAR (Waterhouse 1993a) identified 28 major weeds that merited evaluation as possible targets for biological control. Even if only half of these weeds proved to be attractive targets, this number would require several decades of research, major resources in personnel and equipment and strong support within the region.

The aim of the present volume is to summarise for the major exotic weeds of agriculture in Southeast Asia what is known about their natural enemies and the prospects for classical biological control. The book is intended to serve two purposes. Firstly, to facilitate, for the countries of the region, the selection of promising, individual or collaborative, priority weed targets. Secondly, to provide donor agencies with an overall perspective of the region's major exotic weed problems and prospects for their amelioration; and thus to aid in the selection of projects for support that are best suited to their terms of reference.

It is hoped that it may be possible in the near future to produce a companion volume dealing with major arthropod pests exotic to Southeast Asia.

G.H.L. Rothschild
Director
Australian Centre for International Agricultural Research, Canberra

1 Abstract

Biological control programs have already been mounted in some region of the world against 6 of the 28 major weeds that are exotic to Southeast Asia. Substantial or partial success has been achieved in one or more countries for all of these except *Mikania micrantha*, which is still under investigation. A substantial amount of information on their natural enemies in the region where the weeds evolved is available on all 6. This is in stark contrast with the situation for most of the remaining 22 weed species. Indeed, for more than half of these, so little relevant information is available that it is not possible to evaluate the chances of mounting a successful program. For this group of weeds the first step would be a survey in the centre of origin of the weed. It is probable that surveys could be mounted simultaneously of several candidate weeds in the same region of the world (e.g. Central America or Tropical Africa). The very minimum period for a preliminary survey would be several weeks in both spring and late summer. When the organisms collected had been identified by taxonomists a decision would be facilitated on possible follow-up surveys.

On the basis of available information there are good to excellent prospects for reducing, in at least some parts of the region, the weediness of the following:

Chromolaena odorata
Eichhornia crassipes
Mimosa invisa
Mimosa pigra
Pistia stratiotes
Portulaca oleracea

There are also good reasons for believing that there will prove to be valuable natural enemies for the following:

Ageratum conyzoides
Amaranthus spinosus
Bidens pilosa
Eleusine indica
Melastoma malabathricum
Mikania micrantha

There is insufficient information yet available on the remaining 15 weeds to attempt to evaluate their prospects for classical biological control.

2 Estimation of biological control prospects

Weed	Rating	Family	Any biological control successes?	Attractiveness as a target in SE Asia
Ageratum conyzoides	17	Asteraceae	–	++
Amaranthus spinosus	17	Amaranthaceae	–	++
Bidens pilosa	10	Asteraceae	–	++
Chromolaena odorata	18	Asteraceae	yes	++++
Commelina benghalensis	10	Commelinaceae	–	
Cynodon dactylon	18	Poaceae	–	unsuitable
Echinochloa crus-galli	21	Poaceae	–	
Eichhornia crassipes	20	Pontederiaceae	yes	+++++
Eleusine indica	24	Poaceae	–	++
Euphorbia heterophylla	10	Euphorbiaceae	–	
Euphorbia hirta	10	Euphorbiaceae	–	
Fimbristylis miliacea	23	Cyperaceae	–	
Marsilea minuta	12	Marsileaceae	–	
Melastoma malabathricum	13	Melastomataceae	–	++
Mikania micrantha	13	Asteraceae	–	++
Mimosa invisa	18	Mimosaceae	yes	++++
Mimosa pigra	15	Mimosaceae	yes	++++
Mimosa pudica	17	Mimosaceae	–	
Monochoria vaginalis	26	Pontederiaceae	–	
Nephrolepis biserrata	10	Nephrolepidaceae	–	
Panicum repens	16	Poaceae	–	
Paspalum conjugatum	15	Poaceae	–	
Passiflora foetida	11	Passifloraceae	–	
Pennisetum polystachion	11	Poaceae	–	
Pistia stratiotes	14	Araceae	yes	++++
Portulaca oleracea	10	Portulacaceae	–	+++
Rottboellia cochinchinensis	12	Poaceae	–	
Sphenoclea zeylanica	14	Sphenocleaceae	–	

3 Introduction

Waterhouse (1993a) published information, collated from agricultural and weed experts in the 10 countries of Southeast Asia, on the distribution and importance of their major weeds in agriculture. Ratings were supplied on the basis of a very simple system:

+++	very widespread and very important
++	not widespread but of great importance where it occurs
+	important only locally
•	present, but not an important pest

The advantages and limitations of this system are discussed by Waterhouse (1993a). Of 232 weeds nominated, 140 were rated as highly important, and a subset of 40 particularly so.

The focus of the present work is on the possibilities for classical biological control of those of this subset of 40 that evolved outside Southeast Asia. The assumption is that many of these have been introduced without some of the organisms that help to control them where they evolved. The chances are very remote indeed, for weeds that evolved in Southeast Asia, of introducing sufficiently host-specific organisms from outside the region. Nevertheless, it is possible that useful organisms present in, say, Thailand or Myanmar may not be present in all of the islands constituting the Philippines or Indonesia (or vice versa) and this possibility should be borne in mind.

The origin of 12 of the subset of 40 major weeds is believed to be Southeast Asia, or close by, and these have been excluded from consideration at this stage. The remaining 28 species, 27 of which are treated here, are either known to have evolved in the Americas or Africa or are postulated to have evolved in both Asia and Africa. This latter group is considered because the possibility exists that useful organisms at the African end of the range may not yet have extended their distribution into all of Southeast Asia.

The 28th species, couch grass, *Cynodon dactylon*, has not been dealt with because, in many situations, such as lawns and some pastures, it is regarded as a highly desirable species. Biological control agents would not distinguish between these situations and the many others where it is a serious weed, so other control measures must be employed in the latter instances.

Of course, it is not to be expected that all of any one country's top 20 or even top 10 exotic weeds will necessarily be included in this regional priority list. Indeed, at least some of those omitted might well merit the production of additional dossiers if they are of such importance locally that resources for a program would be likely to achieve a very high priority for a particular country. ACIAR would be interested to hear of weeds that might be considered in this category.

It is not so long ago that Wilson (1964) pointed out that no insects had yet been used for the biological control of aquatic weeds and that it was not clear "whether in the aquatic environment there exists a sufficient development of that monophagy in phytophagous insects that has been the main foundation for the biological control of weeds on land". He referred to the opinion of Brues (1946) that aquatic insects show little host specificity, but warned that this view might be the result of lack of information and recommended an extension of research in this general field. In the intervening 30 years, research on four major water weeds of South American origin has yielded success and even spectacular success with the following: *Salvinia molesta*, *Eichhornia crassipes*, *Alternanthera philoxeroides* and *Pistia stratiotes* (Room 1993).

It is very probable that a parallel can be drawn between the situation with water weeds in 1964 and the "conventional wisdom" of today that grassy weeds are unsuitable targets for classical biological control because of the danger to many major world crops that also belong to the family Poaceae e.g. rice, wheat, maize, sorghum, millet, sugarcane. However, it would be very strange indeed if host specialisation occurred widely in insects attacking all other plant families, but not amongst those attacking the very large number of grasses. In view of the fact that 10 of the 18 world's worst weeds are grasses (Holm et al. 1977) and eight of the 28 major exotic weeds in Southeast Asia are also grasses (Waterhouse 1992, 1993a), it is evident that the time is long overdue for a detailed study of the natural enemies of these grasses in the regions where they evolved. This theme is mentioned further below, in particular in the discussion on *Eleusine indica*.

For any biological control organisms to be approved for introduction into Southeast Asia against weedy grasses they would need to be sufficiently specific that they would not cause economic damage to the crop grasses listed in table 3.1. This list refers to Thailand, but is believed to be much the same as that for other Southeast Asian countries. It does not, however, include pasture species. A number of useful grasses are also harvested from the wild and some may have to be considered also, although there are important weeds (e.g. *Imperata cylindrica*) amongst them. There are, of course, many additional crop grasses of importance outside the region, but of little or no importance in most or all of Southeast Asia. They would certainly have to be taken into consideration in other regions of the world.

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. In many other situations, however, all that may be required is a significant reduction in seeding (for annuals) or in competitiveness (for annuals and perennials) so that the weed no longer has an opportunity of becoming dominant and thus, when necessary, is more readily controlled by cultural or other measures. Thus, even partial biological control (leading to the weed becoming less aggressive) provides desirable plant species with the opportunity to compete more successfully for sunlight and nutrients and may be of significant value.

Another problem is that many weeds display a good deal of variability throughout their distribution, resulting in part from polyploidy, hybridisation with closely related species and other genetic modifications. The taxa thus produced may not be equally susceptible to natural enemies, so it is desirable, where possible, to match ~~them with~~ taxa encountered in the surveys in the area of origin of the weed. It may also be necessary to seek expert taxonomic advice at an early stage, perhaps involving electrophoretic, DNA and other studies, particularly when commencing a project on a weed that has not yet been the target of a biological control investigation.

The summary accounts presented are designed to enable a rapid review to be made of (i) the main characteristics of the major weeds of agriculture that are believed to be exotic to part or all of Southeast Asia, (ii) what is known of their natural enemies and (iii) prospects for reducing their weediness by classical biological control.

The material on weed characteristics draws heavily on the publications by Barnes and Chan (1990), Holm et al. (1977), Noda et al. (1985) and Soerjani et al. (1987). Additional information is available from these sources, including detailed botanical descriptions, vernacular names, biology, agricultural importance and herbicidal control.

I am particularly grateful to the University of Hawaii Press for permission to draw on 21 of the illustrations in its publication 'The World's Worst Weeds' by Holm et al. (1977) to Ancom Berhad, Malaysia (Barnes and Chan 1990) and the Director of BIOTROP Indonesia (Soerjani et al. 1987) to draw on 2 and 3 illustrations respectively from their publications and to the Division of Entomology CSIRO for permission to use illustration 4.16. The figures have been slightly amended by the omission of inserts that are mainly of taxonomic interest. Acknowledgement appears on each of the illustrations used.

In most instances four databases were searched for relevant information:

AGRICOLA (Bibliography of Agriculture) 1970+
BIOSIS (Biological Abstracts) 1989+
CAB (Commonwealth Agricultural Bureaux) 1984+
DIALOG (Biological Abstracts) 1959+

In many cases abstracting journals and other sources published prior to the above commencement dates were also searched. Useful information was also obtained by serendipity from these and other references and from unpublished records. Nevertheless, in many cases the search cannot be described as exhaustive. Even more relevant, however, than attempting an exhaustive search would be a fresh, detailed field survey targeted on the known (or presumed) area of origin of the weed. In any event, in most instances a preliminary investigation would be highly desirable in the area of origin of a weed before deciding whether or not to embark upon a major project. Several such surveys might well be carried out simultaneously where more than one weed occurs in the same general region. Indeed, it is strongly recommended that a pre-project activity be funded to carry out such surveys, with special reference to selected weeds of major importance in Southeast Asia.

Surveys of this nature are particularly important, since the amount of useful, published information on arthropods or other organisms attacking the target weeds is, in general, inadequate to serve as a basis for a sound decision. Although acceptable host specificity is required for classical biological control, it is possible that some of the less specific fungi listed might be developed for use as bioherbicides.

In addition to surveys in the region of origin of the weed(s) it will also be necessary to survey the weed(s) in the country or countries where biological control is to be attempted. This is to indicate whether any of the organisms that might be considered for introduction are already present.

The species treated are drawn from tables 10 and 11 of 'The Major Arthropod Pests and Weeds of Agriculture in Southeast Asia: Distribution, Importance and Origin' (Waterhouse 1993a). It is quite possible that additional weeds rating highly in these tables will prove to be exotic to Southeast Asia (or significant parts of it) and, alternatively, that some considered to be exotic will, on further evidence, be shown to have evolved in the region.

The natural enemies most commonly involved in classical biological control of weeds have been arthropods, although there is a growing interest in, and a few striking successes with, fungi. Because there is a considerable lack of uniformity in the names of many of the insects involved, a separate index is included listing the preferred scientific names. These have been used in the text, replacing those used by the authors quoted. On the other hand, with few exceptions the names used for fungi, bacteria, nematodes and viruses are those of the authors quoted, although it is probable that some names have been changed since they were used. Where the name of a weed or an insect given in a publication is no longer preferred by taxonomists, the superseded name, x, is shown thus (= x), but this usage is not intended to convey any other taxonomic message. Indeed, the superseded name may still be valid, but simply not applicable to the particular species referred to by the author.

I am most grateful for assistance from many colleagues during the preparation of this book. It is not possible to name them all, but special thanks are due to Dr B. Napompeth (Thailand), Dr R. Muniappan (Guam), C.J. Davis (Hawaii) and, in Australia, Dr I.W. Forno, Dr K.L.S. Harley, M.H. Julien, Dr K.R. Norris, J. Prance, Dr D.P.A. Sands, Dr A.J. Wapshere and A.D. Wright of CSIRO and Dr R.E. McFadyen (Queensland Department of Lands). Many others who have contributed unpublished information are acknowledged at appropriate places in the text.

Valuable advice on taxonomic problems has been received from a number of colleagues in the Division of Entomology, CSIRO, Canberra, including Dr M. Carver (Hemiptera), Dr P. Cranston (Diptera), E.D. Edwards (Lepidoptera), Dr I.D. Naumann, Dr K.H.L. Key (Orthoptera), T. Weir (Coleoptera) and Dr E.C. Zimmerman (Curculionidae).

Continuing warm support has been provided by Dr P. Ferrar, Research Program Coordinator, Crop Sciences, ACIAR, Canberra.

It is a pleasure to acknowledge the expert assistance of Mrs A. Johnstone (Ms A. Ankers) in converting my manuscripts into presentable form; and also of Mrs S. Smith and C. Hunt for assistance with the illustrations.

It would not have been possible to continue with these biological control activities in deep retirement without the support, forbearance and encouragement of my wife, to whom particular thanks are due.

Table 3.1 Grasses (other than pasture species) that are important in Thailand.

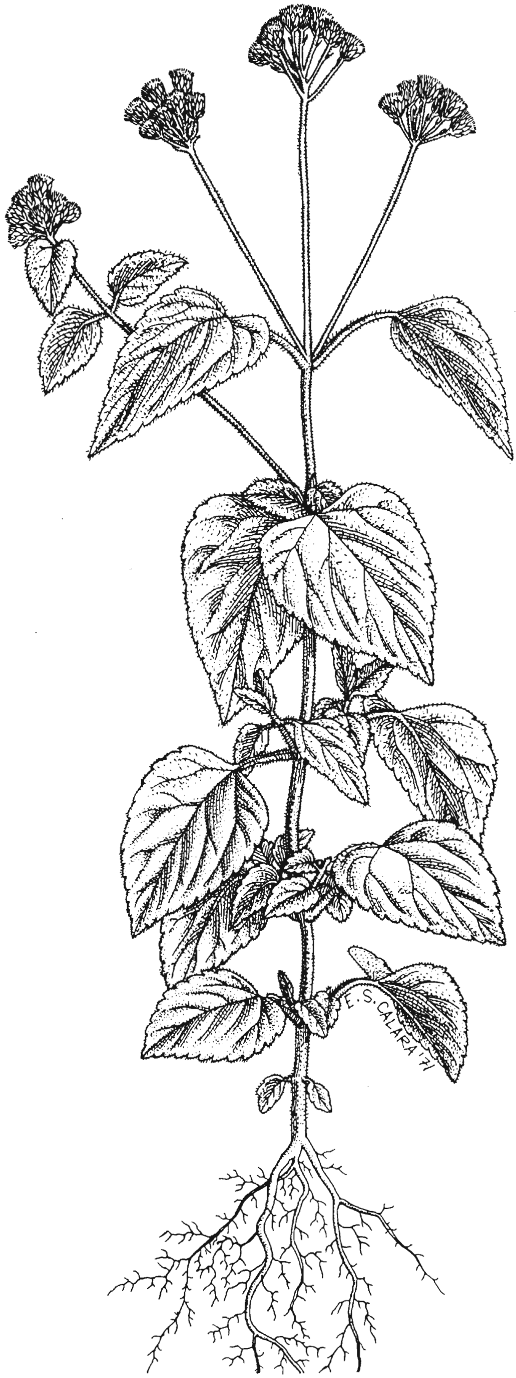
A. Crop Grasses	Importance	
Bambusa spp.	+++	bamboo, construction, furniture, paper
Coix lacryma-jobi	+	job's tears, cereal
Cymbopogon spp.	++	lemongrasses, flavourings
Hordeum spp.	++	barleys
Oryza sativa	+++++	rice
Saccharum officinarum	+++	sugar cane
Setaria italica	++	foxtail millet
Sorghum bicolor	++++	sorghum
Triticum spp.	++	wheats
Zea mays	++++	maize
Zizania latifolia	+	vegetable

B. Grasses harvested from the wild

Arundo donax	giant reed, cane
Dendrocalamus spp.	weaving, vegetables
Gigantochloa spp.	construction, furniture
Imperata cylindrica	paper, roof thatch
Melocanna baccifera	paper, furniture, food
Phragmites spp.	reeds, thatch, mats
Phyllostachys spp.	furniture, vegetable
Schizostachyum dumetorum	rope

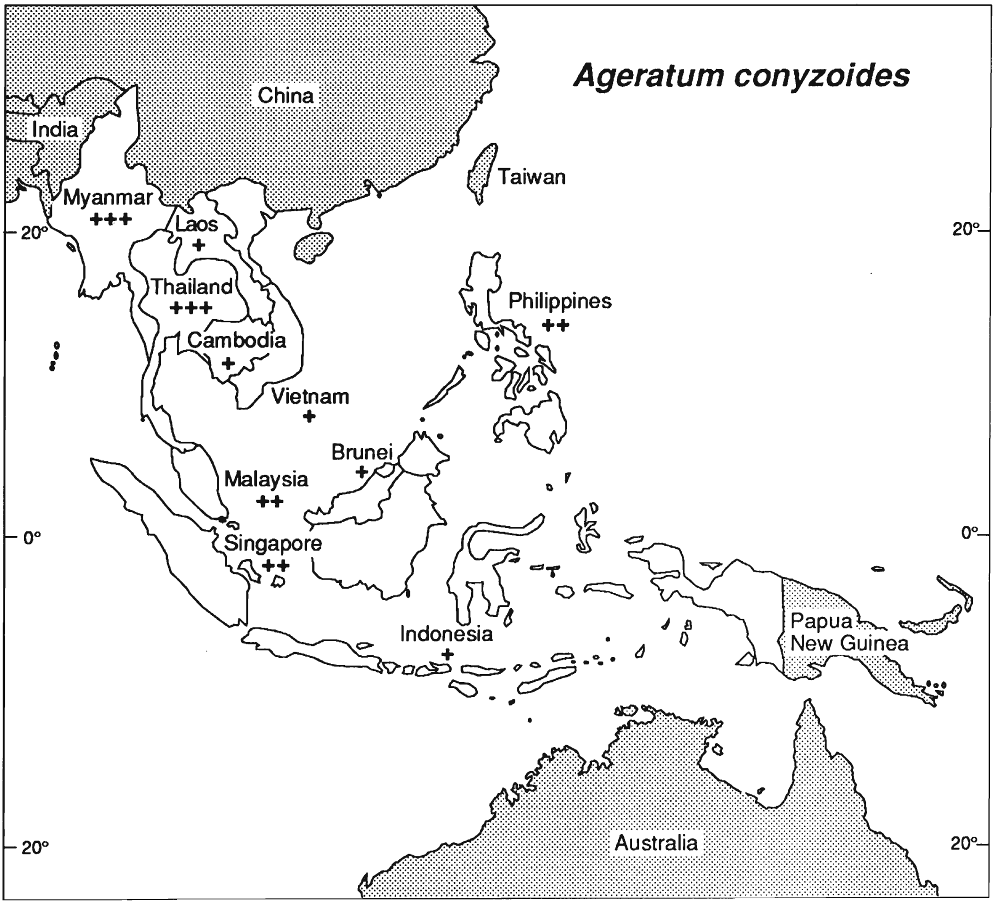
4 Target weeds

1. *Ageratum conyzoides*
2. *Amaranthus spinosus*
3. *Bidens pilosa*
4. *Chromolaena odorata*
5. *Commelina benghalensis*
6. *Echinochloa crus-galli*
7. *Eichhornia crassipes*
8. *Eleusine indica*
9. *Euphorbia heterophylla*
10. *Euphorbia hirta*
11. *Fimbristylis miliacea*
12. *Marsilea minuta*
13. *Melastoma malabathricum*
14. *Mikania micrantha*
15. *Mimosa invisa*
16. *Mimosa pigra*
17. *Mimosa pudica*
18. *Monochoria vaginalis*
19. *Nephrolepis biserrata*
20. *Panicum repens*
21. *Paspalum conjugatum*
22. *Passiflora foetida*
23. *Pennisetum polystachion*
24. *Pistia stratiotes*
25. *Portulaca oleracea*
26. *Rottboellia cochinchinensis*
27. *Sphenoclea zeylanica*



Ageratum conyzoides

(after Holm *et al.* 1977)



Map 4.1 *Ageratum conyzoides*

As a member of the Asteraceae, it would be expected that *Ageratum conyzoides* would have many natural enemies attacking it in its area of origin in Tropical America. However, no study has been made and virtually nothing is known of the situation there. Elsewhere it is attacked by a range of insects, nematodes, fungi and viruses, but almost all have a very wide host range and are not suitable as biological control agents.

Surveys in Tropical America would be necessary to provide data on which prospects for its biological control could be evaluated.

4.1 *Ageratum conyzoides* L.

Asteraceae

goatweed, ageratum; bandotan (Indonesia), rumput tahi ayam (Malaysia), bulak manok, kolokong kabayo (Philippines), ya tabsua, ya sap raeng (Thailand), cò cút heo, bò xít (Vietnam)

Rating

	+++	Myan, Thai
17	++	Msia, Sing, Phil
	+	Laos, Camb, Viet, Brun, Indo

Origin

Tropical America.

Distribution

Pantropical; also in the subtropics and extending into temperate areas from latitude 30°N to 30°S. Widespread in SE Asia. Present in Java prior to 1860.

Characteristics

Ageratum conyzoides is a self pollinated, C3, annual herb. It is erect, often branched, sometimes decumbent and ranges up to 1.2 m at flowering. Its flowers are light blue, white or violet and its leaves and stems are hairy.

Importance

A. conyzoides occurs in both light and heavy soils in moister areas in agricultural land, waste land, roadsides, plantations, pastures and upland rice fields. It may produce 40 000 or more seeds per plant and these are mainly spread by wind and water. They germinate readily and the life cycle can be completed in less than 2 months. *A. conyzoides* is one of about 300 species in the genus, all of which originated in the Americas. Goatweed is important in 46 countries in 36 crops and is troublesome in plantations after grasses have been suppressed (Holm et al. 1977). It is a rapidly colonising, vigorously growing weed in a wide variety of arable crops in which thick carpets of *A. conyzoides* compete strongly for nutrients and moisture. When a stand is destroyed another rapidly takes its place. It is suspected of poisoning cattle, but this is not confirmed from Australia. It was rated 19th of the World's Worst Weeds by Holm et al. (1977), as equal 15th in Southeast Asia (Waterhouse 1993a) and 15th in the Oceanic Pacific (Waterhouse unpub.).

Its crushed leaves smell strongly of coumarin and are used as a styptic for wounds, also for sores, skin diseases, eye inflammation and lung problems (Gonzalez et al. 1991). It is sometimes used as cut flowers in the home.

Natural enemies

Although *A. conyzoides* is listed by Holm et al. (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. From this it might be inferred that natural enemies might be controlling its abundance. However, so little information on natural enemies (Tables 4.1.1 to 4.1.3) was obtained from the databases searched that it is not possible to substantiate this claim. Almost all of the records are from outside its area of origin and one (the agromyzid fly, *Melanagromyza metallica*) is known to have a narrow host range. However, *M. metallica* is already widespread. In addition to India, it is known also from many places including Taiwan, Philippines, Vietnam, Thailand, Indonesia, Melanesia, Papua New Guinea, Solomon Is, Micronesia, Australia and Africa. It lays its eggs on the apical part of the stem. The larva bores into the pith region, gradually extending towards the root and the final instar larva cuts an exit hole at the base of the stem. Mines may extend into the roots and pupae are often present at about ground level in the mines (Singh and Beri 1973).

If *A. conyzoides* is considered to be an important target it will be necessary to survey for organisms attacking it in Central America and northern South America.

Table 4.1.1 Natural enemies of *Ageratum conyzoides*: insects and mites.

Species	Location	Other hosts	References
INSECTS			
Orthoptera			
ACRIDIDAE			
Zonocerus variegatus	Nigeria	*Chromolaena odorata, Lantana camara*	Toye 1974
Hemiptera			
APHIDIDAE			
Aphis craccivora		many	Raychaudhuri 1983
Aphis gossypii		many	Raychaudhuri 1983
Aphis spiraecola (= *A. nigricauda*)	Java	many	Patch 1939, Raychaudhuri 1983
Aulacorthum solani		many	Raychaudhuri 1983
Brachycaudus helichrysi		many	Raychaudhuri 1983
Capitophorus hippophaes		*Eupatorium, Mirabilis, Polygonum*	Ghosh et al. 1971
Hyperomyzus carduellinus			Patch 1939
Myzus ornatus		many	Raychaudhuri 1983
Myzus persicae		many	Raychaudhuri 1983
Neomasonaphis (= *Masonaphis*) *anaphalidis*		many	Raychaudhuri 1983
Uroleucon (= *Macrosiphum*) *solidaginis*			Patch 1939
Vesiculaphis pieridis	India	*Lyonia ovalifolia, Pieris ovalifolia*	Patch 1939

(continued on next page)

Table 4.1.1 (continued)

Species	Location	Other hosts	References
ALEYRODIDAE			
Bemisia tabaci	India, Malaysia, Turkey	a very wide range	Ang et al. 1977, Sastry 1984, Shreni et al. 1979
DIASPIDIDAE			
Mycetaspis personata	Brazil	polyphagous	d'Araujo e Silva et al. 1968a
LYGAEIDAE			
Nysius inconspicuus	India	sesame and many others	Thangavelu 1978
Thysanoptera			
PHLAEOTHRIPIDAE			
Haplothrips gowdei	Hawaii	vector of pineapple yellow spot virus	Sakimura 1937
THRIPIDAE			
Calipthrips ipomoeae	Brazil	polyphagous	d'Araujo e Silva et al. 1968a
Microcephalothrips abdominalis	India	polyphagous	Gopinathan et al. 1981
Thrips tabaci	Hawaii	vector of pineapple yellow spot virus	Sakimura 1937
Diptera			
AGROMYZIDAE			
Calycomyza sp.	USA		Spencer & Steyskal 1986
Melanagromyza metallica	India, etc	no other host mentioned	Singh & Beri 1973
CHLOROPIDAE			
Olcella pleuralis	Trinidad	*C. odorata, C. ivaefolia, C. iresinoides, Fleischmannia microstemon, Wedelia caracasana, Wulffia baccata*	McFadyen 1988a
TEPHRITIDAE			
Xanthaciura insecta	Florida, Trinidad	*C. odorata, F. microstemon W. caracasana*	McFadyen 1988a, Needham 1946
Lepidoptera			
ARCTIIDAE			
Pareuchaetes pseudoinsulata (= *Ammalo insulata*)	Nigeria, Trinidad	*C. odorata*	Bennett & Cruttwell 1973, Olaoye 1974
GELECHIIDAE			
Dichomeris sp.	Trinidad	*C. odorata*	Bennett & Cruttwell 1973
NOCTUIDAE			
Pseudoplusia includens (=*Plusia oo)*	Brazil	polyphagous	d'Araujo e Silva et al. 1968a
Spodoptera frugiperda	Brazil	polyphagous	d'Araujo e Silva et al. 1968a

(continued on next page)

Species	Location	Other hosts	References
PYRALIDAE			
Pionea upalusalis	Trinidad, Puerto Rico, Venezuela	*C. odorata, C. ivaefolia, Austroeupatorium inulaefolium, Fleischmannia microstemon*	McFadyen 1988a
MITES			
Brevipalpus obovatus	India	cotton, *Solanum nigrum, Sonchus asper, Phaseolus vulgaris, Euphorbia hirta, Xanthium sp., Cichorium intybus*	Sadana et al. 1983
Tetranychus urticae	China	a very wide range	Dong et al. 1986

Table 4.1.2 Natural enemies of *Ageratum conzoides*: nematodes.

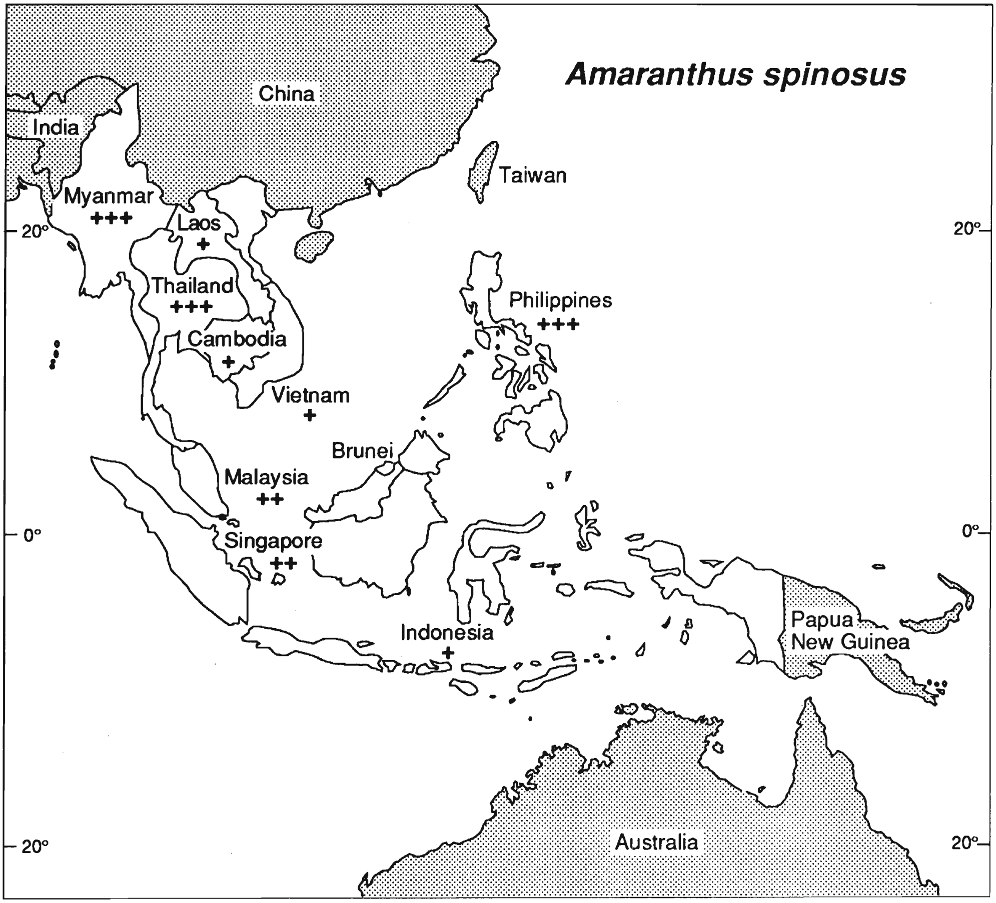
Species	Location	Other hosts	References
Aphelenchoides fragariae	Hawaii	strawberry, *Vanda* orchids, *Impatiens, Nephrolepis biserrata*	Sher 1954
Helicotylenchus multicinctus	Brazil	banana, *Portulaca oleracea* and several weeds	Zem & Lordello 1983
Meloidogyne sp.	Cuba	*Eleusine indica, Croton lobatus, Cynodon dactylon*	Acosta et al. 1986 Holm et al. 1977
Meloidogyne arenaria	Philippines		Valdez 1968
Meloidogyne arenaria thamesis	Philippines		Valdez 1968
Meloidogyne incognita	Philippines	many vegetables and weeds	Mamaril & Alberto 1989
Meloidogyne javanica	Philippines, Nigeria	many vegetables and weeds	Mamaril & Alberto 1989, Salawu et al. 1991 Valdez 1968
Pratylenchus pratensis	Hawaii		Holm et al. 1977
Rotylenchulus reniformis	Hawaii, India	many weeds	Linford & Yap 1940, Lal et al. 1978

Table 4.1.3 Natural enemies of *Ageratum conyzoides*: fungi, bacteria and viruses.

Species	Location	Other hosts	References
FUNGI			
Cercospora agerati			Stevens 1925
Colletotrichium sp.	India		Kulkarni & Sharma 1976
Cylindrocladium quinqueseptatum	India	many commercial hosts	Sulochana et al. 1982
Mycovellosiella perfoliata	India		Srivastava 1981
Puccinia conoclinii			Stevens 1925
Sclerotium rolfsii	India	many	Desai et al. 1980
BACTERIA			
Pseudomonas solanacearum	India	potato, *Ranunculus sceleratus*	Sathiarajan & Sasikumar 1977, Sunaina et al. 1989
VIRUSES			
Ageratum vein yellowing	India, Malaysia	(transmitted by *Bemisia tabaci*)	Ang et al. 1977, Shreni et al. 1979
anemone mosaic			Holm et al. 1977
Bidens mottle		several, including *Zinnia*, petunia & *Verbena*	Logan & Zettler 1984
hibiscus yellow vein mosaic	India	(transmitted by *B. tabaci*)	Jeyarajan et al. 1988
pineapple yellow spot	Hawaii		Sakimura 1937
potato virus Y	India	potato	Joshi & Prakash 1977
tapioca mosaic	India	(transmitted by *B. tabaci*)	Jeyarajan et al. 1988
tobacco leaf curl	India	tomato	Holm et al. 1977, Reddy et al. 1981
tomato leaf curl	Turkey, India	many weeds (transmitted by *B. tabaci*)	Sastry 1984, Jeyarajan et al. 1988
urd bean yellow mosaic	India	(transmitted by *B. tabaci*)	Jeyarajan et al. 1988
Zinnia yellow net	India	(transmitted by *B. tabaci*)	Srivastava et al. 1977

Amaranthus spinosus

(after Holm *et al.* 1977)



Map 4.2 *Amaranthus spinosus*

Mass rearing and release, as required, of the weevil *Hypolixus trunculatus* is reported to provide good control of *Amaranthus spinosus* in Thailand but, of course, this is augmentative rather than classical biological control.

Three other insects (a weevil, a leaf mining fly and a caterpillar) are known which may prove to be adequately specific for classical biological control.

However, almost nothing is known about the natural enemies of *A. spinosus* in tropical America where it evolved and it would thus be necessary to carry out a survey there in order to evaluate what potential biological control agents are available.

4.2 *Amaranthus spinosus* L.

Amaranthaceae

spiny amaranth, spiny pigweed, needle burr; hin nu nive tsu bauk (Myanmar), phak khom nam (Thailand), phti banla (Cambodia), bayam duri (Malaysia and Indonesia), orai (Philippines), dên gai (Vietnam)

Rating

	+++	Myan, Thai, Phil
17	++	Msia, Sing
	+	Laos, Camb, Viet, Indo

Origin

Tropical America.

Distribution

A. spinosus is mainly tropical and subtropical in distribution, but also extends into the temperate zone from latitude 30°N to 30°S.

Characteristics

A. spinosus is an erect, much branched, annual, growing to 1.2 m. Its stems are angled in cross section, fleshy, often reddish and bear many spines. Its leaves are alternate, with a pair of straight spines up to 1 cm long at the base. The inflorescence is long, slender and terminal or arises from leaf axils. The flowers are small, greenish and unisex. It is propagated by reddish brown seeds.

Importance

Spiny amaranth prospers in warm sunny situations, but not where it is cool or shady. It is not reported as a problem in the Mediterranean or Middle East. It is a weed in 44 countries in 28 crops, mainly in the Caribbean, in the west and south of Africa, in India and in Southeast Asia. Up to 235 000 seeds per plant have been recorded. Seeds are spread by wind and water. Some germinate soon, others over several months and still others remain viable in the soil for many years. *A. spinosus* is abundant in cultivated and abandoned fields, along roadsides and in waste places. It is a weed of varying degrees of aggressiveness in many crops, including upland rice, cotton, cowpeas, groundnuts, maize, mangos, millet, pineapples, sugarcane and vegetables. The rigid needle-like spines break off in the hands of workers in sugarcane, cotton and other crops.

A. spinosus may contain high nitrate levels and has been implicated in livestock poisoning. It is avoided by most animals because of its spines. Leaves are sometimes used by humans as a green vegetable. Other *Amaranthus* species are valuable as a grain crop in some South American countries and the family Amaranthaceae contains a number of widely grown ornamental garden species (Purseglove 1968).

Natural enemies

A. spinosus is attacked by a number of natural enemies (Tables 4.2.1 and 4.2.2), but most of the reports come from outside its native range and are of non-specific organisms. The agromyzid fly *Haplopeodes minutus*, known in USA from species of *Amaranthus* and *Chenopodium* (Spencer and Steyskal 1986) and both the beetle *Cassida nigriventris* and the moth *Coleophora versurella*, known in Pakistan from these same plant genera (Khan et al. 1978), may prove to be sufficiently specific to be candidate biological control agents.

The weevil *Hypolixus truncatulatus*, whose larvae tunnel in the stems and form galls, is known from Pakistan, India and Thailand and attacks *Amaranthus spinosus*, *A. viridis* and *Digera arvensis*. Although it has a relatively long life cycle and low reproductive capacity, mass rearing and augmentative releases have resulted in a satisfactory level of control and replaced the use of herbicides in Thailand (Julien 1992, Napompeth 1982, 1989, 1992a). Females deposit eggs singly in cavities scooped out of the shoots. Larvae tunnel down inside the stem to its base, where a gall develops. Breeding continues throughout the year but is at its height in late summer. At this time the life cycle is 44 to 50 days. Pupation occurs within the gall. Larvae and pupae are parasitised by larvae of the pteromalid wasp *Oxysychus* sp. (Agarwal 1985).

Evans (1987) records five fungi from *A. spinosus* but, except for one which is unsuitable because it has a wide host range, too little is known about their host specificity to assess the prospects for their use in classical biological control.

Comment

Almost nothing is known about the natural enemies of *A. spinosus* in tropical America where it evolved. A survey in this region would be necessary to document the organisms attacking it. There are good general grounds for believing that there are some natural enemies that are specific to the family Amaranthaceae. In most countries, members of this family have little value as crop plants, so the chances are that some safe natural enemies will be found that are of value as classical biological control agents.

Table 4.2.1 Natural enemies of *Amaranthus spinosus*: insects and mites.

Species	Location	Other hosts	References
INSECTS			
Hemiptera			
APHIDIDAE			
Myzus persicae	Malawi, Thailand	highly polyphagous	Chapola 1980, Napompeth 1982
COREIDAE			
Cletus fuscescens	Nigeria	*Amaranthus dubius*, *A. cruentus*, *A. hypochondriachus*	Ukwela & Ewete 1989
LYGAEIDAE			
Germalus unipunctatus	Vanuatu		Cock 1984b
Nysius sp.	Vanuatu		Cock 1984b

(continued on next page)

Table 4.2.1 continued

Species	Location	Other hosts	References
MIRIDAE			
Horcias nobilellus	Brazil	polyphagous	d'Araujo e Silva et al. 1968a
PIESMATIDAE			
Piesma cinereum	Brazil	polyphagous	d'Araujo e Silva et al. 1968a
Thysanoptera			
PHLAEOTHRIPIDAE			
Haplothrips longisetosus	India	*Amaranthus viridis, A. oleosa, Chenopodium anthelminthicum*	Dhiman 1986
Coleoptera			
CHRYSOMELIDAE			
Cassida exilis	Pakistan	*Amaranthus viridis, Chenopodium album*	Baloch et al. 1976
Cassida nigriventris	Pakistan	*Amaranthus viridis, Chenopodium album, Spinacia oleracea*	Baloch et al. 1976 Khan et al. 1978
CURCULIONIDAE			
Ceutorhynchus asperulus	India	red gram, *Amaranthus viridis, A. tricolor, Basella alba*	Puttaswamy & Channabasavanna1981, Puttaswamy et al. 1981
Hypolixus truncculatus	Pakistan, India, Thailand	*Amaranthus viridis, Chromolaena odorata Digera arvensis*	Agarwal 1985, Baloch et al. 1976, 1977, Ghani 1965, Julien 1992 Napompeth 1982, 1990b, 1992a
MELYRIDAE			
Astylus lineatus	Brazil	citrus	d'Araujo e Silva et al. 1968a
Diptera			
AGROMYZIDAE			
Haplopeodes minutus	USA	*Amaranthus, Chenopodium*	Spencer & Steyskal 1986
Lepidoptera			
COLEOPHORIDAE			
Coleophora versurella	Pakistan	*Chenopodium botrys*	Khan et al. 1978
CURCULIONIDAE			
Hypolixus ritsemae	Vanuatu		Cock 1984b
LYCAENIDAE			
Zizeeria knysna	Pakistan		Baloch et al. 1976
Zizeeria krupta	Pakistan		Baloch et al. 1977, Ghani 1965
NOCTUIDAE			
Neogalea (= Spodoptera) sunia	Nicaragua	polyphagous	Savoie 1988
Spodoptera eridania	Nicaragua	polyphagous	Savoie 1988
Spodoptera exigua	Nicaragua	polyphagous	Savoie 1988
Spodoptera litura	Philippines	highly polyphagous	Moody et al. 1987

(continued on next page)

Species	Location	Other hosts	References
PYRALIDAE			
Loxostege sp.	Argentina	seed heads of *Amaranthus sp.* (the genus *Loxostege* contains pests)	C.J. Deloach pers. comm.1980
Spoladea (=*Hymenia*) *recurvalis*	India, Pakistan Vanuatu	polyphagous	Baloch et al. 1976 Chaudhury & Kapil 1977, Lock 1984b, Ghani 1965
SCYTHRIDIDAE			
Eretmocera impactella	Pakistan	*Amaranthus viridis*, *Chenopodium album*	Baloch et al. 1977
TORTRICIDAE			
Archips sp.	Pakistan		Ghani 1965
YPONOMEUTIDAE			
Plutella xylostella	Pakistan		Ghani 1965
MITE			
TETRANYCHIDAE			
Tetranychus novocaledonicus	India	*Amaranthus tricolor*, *A. viridis*	Puttaswamy & Channabasavanna 1981

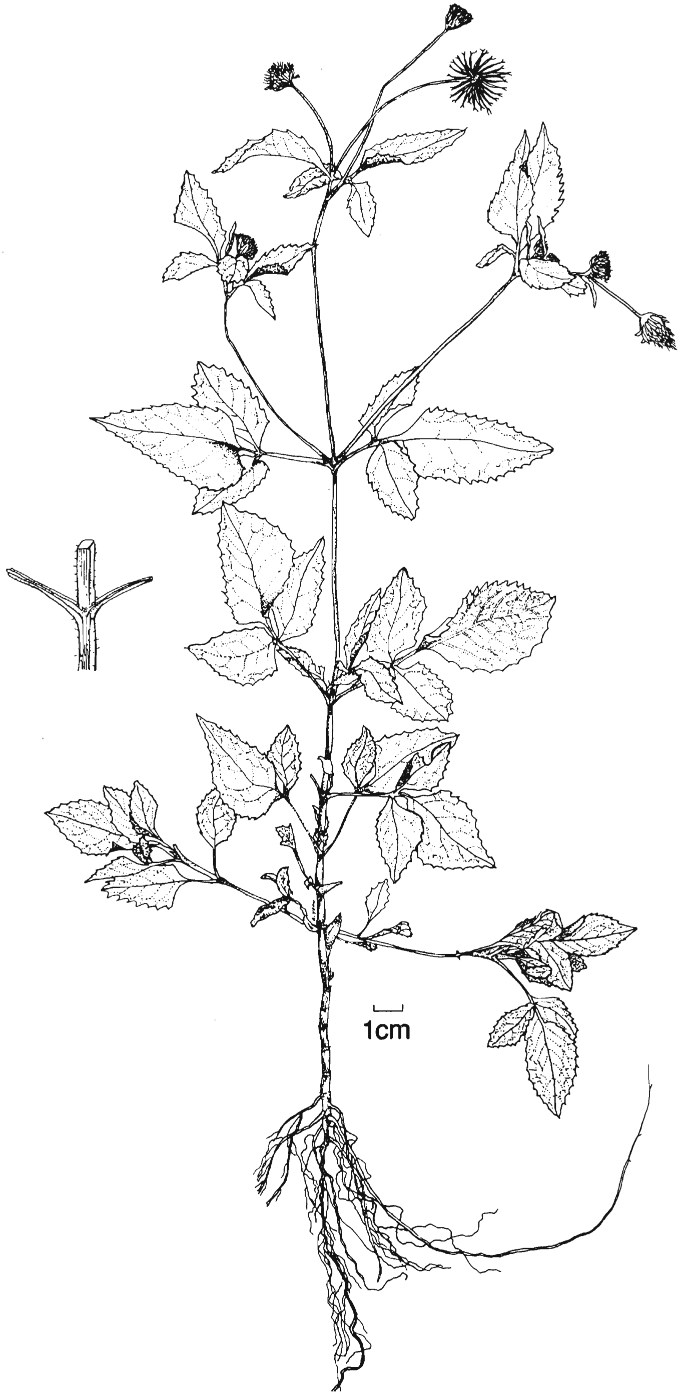
Table 4.2.2 Natural enemies of *Amaranthus spinosus*: nematodes, fungi, viruses.

Species	Location	Other hosts	References
NEMATODES			
Cactodera amaranthi	Cuba	spinach, other species of *Amaranthus*	Stoyanov 1972
Meloidogyne incognita	Philippines		Valdez 1968
Pratylenchus zeae		rice, many weeds	Fortuner 1976
Pseudocephalobus indicus	India	only recorded on *A. spinosus*	Joshi 1972
Rotylenchulus reniformis	India, USA	many weed hosts	Inserra et al. 1989, Lal et al. 1978
FUNGI			
Albugo bliti	Dominica, Jamaica, India, Pakistan, Sudan	many Amaranthaceae	Baloch et al. 1977, Evans 1987
Alternaria compacta	India		Kar & Ashok-Das 1988
Aposphaeria amaranthi	USA	potential bioherbicide for *A. albus*; effect on *A. spinosus* not known	Mintz & Weidemann 1992
Bipolaris indica (as *Drechslera indica*)		many, including *Helianthus, Pennisetum, Portulaca*	Evans 1987, Kenfield et al. 1989

(continued on next page)

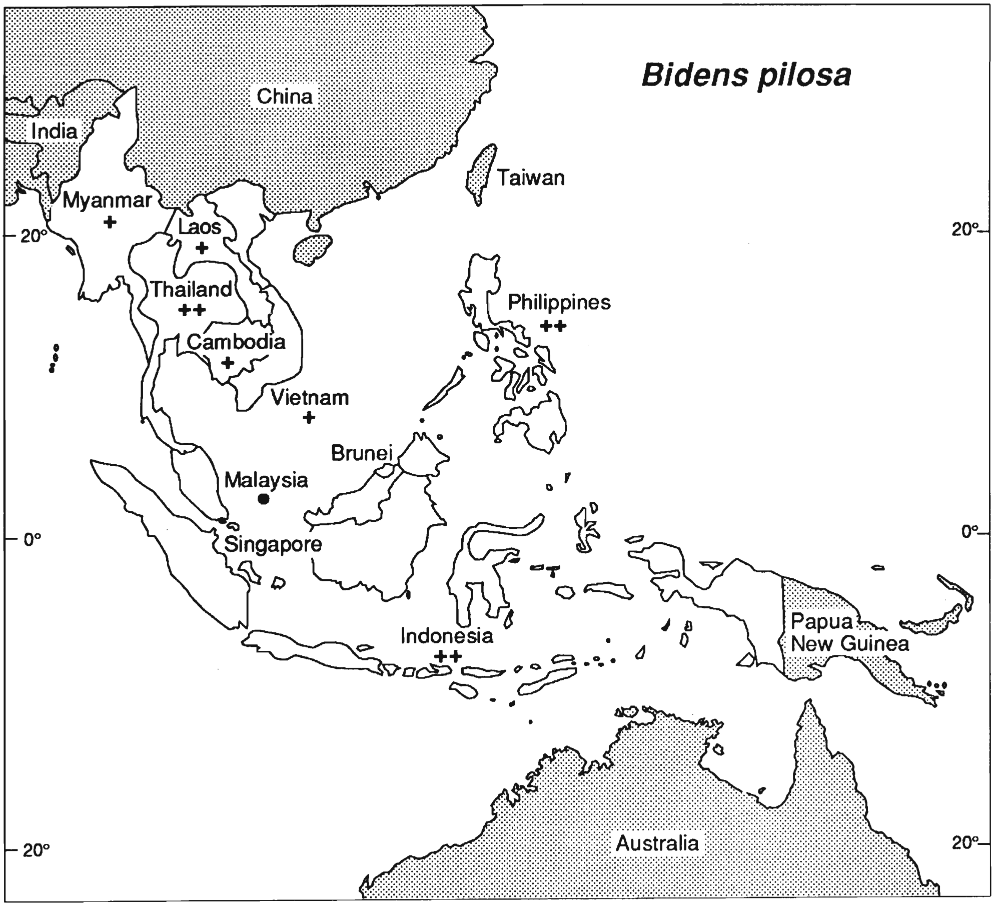
Table 4.2.2 continued

Species	Location	Other hosts	References
Cercospora brachiata (= *C. amaranthi*)	India, Nigeria, Uganda, Trinidad, USA, Japan, China, USSR	many Amaranthaceae	Evans 1987
Fusarium oxysporum f.sp. *elaeidis*	Nigeria	oil palm, *Chromolaena odorata*, *Imperata cylindrica*, *Mariscus alternifolius*	Oritsejafor 1986
Phoma tropica	India		Evans 1987
Puccinia sp.	Hong Kong		Evans 1987
VIRUSES			
cucumber mosaic	India	cucumber, *Solanum*, *nigrum*, *Tagetes erecta*, etc	Suteri et al. 1980
Digera mosaic	India	several weeds	Singh et al. 1975
groundnut rosette			Adams 1967
tobacco bunchy top	Malawi	(*Myzus persicae* is a vector)	Chapola 1980
tobacco mosaic	Philippines		Eugenio & del Rosario 1962



Bidens pilosa

(after Holm *et al.* 1977)



Map 4.3 *Bidens pilosa*

Bidens pilosa is native to tropical America. Preliminary studies, based mainly on Trinidad, indicate that it is attacked by a number of natural enemies, mainly insects, and that several of these may be sufficiently host specific to be considered as biological control agents. Further host specificity studies are required and additional, wider-ranging searches, particularly in South America.

4.3 *Bidens pilosa* L.

Asteraceae

cobbler's pegs, Spanish needle; djaringan ketul (Indonesia), pisau pisau (Philippines) yah koen jam khao (Thailand)

Rating

	++	Thai, Indo, Phil
10	+	Myan, Laos, Camb, Viet
	•	Msia

Origin

Tropical America

Distribution

Pantropical. Known from Java before 1835, but apparently not present in Kalimantan or the Moluccas (Soerjani et al. 1987).

Characteristics

Bidens pilosa is an erect, slender, branching, annual herb growing up to 1.5 m. Its stems are four-angled in cross section and its leaves opposite and sparsely hairy. The abundant yellow flowers are borne in heads on long stalks and produce black, barbed seeds characteristically radiating in all directions from a common base. The recurved, 2-toothed barbs enable the seeds to stick readily to hair and clothing and they are also distributed by wind and water. Cobbler's pegs prefers moister soils and flowers all year round.

Importance

A very common weed of 31 crops in more than 40 countries, *B. pilosa* occurs in gardens, cultivated land, open waste places and along roadsides. It is an important weed of pastures, maize, sorghum, vegetables, cotton, tea, coffee, cassava, coconut, oil palm, citrus, papaya, rice, rubber and tobacco. Single plants produce up to 6000 seeds, many of which germinate readily, permitting three or four generations a year in some regions.

Some seeds remain viable in the soil for at least 5 years. When herbicides have eradicated perennial grasses this weed often becomes dominant.

In South Africa the early spring growth is sometimes eaten by humans, but has low nutritive value. It has a pungent essential oil that may taint milk.

Natural enemies

These are also dealt with in 'Biological Control: Pacific Prospects' (Waterhouse and Norris 1987) which did not assess *B. pilosa* a particularly promising target for biological control. However, more information has since become available (Table 4.3.1 and 4.3.2), particularly concerning leaf miners and seed head feeders of the fly family Agromyzidae. This suggests that there may be good prospects for some of these natural enemies.

Few details are available of the natural enemies of *B. pilosa* in Brazil. The pupal stage of the chrysomelid beetle *Phaedon pertinax* (= *P. consimilis*) lasts 6 to 8 days and the pentatomid bug *Stiretrus erythrocephalus* passes through 4 instars in 30 days (Ribeiro 1953). Thrips killed 22.25% of *B. pilosa* plants (particularly seedlings) and Diptera infested 97.8% of flower heads. Parasitisation of these Diptera by wasps and flies, varied from 40.96% to 58.91% according to the size of the population (Esposito et al. 1985).

About half of the 2500 species of the family Agromyzidae have known hosts and almost all of this group are restricted in their feeding to a single family or genus. Only 16 of the species (0.6% of the total) are truly polyphagous, feeding on a number of unrelated families (Spencer 1990). Agromyzid flies are, therefore, worth serious consideration as classical biological control agents. In this context, plants of the genus *Bidens* appear to be particularly attractive to agromyzid flies for they support 19 species (Table 4.3.3).

In the tribe Coreopsideae (of the family Asteraceae) only two (*Bidens* and *Coreopsis*) of its 26 genera support Agromyzidae (Table 4.3.4). *Coreopsis* is native in North America, but no agromyzids are known on it there, although three polyphagous species are known to attack it in Europe, India or Australia (Spencer 1990).

Eleven of the above 19 species are known from *Bidens pilosa* (Table 4.3.1). Of these, three are restricted to the genus *Bidens* (perhaps even to *B. pilosa*), two are polyphagous, and the remaining six have one or more additional hosts in other genera of the Asteraceae. Ten of the eleven species are restricted to the Americas and further host specificity tests may well indicate that many are valuable biological control agents. Four of the ten form blotch mines (*Amauromyza maculosa*, *Calycomyza allecta*, *C. platyptera* and *Liriomyza archboldi*), one makes long, linear irregular mines (*Liriomyza venegasiae*), and three feed in the seed heads (*Liriomyza insignis*, *Melanagromyza bidentis* and *M. floris*) (Spencer 1990, Spencer and Steyskal 1986).

The flower heads of *B. pilosa* are also attacked by three species of Tephritidae in Central America and by one of these in India. Adult weevils of the genera *Baris*, *Centrinaspis* and *Promecops* feed in the flowers of *B. pilosa* and other Asteraceae, but are thought not to breed there. Several other insects (at least three other beetles and a pierid butterfly) have also been recorded from *B. pilosa* and sometimes from other Asteraceae as well.

Table 4.3.4 shows the position of the genus *Bidens* as a member of the tribe Coreopsidae, within the family Asteraceae. There may well be natural enemies that attack it, but not any species of agricultural or special environmental significance.

Attempts at biological control

There have been none.

Table 4.3.1 Natural enemies of *Bidens pilosa*: insects.

Species	Location	Other hosts	References
Hemiptera			
ALEYRODIDAE			
Dialeurodes vulgaris	India	coffee, *Erythrina lithosperma*	Venkataramaiah 1974
APHIDIDAE			
Aphis coreopsidis	Brazil	soybean	Almeida 1979, d'Araujo e Silva et al. 1968a
Aphis illinoisensis	Brazil		d'Araujo e Silva et al. 1968a
Uroleucon (= *Dactynotus)* sp.	Brazil, USA	tobacco, lettuce	Christie et al. 1974, d'Araujo e Silva et al. 1968a
MIRIDAE			
Garcanus gracilentus	Brazil	sweet potato, polyphagous	d'Araujo e Silva et al. 1968a
Horcias nobilellus	Brazil	polyphagous *Amaranthus spinosus*	d'Araujo e Silva et al. 1968a
PENTATOMIDAE			
Stiretrus erythrocephalus	Brazil		Ribeiro 1953
Thyanta perditor	Brazil	soybean	Grazia et al. 1982
Coleoptera			
APIONIDAE			
Apion luteirostre	South America	*Mikania micrantha*	Cock 1980
CHRYSOMELIDAE			
Chalcophana viridipennis	Brazil		d'Araujo e Silva et al. 1968a
Chlamisus insularis	Trinidad	*Chromolaena odorata*, *C. ivaefolia*	McFadyen 1988a
Phaedon pertinax (= *P. consimilis*)	Brazil, (not in Trinidad)	*Mikania micrantha*	Cock 1980, d'Araujo e Silva et al. 1968a, Ribeiro 1953
Physimerus pygmaeus	South America	*Mikania micrantha*	Cock 1980
CURCULIONIDAE			
Baris sp.	Trinidad	(feed in *B. pilosa* flowers)	Cruttwell 1971a
Centrinaspis sp.	Trinidad	(feed in *B. pilosa* flowers)	Cruttwell 1971a
Promecops sp.	Trinidad	(feed in *B. pilosa* flowers)	Cruttwell 1971a
Rhodobaenus cariniventris	Trinidad	adults feed on stems, and petioles of *B. pilosa*, *Chromolaena odorata*, *C. ivaefolia*, *Austroeupatorium inulaefolium*	McFadyen 1988a
Rhodobaenus tredecimpunctatus	Trinidad	feed in *B. pilosa* stems: and in several other Asteraceae	McFadyen 1988a
Diptera			
AGROMYZIDAE			
Amauromyza maculosa	Trinidad (also N&S America, Hawaii)	polyphagous, but favours Asteraceae	Cruttwell 1971a, Spencer 1990, Spencer & Steyskal 1986

(continued on next page)

Species	Location	Other hosts	References
Calycomyza allecta	Trinidad (also Brazil, Guadeloupe, Venezuela)	*Helianthus, Rudbeckia* and garden Asteraceae	Cruttwell 1971b, Frick 1956, Spencer 1990, Spencer & Steyskal 1986
Calycomyza platyptera	USA (Florida, California)	Asteraceae, including *Aster, Helianthus, Zinnia*	Spencer 1990 Spencer & Steyskal 1986
Liriomyza archboldi	Florida (Bahamas, Costa Rica)	restricted to *Bidens*	Spencer 1990, Spencer & Steyskal 1986
Liriomyza insignis	Costa Rica	restricted to *Bidens*	
Liriomyza trifolii	cosmopolitan	polyphagous, including *Chrysanthemum*	Spencer 1990
Liriomyza venegasiae	Southern California	*Venegasia carpesioides*	Spencer 1990, Spencer & Steyskal 1986
Liriomyza sp.	Argentina	restricted to *Bidens*	Spencer 1990
Melanagromyza bidentis	Florida, Caribbean	*Verbesina* sp.	Spencer 1990
Melanagromyza floris	Costa Rica, Mexico, Trinidad (also Florida, Neotropics)	*Calendula* sp	Cruttwell 1971a, Spencer 1990, Spencer & Steyskal 1986
Melanagromyza splendida	USA, Hawaii	Asteraceae including *Helianthus, Lactuca*	Spencer 1990, Spencer & Steyskal 1986
Phytomyza atricornis	Australia	polyphagous, including *Cineraria*	Kleinschmidt 1970
CECIDOMYIIDAE			
Asphondylia bidens	Florida		Steyskal 1972
DROSOPHILIDAE			
Cladochaeta nebulosa	Florida		Steyskal 1972
TEPHRITIDAE			
Dioxyna sororcula (= *D. picciola*)	Florida, Trinidad, widespread	attacks several Asteraceae in India	Cruttwell 1971a, 1972a,b, Steyskal 1972
Xanthaciura insecta	Florida, Trinidad	*Ageratum conyzoides, Chromolaena odorata Fleischmannia caracasana*	McFadyen 1988a, Steyskal 1972
Lepidoptera			
ARCTIIDAE			
Hypercompe (=Ecpantheria) hambletoni	Brazil		d'Araujo e Silva et al. 1968a
NOCTUIDAE			
Cropia (=Dyops) minthe	Brazil		d'Araujo e Silva et al. 1968a
Mocis latipes	Brazil	*Panicum maximum, Paspalum notatum, Hyparrhenia rufa*	Lourencao et al. 1982
Thysanoplusia (= Diachrysia) orichalcea	Kenya	coffee and other crops	Bardner & Mathenge 1974
PIERIDAE			
Perrhybris phaloe (= *Ascia buniae phaloe*)	Trinidad		Cruttwell 1971a

Table 4.3.2 Natural enemies of *Bidens pilosa*: nematodes, fungi, mycoplasmas, viruses.

Species	Location	References
NEMATODES		
Meloidogyne sp.	Hawaii	Linford et al. 1949
Meloidogyne hapla	India	Singh et al. 1979
Pratylenchus minutus	Hawaii	Linford et al. 1949
Rotylenchulus reniformis	USA	Inserra et al. 1989, McSorley et al. 1981
FUNGI		
Cercospora bidentis	Mauritius	Rochecouste & Vaughan 1959
Cercospora megalopotamica	Hawaii	Stevens 1925
Entyloma guaraniticum	Mauritius	Rochecouste & Vaughan 1959
Uromyces bidenticola	Hawaii, Mauritius	Anon 1960, Rochecouste & Vaughan 1959
MYCOPLASMAS		
aster yellows	Hawaii	Holm et al. 1977
Bidens witches broom	Brazil	Vega et al. 1981
VIRUSES		
Bidens mosaic	Brazil	Kuhn et al. 1982
groundnut rosette	Hawaii	Adams 1967
Sonchus yellow net	Florida	Christie et al. 1974
soybean mosaic	Brazil	Almeida 1979
tomato spotted wilt	Hawaii	Sakimura 1937
PARASITIC PLANT		
Cassytha filiformis	Hawaii	Raabe 1965

Table 4.3.3 Species in Agromyzid genera attacking *Bidens*.

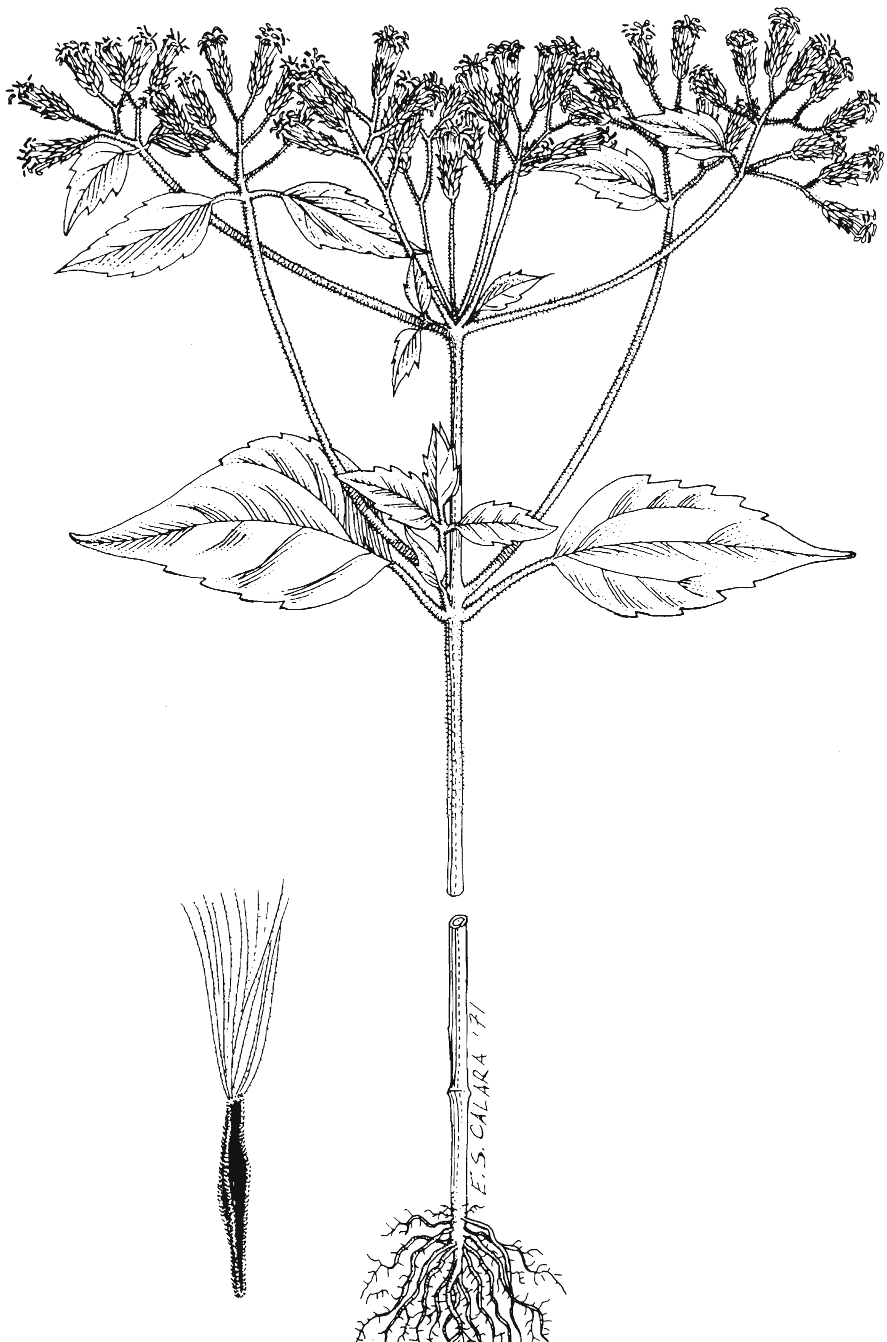
Genus	Specific to *Bidens*	Specific to Coreopsideae	Polyphagous
Melanagromyza		7	
Amauromyza		1	
Liriomyza	3	3	1
Calycomyza		3	
Chromatomyia			1
Total	3	14	2

Table 4.3.4 Relationship of four major Southeast Asian weeds and some economically important genera within the family Asteraceae.

Family Asteraceae: 21 000 species (Mabberley 1987)

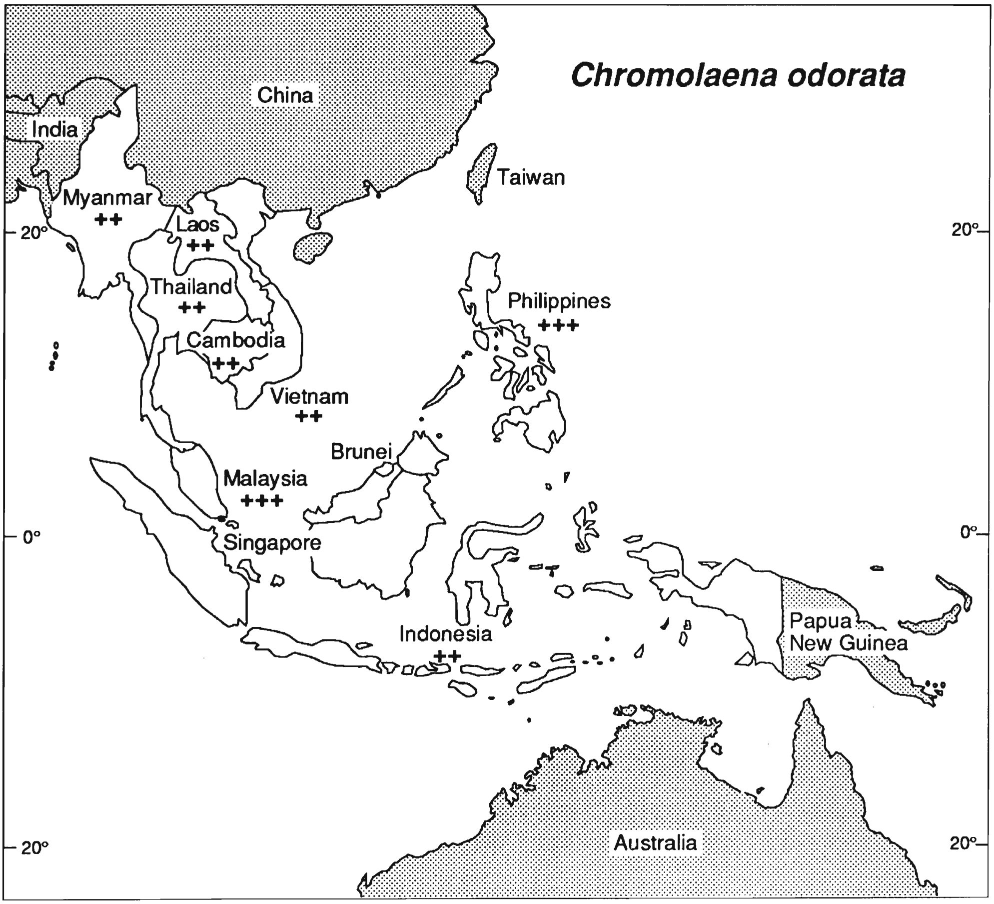
Tribe	Some economically important genera	Weed species
Arctoteae		
Carlineae		
Echinopsideae		
Cardueae	*Carthamnus, Cynara*	
Mutisieae		
Lactuceae	*Cichorium, Lactuca*	
Vernonieae		
Inuleae		
Astereae	*Aster*	
Eupatorieae		*Ageratum conyzoides, Chromolaena odorata, Mikania micrantha*
Calenduleae		
Senecioneae	*Cineraria*	
Anthemideae	*Chrysanthemum*	
Heleniae	*Dahlia*	
Madieae		
Heliantheae	*Cosmos, Helianthus, Zinnia*	
Tageteae		
Coreopsideae	*Coreopsis*	*Bidens pilosa*

The family Asteraceae, by far the largest in the dicotyledons, has been subdivided into 18 tribes, some 1300 genera and about 21 000 species (Mabberley 1987). It contains surprisingly few economically important crop plants, of which lettuce (*Lactuca sativa*), sunflower (*Helianthus annuus*) and globe artichoke (*Cynara scolymus*) are the major species. However, there are a number of commercially important garden plants, especially in the genus *Chrysanthemum*.



Chromolaena odorata

(after Holm *et al.* 1977)



Map 4.4 *Chromolaena odorata*

Chromolaena odorata is not a problem weed in the tropical Americas where it evolved. It is attacked there by more than 200 insects, at least a quarter of which are probably sufficiently host specific to be considered as classical biological control agents. The aggressiveness of *C. odorata* in countries to which it has spread is probably due to the absence of most of these natural enemies.

The arctiid moth *Pareuchaetes pseudoinsulata* has been established in India, Sri Lanka, Philippines, Sabah (Malaysia), the Mariana Is (Guam, Rota, Saipan, Tinian, Aguijan) and Federated States of Micronesia (Yap, Pohnpei, Kosrae), but only in the two latter island groups has it had spectacular success in controlling the weed. The mite *Acalitus adoratus* has spread naturally to Southeast Asia and Micronesia but, as yet, is having minor impact.

It is probable that a group of natural enemies will be necessary to bring about effective biological control of *C. odorata* in Southeast Asia, but there are a number of species that are well worthy of attention and longer term prospects for control appear promising.

4.4 *Chromolaena odorata* (L.) R.M. King and H. Robinson
(Formerly *Eupatorium odoratum*)

Asteraceae

Siam weed, devil weed; bizat, tawbizat (Myanmar), tontrem khet (Cambodia), French weed (Laos), pokok tjerman (Malaysia), kirinyu, kumpai jepang, rumput gol kar (Indonesia), hagonoy (Philippines) saab sua, yah sua mop (Thailand), cò hoi (Vietnam)

Rating

	+++	Msia, Phil
18	++	Myan, Thai, Laos, Camb, Viet, Indo

Origin

Central America and tropical South America (from Florida to northern Argentina).

Distribution

C. odorata is a weed throughout Southeast Asia, Irian Jaya, Papua New Guinea, New Britain, Mariana and Caroline Is, southern China, Taiwan, Sri Lanka, Bangladesh, India, West, Central and South Africa.

Characteristics

C. odorata is an upright or scrambling, thicket-forming, perennial shrub, growing from 1.5 to 3 m high. Its roots are fibrous with a few well formed anchor roots and many laterals, the stems round, yellowish, hairy or almost smooth and profusely branched. Its leaves are opposite, with toothed margins and are conspicuously three veined. The flowers are at the tips of all stems, in clusters of 20 to 60, white or pale lilac. The achenes consist of 5 mm-long seeds with hooks on their angles, together with a pappus of 5 mm-long white bristles. The leaves have a pungent odour when damaged. Seed production is prolific (as many as 2 million per plant) and seeds provide the main mode of reproduction. The achenes float long distances in the air and the seed hooks cling to hair and clothing. Germination occurs as soon as there is adequate moisture, although some 66% of seeds are not viable. Buried seeds lose up to 50% of their viability after 2 years (Yadav and Tripathi 1982).

Importance

C. odorata is not a serious weed in the Americas and no specific control methods are necessary (McFadyen 1991a). This is in stark contrast to its serious weed status in the countries to which it has spread and has been attributed to the many natural enemies that attack it in the Americas (McFadyen 1989, 1991c). It was introduced to Calcutta in the 1840s, had spread into Sri Lanka, Southeast Asia and Nigeria by the 1940s and into Irian Jaya, New Britain and Micronesia by the 1980s. It is forecast to spread widely and aggressively in equatorial Africa, northern and eastern Australia and the Pacific (McFadyen 1988b, 1989).

C. odorata grows in many soil types, but prefers well drained conditions and an annual rainfall above 1000 mm. Although it is not a problem in continuously cultivated land, it is most common and causes most losses in plantation crops, including coconut, rubber, oil palm, tea, coffee, cocoa, teak and cashew. It also thrives in areas newly cleared for planting, in abandoned or neglected fields, wastelands and along roadsides. It is sometimes a weed in pastures. Its rapid growth enables it to smother most competitors and it inhibits many with its allelopathic properties. It dies back after flowering in areas with a pronounced dry season and then becomes a fire hazard. After burning or cutting, the plants shoot freely from the crown. They are capable of forming dense tangled bushes two to three metres high, occasionally reaching six metres as climbers on other plants. The stems branch freely, with 20 or more laterals developing from axillary buds and often bent over under their own weight. Impenetrable stands of the weed cut off access to pastures and provide hiding places for rats, pigs and other undesirable animals. *C. odorata* is intolerant of shade, so that it dies out when the canopy closes in plantations (Ambika and Jayachandra 1990, McFadyen 1988b, 1991a). The shoots and young leaves contain nitrate at levels 5 to 6 times those toxic to stock and also pyrrolizidine alkaloids and cattle deaths occur following grazing. Hand weeding of *Chromolaena* is reported to cause skin allergy and scratches to result in infections (Ambika and Jayachandra 1990).

It is interesting that the spread of *C. odorata* in West Africa has led to a polyphagous grasshopper *Zonocerus variegatus* becoming a pest. Although they are unable to mature on the weed as the only diet, hoppers are strongly attracted to the plant and especially to its flowers; and thickets are preferred night roosting sites. Boppré (1991) hypothesises that the pyrrolizidine alkaloids accumulated from feeding on *C. odorata* protect the grasshoppers and their eggs from predators and parasitoids, leading to increased fitness and population density. However, this only occurs during the dry season, but not in the wet season when *C. odorata* does not bloom.

Claims have been made (e.g. Field 1991, Herren-Gemmill 1991) that, under some circumstances, *C. odorata* may be beneficial to resource-poor farmers. One potential advantage, is its ability to outcompete another serious weed, alang-alang (*Imperata cylindrica*). However, McFadyen (1992) pointed out that a suitable perennial legume would be even more beneficial than *C. odorata,* and she also refuted a number of other claims. In Sri Lanka the indigenous legume *Tephrosia purpurea* has been successfully used to suppress weeds including *C. odorata* under coconut (Salgado 1972). Whatever potential benefits there may be in the presence of *C. odorata* there is an enormous body of fact to demonstrate that *C. odorata* has serious adverse effects on agricultural productivity in countries to which it has been introduced.

Natural enemies

A good deal is known about the insects attacking *Chromolaena odorata*, mainly as a result of studies aimed at biological control which started in the late sixties at the Commonwealth Institute of Biological Control Station in Trinidad. A number of scientists were involved, but principally R.E. McFadyen (née Cruttwell) (Bennett and Cruttwell 1973, Bennett and Rao 1968, Bennett and Yaseen 1975, Cock 1984a, Cock and Holloway 1982, Cruttwell 1973a,b, 1974, 1977a,b, Cruttwell and Bennett 1969, McFadyen 1988a,b, 1991a,b, Yaseen and Bennett 1977).

An extensive bibliography dealing with all aspects of *C. odorata*, including its natural enemies and biological control, was compiled by Muniappan et al. (1988a), later supplemented in *Chromolaena odorata* Newsletters 3 (1990) and 6 (1992). The proceedings of three International Workshops on Biological Control of *Chromolaena odorata*, held in 1988, 1991 and 1993 also contain a wealth of up-to-date information.

In the Americas *C. odorata* is attacked by at least 207 insect and 2 mite species (McFadyen 1988a). Of these, about half are probably polyphagous, a quarter are restricted to the Asteraceae and a quarter specific to *Chromolaena*. All stages of growth of the above ground parts of the plants are attacked, but the roots have not been examined (McFadyen 1991a) and not all regions where *C. odorata* occurs naturally were visited. For other regions of the world McFadyen (1988a) quotes records of 42 insect and 9 mite species, the vast majority of which are, or are likely to prove, polyphagous. Since then a few additional species have been recorded, all but one of which (an eriophyid mite, see India below) are likely to be polyphagous.

In Trinidad, the cumulative effect of the natural enemies is great, between 25 and 50% of all growing tips being destroyed. Seed germination is as low as 17% and many flowerheads fail to produce seed. Seedlings often succumb to the attack of stem and tip feeding insects and competitiveness and growth of established plants is greatly reduced by insect attack. At different sites and in different seasons damage is caused by different insects and, in general, is heaviest in shaded sites. Some of the insects are heavily attacked by parasitoids and if introduced without these to another country might prove to be even more effective.

In addition to an arctiid moth (*Pareuchaetes pseudoinsulata)* and a weevil (*Apion brunneonigrum),* which have already had considerable attention paid to them (see next section), McFadyen (1991c) has nominated an additional 11 insects for priority evaluation (Table 4.4.1). Furthermore, others (Cruttwell 1974, Cock 1984a, Cock and Holloway 1982, McFadyen 1988c, Muniappan and Viraktamath 1986) have suggested an additional 22 species (Table 4.4.2) which were evidently considered less important by McFadyen (1991c). It is clear therefore that, if required, there are many promising candidates for detailed consideration. The additional species of *Pareuchaetes* suggested by Cock and Holloway (1982) have not been investigated in detail, but all are believed to breed on *C. odorata* or related species and several may be better adapted climatically and biologically than *P. pseudoinsulata* to conditions in many overseas countries.

Although no special search has been carried out except in Trinidad and Tobago a number of fungal pathogens occurring on *C. odorata* are shown in table 4.4.3. Half of the records come from outside its area of origin and must, therefore, be suspected of having a wider than desirable host range. Possibly *Cionothrix praelonga* is of greatest interest, since preliminary tests indicate that it may be host specific (Ooi et al. 1991). It is autoecious (i.e. it does not have an alternate host), occurs in the Caribbean and Venezuela and

Table 4.4.1 Potential biological control agents for *C. odorata*: insects (after McFadyen 1991c).

Species	Part attacked	Damage	Problem	Country found
Coleoptera				
CHRYSOMELIDAE				
Aulacochlamys sp.	stem	moderate		Trinidad
Chlamisus insularis	stem	minor		all Americas
Pentispa explanata	leaf miner	moderate	prefers shade	Trinidad
CURCULIONIDAE				
Rhodobaenus cariniventris	stem	great		Trinidad
Diptera				
AGROMYZIDAE				
Melanagromyza eupatoriella	shoot borer	great	cage mating	West Indies, S. America
CECIDOMYIIDAE				
Clinodiplosis sp.	shoot galls	great	rearing	Trinidad
Perasphondylia reticulata	bud galls	great	cage rearing	all Americas
TEPHRITIDAE				
Procecidochares sp.	stem galls	moderate	parasites	Americas
Lepidoptera				
BUCCULATRICIDAE				
Bucculatrix sp.	leaf miner	minor		Mexico
NYMPHALIDAE				
Actinote anteas	leaf	great	cage mating	Trinidad, Costa Rica
PYRALIDAE				
Mescinia parvula	shoot borer	great	cage mating	all Americas

causes conspicuous leaf lesions. *Pseudocercospora eupatorii-formosani* is reported to be common and damaging on *C. odorata* in Brunei, but is widespread already in South and Southeast Asia (Chacko 1988, Evans 1987, Peregrine and Ahmad 1982).

Attempts at biological control

Four insects have been released for biological control, the weevil *Apion brunneonigrum,* the fly *Melanagromyza eupatoriella* and two moths *Mescinia parvula* and *Pareuchaetes pseudoinsulata* (Table 4.4.4). Of these, only the last has become established, fairly readily in Sri Lanka, Guam and other Micronesian islands, but with some difficulty in India and Sabah (Malaysia) and it has since spread unaided to the Philippines and Brunei. It failed to become established in Thailand, Ghana, Nigeria and South Africa. It has produced spectacular defoliation and death of many plants in Guam

Table 4.4.2 Additional potential biological control agents for *C. odorata*: arthropods.

Species	Part attacked	Country found
Coleoptera		
CERAMBYCIDAE		
Aerenica hirticornis	stem borer	Trinidad, Bolivia, Brazil, Argentina
CURCULIONIDAE		
Baris sp.	flowers, leaf buds	Trinidad
Centrinaspis sp.	flowers, leaf buds	Trinidad, Costa Rica
Diptera		
CECIDOMYIIDAE		
Asphondylia corbulae	flower galls	El Salvador, Trinidad
Clinodiplosis eupatorii	leaf galls	Central America, Brazil, West Indies
Clinodiplosis sp.	bud galls	Trinidad
Contarinia sp.	flowers (achenes)	Trinidad
Neolasioptera brickelliae	flowers (achenes)	Trinidad
Neolasioptera cruttwellae	stem galls	Trinidad
Neolasioptera eupatorii	stem galls	USA, Trinidad, Bolivia
Neolasioptera frugivora	flowers (achenes)	Trinidad
TEPHRITIDAE		
Cecidochares fluminensis	flowers	Trinidad, SE Brazil
Procecidochares connexa	stem galls	Mexico, Brazil, Bolivia
Lepidoptera		
ARCTIIDAE		
Pareuchaetes aurata aurata	leaves, buds	Paraguay, Argentina, SE Brazil, Bolivia
Pareuchaetes aurata aurantior	leaves, buds	Amazon River
Pareuchaetes arravaca	leaves, buds	Surinam and French Guiana
Pareuchaetes insulata	leaves, buds	Southern USA, Mexico, Caribbean, Colombia
Pareuchaetes misantlensis	leaves, buds	Mexico
Pareuchaetes sp.	leaves, buds	Mexico
GELECHIIDAE		
Dichomeris (= *Trichotaphe*) sp.	leaf roller (see Cruttwell 1973b)	Trinidad
LYCAENIDAE		
Calephelis laverna	leaves	Brazil, Trinidad, Venezuela, Central America
Acarina		
ERIOPHYIDAE		
Calacarus sp.	shoots	India

Table 4.4.3 Natural enemies of *C. odorata*: fungi.

Species	Country found	References
Anhellia niger	Trinidad, Tobago	Ooi et al. 1991
Cercospora sp.	Peninsular Malaysia, Sabah	Singh 1980
Cercospora eupatorii	North America, Cuba, Nepal, India, Ivory Coast	Chacko 1988, Evans 1987
Cercospora eupatoriicola	India, Bangladesh	Chacko 1988, Evans 1987
Cercospora eupatorii-odoratii	Malaysia	Chacko 1988, Evans 1987
Cionothrix praelonga	Dominica, Tobago, Venezuela	Chacko 1988, Evans 1987
Fusarium oxysporum f. sp. *elaeidis*	Trinidad, Tobago	Oritsejafor 1986
Guignardia eupatorii	Sri Lanka	Chacko 1988, Evans 1987
Mycovellosiella perfoliata	Trinidad, Tobago	Ooi et al. 1991
Phoma sp.	Trinidad, Tobago	Ooi et al. 1991
Phomopsis eupatoriicola	not recorded	Chacko 1988, Evans 1987
Phyllosticta eupatoriicola	not recorded	Chacko 1988, Evans 1987
Pseudocercospora eupatorii-formosani	India, Myanmar, Thailand, Malaysia, Borneo, Brunei,	Chacko 1988, Evans 1987
Septoria sp.	Guam	Russo 1985
Septoria ekmaniana	Trinidad, Tobago	Ooi et al. 1991

and striking but sporadic defoliation in Sri Lanka. In India, populations have built up but damage has seldom been great. Where established, it is heavily attacked by a range of predators and these are believed to have prevented successful establishment in several countries.

The eriophyid mite *Acalitus adoratus* causes abnormal growth of the epidermal hairs on young leaves and stems of *C. odorata*. Although it was never purposely introduced, it was observed in Thailand in 1984 and the Philippines in 1987, but had probably been present for some years. It is also widespread in Java and Sumatra, but there is no information from other Indonesian islands. It is present in Yap and Palau in the Caroline Islands and was observed on Guam in November 1993 (R. Muniappan pers. comm.). It is not present in India and it is not known whether it is present in Sri Lanka (Cruttwell 1977b, McFadyen 1991b, 1993, Muniappan et al. 1988a).

Further details follow of the situation in individual countries and of the biology of some of the more promising natural enemies.

Asia

INDIA

In one study, 11 insects and 3 mites were found attacking *C. odorata*. All except *Calacarus* sp. (Eriophyidae) are polyphagous (Muniappan and Viraktamath 1986, Viraktamath and Muniappan 1992). Most eriophyid mites have a highly restricted host range, so it is not clear whether it may even have accompanied the weed from the

4.4.4 Introductions for the biological control of *Chromolaena odorata*.

Species	Country	Liberated	Result	References
Coleoptera				
BRENTHIDAE				
Apion brunneonigrum	Ghana	1975	–	Cock 1984a, 1985,
	Guam	1984	–	Nafus & Schreiner 1989
	India	1972–83	–	Chacko & Narasimham 1988, Cock 1984a, 1985
	Malaysia (Sabah)	1970	–	Ooi et al. 1988a,b
	Nigeria	1970–75	–	Cock 1984a, 1985
	Sri Lanka	1974–76	–	Cock 1984a, 1985
Lepidoptera				
ARCTIIDAE				
Pareuchaetes aurata aurata	South Africa	1990	?	Julien 1992, Kluge & Caldwell 1993
Pareuchaetes pseudoinsulata	Pohnpei	1988–92	+	Esguerra et al. 1991, Esguerra et al. 1994 Muniappan et al. 1988b
	Ghana	1973	–	Cock 1985, Cock & Holloway 1982
		1989	?	Julien 1992
	Guam	1984	+	Nafus & Schreiner 1989, Seibert 1989
	India	1973	–	Chacko & Narasimham 1988, Cock & Holloway 1982
		1984	+	Chacko & Narasimham 1988, Julien 1992, Muniappan et al. 1989, Satheesan et al. 1987
	Indonesia	1991, 1993	?	McFadyen pers. comm.
	Kosrae	1992	+	Esguerra et al. 1994
	Malaysia (Sabah)	1970	+	Cock & Holloway 1982, Ooi et al. 1988a,b, Syed 1979a
	Northern Marianas	1986–87	+	Nafus & Schreiner 1989, Seibert 1989
	Nigeria	1973–78	–	Cock & Holloway 1982
	South Africa	1989	–	Julien 1992, Kluge 1991, Kluge & Caldwell 1991
	Sri Lanka	1973	+	Dharmadhikari et al. 1977
	Thailand	1987	–	Napompeth et al. 1988
	Yap	1988–91	+	Marutani & Muniappan 1991a, Muniappan et al. 1988b
PYRALIDAE				
Mescinia parvula	Guam	1984	–	Nafus & Schreiner 1989

Americas. In another study 21 polyphagous insects were recorded from *C. odorata*, of which the most widespread and numerous were *Aphis fabae* and *A. spiraecola* (Lyla and Joy 1992, Lyla et al. 1987). Some of these same species are included amongst the 31 insects and 9 mites recorded on *Chromolaena* by Chacko and Narasimham (1988).

Pareuchaetes pseudoinsulata from Trinidad was cleared of a nuclear polyhedral virus and mass reared. It was first released in 1973 at several sites in Karnataka, but no establishment occurred. Observations suggested that two ants, *Myrmicaria brunnea* and *Oecophylla smaragdina,* were major predators (Cock and Holloway 1972). *P. pseudoinsulata* from Sri Lanka (where it had been sent and had already become established) was next released and appeared to be doing well until unexpectedly wiped out by virus (Cock 1985). However, further material from Sri Lanka was laboratory reared and 36000 larvae and 1000 adults released from 1984 onwards, this time in Kerala. This procedure resulted in field establishment (Chacko and Narasimham 1988, Joy et al. 1993, Muniappan et al. 1989, Satheesan et al. 1987). Most recently, the establishment of *P. pseudoinsulata* at Sullia Taluk in Karnataka State and defoliation of *Chromolaena* thickets over about 1000 km^2 was reported in December 1992 (R. Muniappan pers. comm. 1993). However the overall performance of the moth has been unsatisfactory (Joy et al. 1993).

Small releases of the weevil *Apion brunneonigrum* have been made since 1972, but establishment has not resulted (Cock 1985, Ooi et al. 1991).

SRI LANKA

P. pseudoinsulata was received from India in 1973 and about 2000 larvae released in a coconut estate in the North Western Province. Six months after release spectacular defoliation was observed of a hectare of previously impenetrable growth of *C. odorata*. In addition to leaves, terminal buds and tender stems were being consumed. Further releases were made and two years later it was estimated that some 800 ha of *C. odorata* had been defoliated (Dharmadhikari et al. 1977). Since then sporadic, heavy defoliation has mainly occurred at the beginning of the dry season at the time of flowering. This has caused great damage and, at times, death of the weed. However *P. pseudoinsulata* populations fluctuate considerably, due in no small measure to natural enemies. Young larvae are taken by birds and predatory *Sycanus* bugs. They are also parasitised by the braconid *Apanteles creatonoti* and the tachinid *Exorista* sp. (Kanagaratnam 1976). In one series of experiments from 63 to 100% of pupae were consumed by ants, termites and lizards (Mahindapala et al. (1980). Perera (1981) fed *P. pseudoinsulata* larvae on *C. odorata* leaves dipped in 32P labelled sodium orthophosphate, transferred them to *C. odorata* in the field and collected predators from pitfall traps. Several carabids and a histerid showed no radioactivity, nor did the ants *Odontomachus simillimus* and *Diacamma rugosum* which were observed carrying away treated larvae to their nests, indicating that they do not feed on the larvae soon after capture. There was no unusual preponderance of predatory wasps, but birds were observed picking up larvae so it is likely that they were the cause of the sudden decline in larval population (P.A.C.R. Perera pers. comm. 1993).

How effective the moth is as a control agent is yet to be determined. However, Perera (1981) calculated that a *P. pseudoinsulata* larva from hatching to pupation consumes an average of 184.6 cm^2 of leaf. Based on measurements of a heavy growth of *C. odorata*, there are 22.42×10^8 cm^2 of leaf area per ha requiring about 12 million larvae to produce defoliation. Assuming an average egg production of 200 per female moth and a 1:1 sex ratio, 12 million larvae could be produced in two generations (3 months) with a release of 600 to 700 females. Cock and Holloway (1982) have suggested that there is a better climate match between Sri Lanka and Trinidad than for most of the other countries where the moth has been released.

Apion brunneonigrum were released between 1974 and 1976 and, two months after release, were seen on flower heads but have not been recovered since (Cock 1985, Kanagaratnam 1976, Ooi et al. 1991).

Southeast Asia

BRUNEI

Although no releases of *P. pseudoinsulata* have been made, two females were trapped in the early 1980s, presumably having resulted from the colonies established in neighbouring Sabah (Malaysia) (Cock 1985).

INDONESIA

An aphid has been observed to attack young shoots and cause leaf curl of *C. odorata*. Work on biological control of the weed was initiated in 1991 with the introduction of *P. pseudoinsulata* to Sumatra, but there is no information on the outcome. There is a current project (1993) under R.E. McFadyen to study the host specificity of the tephritid fly *Procecidochares connexa* and either the moth *Mescinia parvula*, the stem boring *Melanagromyza eupatoriella* or the butterfly *Actinote anteas* with a view, if judged safe to do so, to liberation in Indonesia and the Philippines (R.E. McFadyen pers. comm., Tjitrosoedirdjo 1991, Tjitrosoedirdjo et al. 1991).

MALAYSIA (SABAH)

Aphis spiraecola attacks young shoots of *C. odorata* and causes leaf fall (Bennett and Rao 1968).

P. pseudoinsulata was introduced from India to Sabah in 1970 and releases made between 1970 and 1974 of over 4000 eggs, 40 000 larvae and 700 adults. Temporary establishment occurred in two areas in 1973 and 1974, but both colonies then appeared to die out over the next couple of years. This was considered to be due to general predators, such as ants (Cock and Holloway 1982). However, in 1983 and 1987, pockets of larvae appeared scattered over Sabah and often distant from the sites of original release (Ooi et al. 1988a,b). There is a good climate match between Sabah and Trinidad, which may explain the establishment (Cock and Holloway 1982).

Small releases of *A. brunneonigrum* were made in 1970 and recoveries were reported a year later, but there is no indication that the weevil has survived (Ooi et al. 1988a,b, Syed 1973, 1975, 1979a,b).

PHILIPPINES

Aphis gossypii, *A. spiraecola* (= *A. citricola*) and the tortricid *Homona coffearia* were found attacking *C. odorata* (Torres 1986) and the total of natural enemies increased to 11 by 8 additional (unspecified) insects (Torres 1988). Although it had not been intentionally introduced, numerous larvae of *P. pseudoinsulata* were discovered in 1985 in a limited area near the coast of Palawan. They were feeding on the leaves and stems of *C. odorata* under coconut trees and along roads, but surveys elsewhere at the time revealed no evidence of *P. pseudoinsulata* larvae (Aterrado 1986a,b, Torres and Paller 1989). However *P. pseudoinsulata* was discovered later in Zamboanga City, Bohol and northern Leyte provinces in the Visayas islands (Aterrado and Talatala-Sanico 1988).

The eriophyid mite *Acalitus adoratus* was discovered in the Philippines in 1987 (McFadyen 1991b).

THAILAND

A number of insects were found attacking *C. odorata*: the aphids *Aphis craccivora, A. gossypii* and *A. spiraecola,* the weevil *Hypolixus trunculatus,* a stem boring cicindelid larva and the arctiid moth *Amsacta lactinea.* They were causing little damage (Napompeth 1990a,b, Napompeth et al. 1988, Napompeth and Winotai 1991).

P. pseudoinsulata was introduced from Guam from 1986 to 1988 but, despite repeated field releases in 1987 and 1988, did not become established. The shoot miner *Melanagromyza eupatoriella* was introduced from Trinidad in 1978, but could not be reared and was not released.

The mite *Acalitus adoratus,* detected in 1984, has since spread to all *C. odorata* infested areas, but is not having a significant effect on the weed.

VIETNAM

Infestations of *Aphis craccivora* and *A. gossypii* have been recorded on *C. odorata*, but no releases of biological control agents have been made (Napompeth and Hai 1988).

Pacific

GUAM

P. pseudoinsulata was introduced from India and Trinidad, mass reared and first released in Guam in 1984 and later in the Northern Marianas. Initially late instar larvae were released in batches of up to 800, but were heavily attacked by ants, spiders, toads and other general predators and failed to become established. Next, groups of 500 or more adult moths were released at a number of sites, resulting in establishment in all release areas. Populations built up rapidly, defoliation of *Chromolaena* soon followed and almost all plants were stripped. Shoots arising from the crowns were also attacked as they appeared and, within a year, over 90% of the plants were killed. The moth spread rapidly and by 1987 had reached almost all infested areas of Guam. Eventually more than 25 000 ha of the weed had been defoliated (Muniappan 1988c, Nafus and Schreiner 1989, Seibert 1989). A parasitoid *Exorista xanthaspa* (= *E. civiloides*) caused up to 30% mortality and predation by ants, spiders, toads and lizards occurred (Seibert 1989).

It was observed that the feeding of *P. pseudoinsulata* larvae caused the leaves of *C. odorata* to turn yellow, an effect that could not be produced by simply applying larval excreta to the plant. Yellow leaves were tougher and had a higher level of nitrate and, when larvae were forced, much against their preference, to feed on yellow leaves, they exhibited slow growth and high mortality. Furthermore, larvae continued to feed on yellow plants both by day and night (exposing them to daytime predators), whereas on green plants they fed at night and hid at ground level by day (Marutani and Muniappan 1991b). Interestingly, the yellow plants appear to lose their allelopathic properties and hence this major aid to dominance over other vegetation. The yellowing is reversible if the insects are removed (McConnell et al. 1992, Muniappan and Marutani 1992).

Three additional insects were released to aid in the control of *Chromolaena*, but there is no evidence of establishment. *Apion brunneonigrum* was released early in 1984 at the beginning of the dry season when the above ground growth of *Chromolaena* dies back. Because of the unsuitable condition of the host plants the beetle was not expected to become established. Small numbers of *Mescinia parvula* were released late in 1984 and again late in 1986 (Seibert 1989). The mite *Acalitus adoratus* appeared in Guam in 1993 (R. Muniappan pers. comm.).

Larvae of the pyralid moth *Eucampyla etheiella* were observed attacking young flower buds and mature flowers and causing extensive damage. Larvae were parasitised by the eulophid *Elachertus* sp. and the elasmid *Elasmus* sp. (Marutani and Muniappan 1990).

NORTHERN MARIANAS (ROTA, TINIAN, SAIPAN, AGUIJAN)

P. pseudoinsulata has been established from liberations in 1986 and 1987 on all of these islands (Muniappan et al. 1989, Nafus and Schreiner 1989).

Federated States of Micronesia

KOSRAE

Monthly releases of *P. pseudoinsulata* larvae in batches of 1000 to 4000 were made from early 1992 in sunny areas and defoliation of *C. odorata* was observed six months later. Predators were less active in sunny than in shady locations (Esguerra et al. 1994).

PALAU

Although no releases of biological control agents have been made, the mite *Acalitus adoratus* was found to be present (Muniappan et al. 1988b).

POHNPEI

P. pseudoinsulata larvae were introduced from Guam in 1988, some liberated and others mass reared during which both larvae and adults were released until 1992. In four release sites extensive feeding injury and heavy defoliation of *C. odorata* was observed in 1991 and populations persisted in 1992 in burnt areas where Siam weed was regenerating from root stocks (Esguerra et al. 1994). Heavy predation, especially in shaded conditions, was observed on all stages by ants, spiders, birds and lizards (Esguerra et al. 1991, 1994).

YAP

C. odorata was first reported in 1987. *P. pseudoinsulata* was released in 1988 at 14 different sites, but failed to become established except at one location where only 100 larvae and 104 adults had been released (Muniappan et al. 1988b). It eventually disappeared at this site. However releases of 500 larvae in September and October and several hundred in December 1990 to June 1991 resulted in establishment (Marutani and Muniappan 1991a). As on Guam and Rota, larvae of *Eucampyla etheiella* were found causing extensive damage to buds and mature flowers (Marutani and Muniappan 1990). The eriophyid mite *Acalitus adoratus* was found attacking *C. odorata* late in 1988, although it was not observed during a survey of the weed in May of that year (Muniappan et al. 1988b).

Africa

GHANA

P. pseudoinsulata from India was used to establish a culture and releases were made between 1973 and 1978 in a variety of habitats including oil palm plantations. Although small amounts of leaf damage were observed shortly after release, no recoveries were made. Failure to establish was ascribed to predators, in particular to ants (Cock and Holloway 1982).

One small release of *Apion brunneonigrum* was made in 1975, but it failed to become established (Cock 1985).

NIGERIA

P. pseudoinsulata shipped from Ghana between 1973 and 1978 were released, but no establishment occurred (Cock and Holloway 1982).

A. brunneonigrum was sent from Trinidad from 1970 to 1975, but there is no record of establishment (Cock 1985).

SOUTH AFRICA

Disease-free adults of *P. pseudoinsulata* originating from Guam were released in batches of 500 to 1000 at 10 sites in Natal in 1989, but there are no signs of establishment. Very heavy egg predation (up to 82%) by ants and chrysopids was observed (Kluge 1991, Kluge and Caldwell 1991). *P. pseudoinsulata* has been obtained from Florida where the climate is similar to that in Natal and where there is a rich ant fauna. It is (as of 1991) to be released as soon as laboratory cultures of larvae have been cleared of microsporida.

The larvae of another arctiid moth, *Pareuchaetes aurata aurata*, from *Chromolaena jujuensis* in Argentina were found to feed voraciously and complete their development on *C. odorata*. Females scatter their eggs around the base of the host plant and it is hoped that this will help to overcome the problem of ant predation. After specificity testing it has been released in Natal, but no further information is available (Kluge and Caldwell 1993).

A laboratory culture of the butterfly *Actinote anteas* has been established with material collected in Costa Rica and host testing is to commence (Kluge and Caldwell 1991).

Work is also in progress on the host specificity of the weevil *Rhodobaenus* *cariniventris* and a leaf spot disease caused by *Septoria* sp. (Kluge and Morris 1992).

Major natural enemies

Acalitus adoratus Acarina: Eriophyidae

Recorded originally from Trinidad, Florida, Brazil and Bolivia, it appeared without special assistance in Thailand, Philippines, Indonesia (Java and Sumatra), Caroline Is (Yap, Palau) Guam and southern China. It was not present in India in the mid 1980s nor in Sri Lanka or West Africa (McFadyen 1993).

These tiny mites (0.14 to 0.18 mm long) usually live on the lower surface of leaves. Their feeding induces abnormal growth of the epidermal hairs, resulting in the formation of erineum patches, the term given to areas covered with dense twisted hairs amongst which the mites live. These appear as white patches on the leaves, usually 0.5 to 3 mm in diameter, and the whole leaf surface may be affected. The patches often turn yellow on older leaves. The nymphs and adults feed, and the eggs are laid, between the epidermal hairs. Particularly heavy infestations develop in dry and exposed situations and, although the damage is not spectacular, heavy attack stunts, distorts and slows growth, thereby reducing competitiveness. Tests indicated that, as with many other eriophyid mites, *A. adoratus* is host specific.

When infested leaves senesce, *A. adoratus* leave the erineum patches and are preyed upon by other mites and by the larvae of a cecidomyiid fly, *Arthrocnodax meridionalis* (Cruttwell 1977b, McFadyen 1991b, Muniappan et al. 1988a,b).

It is suggested that *A. adoratus* was accidentally introduced to Sabah when field-collected adults of the weevil *Apion brunneonigrum* in Trinidad were released directly in the 1970s; and that it has since spread naturally and on leaves of *C. odorata* used as packing material around fruit and other produce (McFadyen 1993).

Actinote anteas Lepidoptera: Nymphalidae

Recorded from Costa Rica and Trinidad. The host specificity of this acraeinine defoliator is being examined in South Africa (Kluge and Caldwell 1991).

Apion brunneonigrum Coleoptera: Apionidae

This weevil has been recorded from Trinidad, Venezuela and Argentina. Small releases were made in West Africa, India, Sri Lanka, Sabah and the Marianas, but the weevil persisted only in Sabah and then apparently only briefly. The reasons for these failures have not been investigated.

Cruttwell (1973a) studied its biology and host specificity and found that it would feed and develop only on *C. odorata* and *C. ivaefolia*. It has never been recorded damaging economic plants either in Trinidad or South America. The life history is closely linked with the development of its host, the adults becoming reproductively mature at the time that the plant produces young flower buds which provide food for egg maturation. Eggs are deposited in the developing flower heads and larvae feed within the flower heads, destroying the seeds. Pupation occurs in the flowerheads and, until the next flowering, adults feed on tender growth, usually in shaded situations, and may do considerable damage (Cock 1984a). An individual larva destroys 30 to 60 seeds during development and the ovipositing female many young flowers. *A. brunneonigrum* thus has potential for causing considerable damage, particularly in lightly shaded conditions.

***Aulacochlamys* sp. Coleoptera: Chrysomelidae**

Widespread and occasionally abundant in Trinidad, where it causes moderate damage. Eggs are laid singly in a cylindrical ribbed case formed from faeces. These cases form the apex of a conical larval case which is enlarged as the larva grows. Larvae feed on the surface of stems and leaf petioles. Mature larvae attach the 3.5 to 3.7 mm long case to a stem and pupate inside. Adults emerge one to two weeks later. The small black adults (1.8 to 2.5 mm long) feed on the surface of stems and petioles. No parasitoids are known (McFadyen 1988a).

***Bucculatrix* sp. Lepidoptera: Bucculatricidae**

Recorded from *C. odorata* in Mexico and *Chromolaena jujuensis* (= *Eupatorium hookerianum*) in Argentina. Larvae are solitary leaf miners and pupate in the mines (McFadyen 1988a).

***Chlamisus insularis* Coleoptera: Chrysomelidae**

Recorded from Mexico, Panama and Trinidad. The life history is similar to that of *Aulacochlamys* sp., but this species is somewhat larger. The mature larval case is conical with a rough surface and 6 to 7 mm long. The adults are black with golden markings and 3.3 to 4.3 mm long. Adults are known to feed on *C. odorata*, *C. ivaefolia* and *Bidens pilosa*. A black, solitary eulophid egg parasitoid is known (McFadyen 1988a).

***Clinodiplosis* sp. Diptera: Cecidomyiidae**

Recorded from *C. odorata* and *C. ivaefolia* in Trinidad. Up to three larvae at a time live between the bud leaves of stem tips or axillary buds, destroying tissue and preventing growth. A gall is formed by the slight swelling of the bud leaves which become red and densely covered with hairs. Mature larvae drop to the ground and pupate just below the soil surface. Adults emerge 11 to 18 days later. This gall midge is abundant and widespread in Trinidad, breeds throughout the year and causes considerable damage to *C. odorata* (McFadyen 1988a).

***Mescinia parvula* Lepidoptera: Pyralidae**

Recorded from Trinidad; similar larvae were found on *C. odorata* in Mexico and Brazil and on *C. jujuensis* in Argentina. A few individuals were released on Guam in 1984, but there has been no evidence of establishment.

Ovipositing females select leaves with dense hairs (in effect young leaves) with the result that developing buds are nearby. Eggs are laid individually amongst the epidermal hairs on the underside of the young leaves and hatch in 5 to 6 days. Young larvae move to a terminal or axillary bud and several may enter the same bud. They bore down the stem destroying meristematic tissue and preventing growth. Larvae may leave a stem and enter a new bud. After 13 or so days larvae leave the stem to spin a flimsy cocoon, either attached to the plant or among ground litter, in which they pupate. Adults emerge 10 to

11 days later and live up to 6 days. Attempts to induce mating in cages in Trinidad were unsuccessful. In specificity tests larvae fed on only a few Asteraceae other than *C. odorata* and C. *ivaefolia* but, with the exception of 1 out of 30 larvae placed on *Dahlia,* no development was ever completed. Over a three year period in Trinidad, no oviposition or attack was observed on *Dahlia* plants growing near *C. odorata* which was frequently attacked by *M. parvula.* Furthermore, since *Dahlia* leaves are not hairy, it is most unlikely that *M. parvula* would ever oviposit on them. Larvae in Trinidad are attacked by eight hymenopterous and one tachinid parasitoid and, if freed from these, might do considerably more damage to *C. odorata* (Cruttwell 1977a).

***Pareuchaetes aurata aurata* Lepidoptera: Arctiidae**

This subspecies occurs in south-eastern Brazil, Paraguay and northern Argentina at latitudes (26° to 30°S) similar to those of Natal, South Africa. It has an average life cycle of 30 days at 26° to 29°C and 58 days at 22° to 25°C. Its larvae are nocturnal feeders and shelter at the base of plants during the day. In the laboratory, pupation occurred in a flimsy cocoon spun between leaves on the plant. Mating may occur on the night of emergence and an average of 242 eggs are laid over the next eight days. These are laid singly on the ground and, in the laboratory, newly-hatched first instar larvae were able to walk up about 2m of stem to commence feeding. In the field *P. aurata aurata* is found in shaded habitats near surface water.

In Argentina, larvae and pupae are infected with a microsporidan disease (*Nosema* sp.), up to 20% of larvae are parasitised by a complex of braconid, chalcidid and tachinid parasitoids and all stages are subject to attack by predatory ants.

The usual host plant of *P. aurata aurata* is *Chromolaena jujuensis,* but it has been successfully reared for more than 10 generations on *C. odorata.* In the field it has never been recorded as a pest on any of the many commercially important crops grown in its natural area of distribution. It was liberated in Natal (South Africa) in 1990 (Kluge and Caldwell 1993).

***Pareuchaetes pseudoinsulata* Lepidoptera: Arctiidae**

This moth is native to Trinidad, Tobago and the north-eastern coast of Venezuela. It has become established in Brunei, Guam, India, Philippines, Sabah, Sri Lanka, the Northern Marianas and Yap, but has failed to do so in Ghana, Nigeria, South Africa and Thailand. It was previously misidentified first as *Ammalo arravaca* and then as *A. insulata,* which is a closely related but distinct species (Cock and Holloway 1982).

The moth, which lives up to about 10 days, lays 150 to 250 eggs (maximum 580) in groups attached to the lower surface of the leaves of *C. odorata.* Larvae feed on the leaves and are gregarious until the 3rd instar, but then disperse. From the 4th instar on they feed at night, hiding by day amongst debris at the base of the plant, where they later pupate. The life cycle varies from 40 to 60 days and breeding occurs throughout the year. Host specificity studies in Trinidad showed that development occurred only on *Chromolaena ivaefolium*, *C. microstemon* and *C. odoratum.* In addition larvae developed, but only as far as the 3rd instar, on *Ageratum conyzoides* (Bennett and Cruttwell 1973), although in Sri Lanka, adults were produced on this weed. However their eggs had a somewhat lower hatchability than those from adults bred on *C. odorata* (Mahindapala et al. 1980). A high degree of host specificity has since been confirmed by others (e.g. Ahmad and Thakur 1991, Sankaran and Sugathan 1974, Syed 1979a) and no damage to plants other than to *C. odorata* has been reported either in the Americas or in the overseas countries where it has become established.

In Trinidad the eggs are parasitised by a scelionid wasp and the larvae by five species of tachinid fly. A nuclear polyhedrosis virus also affects the larvae (Bennett and Cruttwell 1973) and may have been responsible for breeding difficulties in some overseas countries, although other countries have experienced no problems in establishing cultures.

***Pentispa explanata* Coleoptera: Chrysomelidae**

This hispine beetle is recorded on *C. odoratum* from Mexico to Colombia and from Venezuela on *Pithecoctenium* sp. (Bignoniaceae). In Trinidad adults are widespread on *C. odorata* and C. *ivaefolia*, but would not feed on *Pithecoctenium echinatum.*

Eggs are inserted singly under the leaf epidermis and covered with a faecal plug. Larvae hatch after about 12 days and form irregular blotch mines which expand to 2 to 3 cm in diameter 20 to 25 days later when larvae are mature. Pupation occurs in the mine and adults emerge 5 to 8 days later. Adults disperse and feed on the underside of the leaves producing characteristic scars. There is one generation a year. Larvae are parasitised by a solitary ectoparasitic elasmid *Austelasmus* sp. and are taken by predatory wasps (McFadyen 1988a).

***Perasphondylia reticulata* Diptera: Cecidomyiidae**

This gall fly is recorded from *C. odorata* and C. *ivaefolia* in Trinidad, Brazil and Bolivia and from *C. odorata* and *Eupatorium* sp. in El Salvador.

Larvae occur singly in a hollow pear-shaped gall, 7 to 9 mm long, in stem tips and axillary buds. *P. reticulata* causes considerable damage but is generally uncommon and confined to the cooler valleys in Trinidad. However it is commoner in Brazil and Bolivia. It is attacked by several parasitoids in Trinidad and Bolivia (McFadyen 1988a).

***Procecidochares connexa* Diptera: Tephritidae**

This gall fly is recorded from Mexico, Brazil and Bolivia.

Eggs are inserted in the tip of the stem and abnormal growth commences even before they hatch. One to seven larvae feed in separate curved tunnels in the developing gall. Mature larvae pupate in the tunnel behind an epidermal window through which the adult emerges later. The galls slow and distort growth and cause moderate damage.

Larvae are parasitised by a number of wasps throughout their range (McFadyen 1988a).

***Rhodobaenus cariniventris* Coleoptera, Curculionidae**

This weevil is recorded from Trinidad and USA. Eggs are deposited in a slit between two rows of punctures encircling the stem, which result in wilting of the stem tip. On hatching, larvae feed for a few days in the wilted portion then tunnel into the sound tissue below the punctures. Bennett (1955) reports that, after a month, they pupate in the stem at the base of the plant and adults emerge 10 days later. However, McFadyen (1988a) states that, when mature, the larva cuts off from the hollow tip of the stem a piece about 2cm long containing it. This falls to the ground, where the open ends are plugged with frass, and pupation occurs. Adults feed on stems and petioles of *Bidens pilosa, Chromolaena inulaefolium,* C. *ivaefolia* and *C. odorata* (all Asteraceae). Larvae tunnel in the stems of all these except *B. pilosa* (McFadyen 1988a). Cruttwell (1974) suggested that the feeding of adults might be insufficiently restricted, but the situation merits further investigation.

R. cariniventris is parasitised in Trinidad by an external egg parasitoid *Euderus* sp. (Eulophidae) (Bennett 1955).

Comments

The genus *Chromolaena* belongs to the tribe Eupatorieae (Table 4.3.4), which is mainly of American origin. There are no crop plants or important ornamentals in this tribe. However, it does contain the major weeds *Ageratum conyzoides* (4.1) and *Mikania micrantha* (4.14) and several less important species: *Ageratina altissima* in eastern USA, *A. adenophora* and *A. riparia* in India to southern China, Australia, Hawaii and South Africa and *Austroeupatorium inulaefolium* in Indomalaysia and Sri Lanka. There are 129 species of *Chromolaena*, all from Central and South America. *Chromolaena ivaefolia* and *C. laevigata* are widespread and occasionally weedy in the Americas, but only *C. odorata* has spread elsewhere (McFadyen 1991a). These relationships suggest that many of the insects that attack *C. odorata* and its close allies are likely to be sufficiently host specific to be considered for classical biological control.

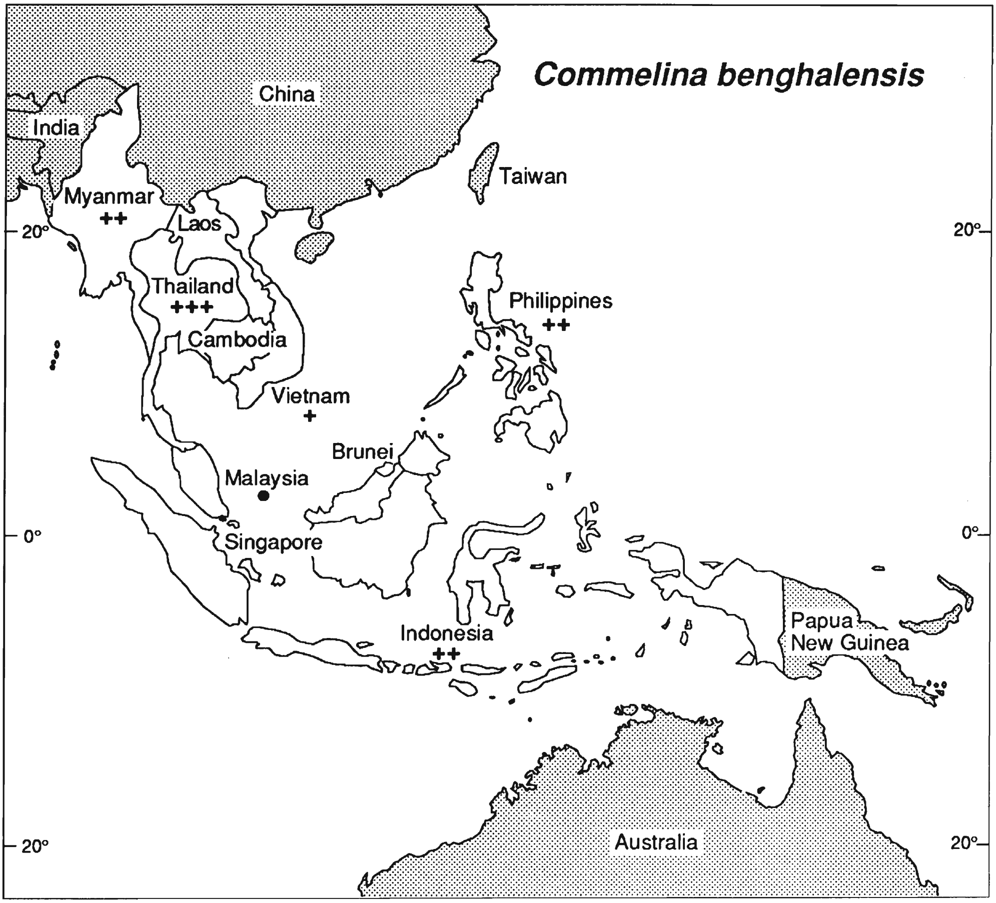
There has been discussion concerning the possible reasons for *Pareuchaetes pseudoinsulata* establishing fairly readily in Sri Lanka and Guam, with difficulty in India and Sabah and not at all in Africa (e.g. Cock 1984a, Cock and Holloway 1982, Seibert 1989). The desirability is rightly emphasised of matching, where possible, the climate of the area from which it (or any other biological control agent) is collected with that of the area in which it is to be released. Since *P. pseudoinsulata* has no diapause and breeds all year round, it will at least experience great difficulty in bridging (or find it impossible to bridge) the gap created by almost complete leaf loss of *C. odorata* in areas where there is a severe and long dry season. However, if this were the only problem, the moth should be able to establish itself at least briefly before being eliminated by starvation: this sequence has not, however, been documented. What, however, has been widely reported is the very high level of predation on eggs, larvae and pupae, in particular by ants and spiders, but also by other invertebrate and vertebrate predators (e.g. Kluge 1991, Kluge and Caldwell 1991). It seems probable that massive predation has been the cause of rapid demise of many releases. Thus, release sites should be chosen (or treated) so as to minimise predation. Although significant predation was also observed on Guam, the lower diversity of predators (and other organisms) on islands may well have contributed to the comparatively ready establishment of *P. pseudoinsulata* there and on other Pacific islands. Furthermore, the release of significant numbers (500 or more) of adults rather than of eggs or larvae may have assisted in avoiding rapid elimination of the released material.

The general vigour of the released insects and the presence or absence of microsporida or viruses would also play a crucial role in successful establishment and it is probable that these factors have not always been adequately considered.

It is possible that the high level of predation and of parasitisation of the biological control agents will, in many areas, so lessen the potential each has to cause damage to *C. odorata* that the combined effects of several will be required to bring about an adequate and sustained reduction in its weediness. Fortunately, many potentially suitable insects are available for study.

Commelina benghalensis

(after Holm *et al.* 1977)



Map 4.5 *Commelina benghalensis*

Only a very few natural enemies of *Commelina benghalensis* have been recorded, the two of possible interest occurring in the Americas, where it is not regarded as a weed. Its centre of origin is said to be the Old World Tropics, although it is widely reported as a weed in southern Africa and also from India eastwards to Australia. A survey for natural enemies is required not only in the Old World Tropics, but also in the tropical and subtropical Americas.

On existing knowledge it is not possible to assess its promise as a target for classical biological control.

4.5 *Commelina benghalensis* L.

Commelinaceae

dayflower, hairy wandering jew; myet cho (Myanmar), gewor (Indonesia), pak prab (Thailand) alikbangon (Philippines)

Rating

	+++	Thai
10	++	Myan, Indo, Phil
	+	Viet
	•	Msia

Origin

Old world tropics (?Africa).

Distribution

Widespread in the tropics and subtropics, but also in temperate areas.

Characteristics

A succulent, creeping, perennial (tropical and subtropical) or annual (temperate), with branched, creeping stems up to 0.4 m long, rooting at the nodes, leaves opposite; short-stalked blue or lilac flowers.

Importance

C. benghalensis is reported as a weed in 25 crops in 28 countries, but apparently not as a weed in South America (Holm et al. 1977). It is very persistent, readily forming dense, pure stands and smothering out other low-growing plants including vegetables, grains, pasture grasses and legumes. It prefers high soil moisture and fertility, but can persist in sandy or rocky soil, even under fairly dry conditions, only to grow rapidly with the onset of rain. It can produce up to 1600 seeds per plant, roots readily at the nodes of creeping stems and regenerates rapidly in this fashion when broken or cut.

It is a weed of cultivated lands, field borders, wet pastures, gardens, roadsides and waste places. It can withstand flooding and waterlogged conditions. In rice and other lowland crops it is subaquatic and grows readily on banks of irrigation ditches.

Species of *Commelina* are sometimes used as famine food in India and for animal fodder or poultices in Indonesia, Malaysia and Africa (Burkill 1935).

Natural enemies

Very few natural enemies (Table 4.5.1) have been reported to attack *Commelina benghalensis* and, of these, only two agromyzid leaf miners from the Americas appear to hold any promise. However, it appears that no detailed search has been carried out in the Old World Tropics, the presumed centre of origin of the weed. It is, perhaps, significant that

C. benghalensis is not reported as a weed anywhere in the Americas, although it is a problem in many countries of southern Africa, as well as in India, Sri Lanka, Bangladesh and Southeast Asia (Holm et al. 1977). It is also of interest that no agromyzids have been reported on *Commelina* in Africa or Asia (Spencer 1973). *Liriomyza commelinae* (Table 4.5.1) is restricted to USA, the Caribbean and South America (Brazil, Venezuela, Argentina) and is known from the genera *Commelina* and *Tradescantia*, both of the family Commelinaceae (Spencer and Steyskal 1986). Another agromyzid on *Commelina*, *Liriomyza robustae*, is known from central Columbia and the Andes, but only from one species *Commelina robusta* (Spencer 1990).

This suggests strongly that *C. benghalensis* should also be examined for natural enemies in tropical and subtropical areas of the Americas.

Table 4.5.1 Natural enemies of *Commelina benghalensis*.

Species	Location	Other hosts	References
INSECTS			
Orthoptera			
GRYLLIDAE			
Euscyrtus concinnus	Philippines		Barrion & Litsinger 1980
Hemiptera			
CICADELLIDAE			
Tarophagus proserpina	Philippines	taro, cassava, sweet potato, etc.	Duatin et al. 1986
PENTATOMIDAE			
Scotinophara latiuscula	Philippines	rice, *Echinochloa crus-galli*, *Fimbristylis miliacea*	Barrion & Litsinger 1987
Diptera			
AGROMYZIDAE			
Amauromyza sp.	Cuba		Spencer 1973, 1990
Liriomyza commelinae	Southern USA, Central and S. America	restricted to *Commelina* and *Tradescantia*	Spencer & Steyskal 1986
VIRUS			
groundnut rosette	Malawi		Adams 1967
NEMATODES			
Helicotylenchus multicinctus	Ivory Coast	banana, many weeds	Luc et al. 1990
Meloidogyne incognita	Philippines		Valdez 1968
Meloidogyne javanica	India		Dahiya et al. 1988
Pratylenchus sp.	Ivory Coast	banana, several weeds	Luc et al. 1990
Radopholus similis	Ivory Coast	*Musa* spp., several weeds	Luc et al. 1990

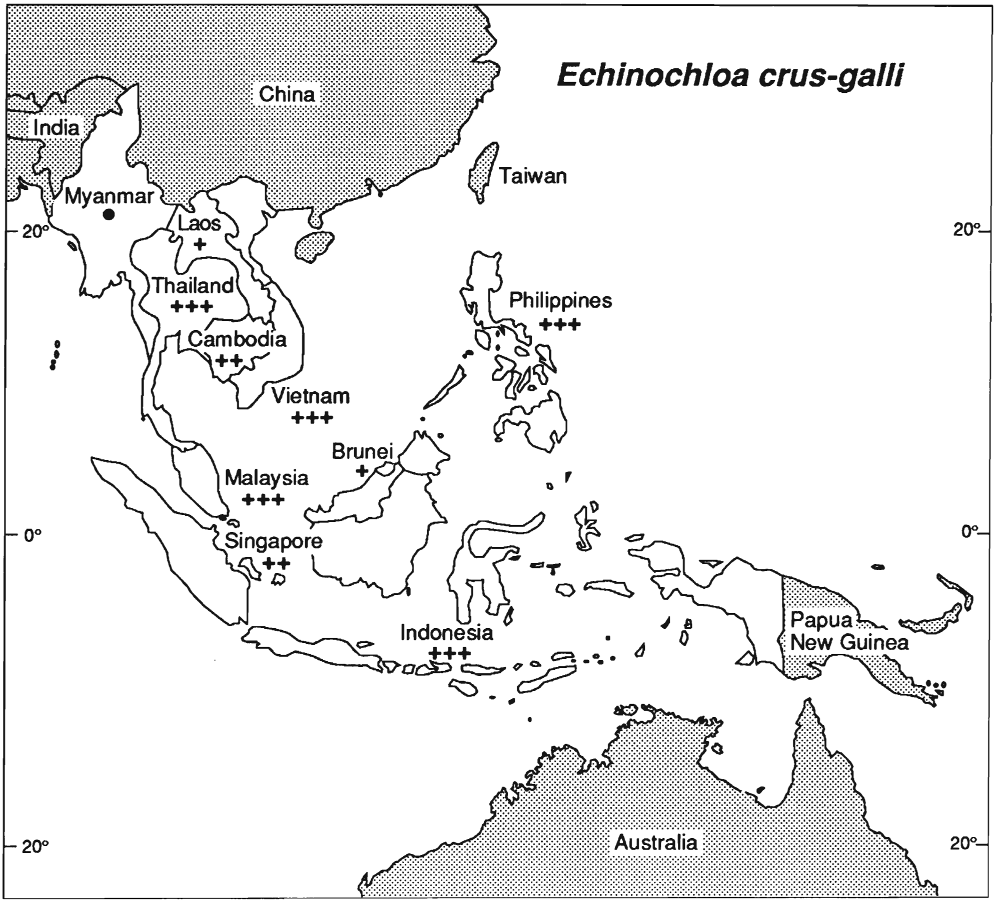
(continued on next page)

Table 4.5.1 (continued)

Species	Location	Other hosts	References
FUNGI			
Corticium sasakii	India	rice, and weeds, including *Cynodon dactylon, Eleusine indica Fimbristylis miliacea*	Roy 1973
Drechslera hawaiiensis			Narendra and Rao 1973
Kordyana celebensis	Philippines	*Commelina diffusa*	Gruezo 1990
Pyricularia spp.	India		Malleswaria-Rao & Narayana-Rao 1981
Pyricularia oryzae var. *commelinae*	Thailand		Hashioka 1973

Echinochloa crus-galli

(after Holm *et al.* 1977)



Map 4.6 *Echinochloa crus-galli*

Echinochloa crus-galli is said to be native to Europe and India, but very few organisms attacking it have been reported from this vast region and a survey is required. Elsewhere, as would be expected, most natural enemies are polyphagous and attack rice and other crops. Examination is needed of the host specificity of a weevil and of a gall fly reported from USA and of a moth reported from Malaysia and Japan.

4.6 *Echinochloa crus-galli* (L.) Beauv.

Poaceae

barnyard grass; myet ihi (Myanmar), hay kai mangda, ya plong, lamaan (Thailand), smao bek kbol (Cambodia) cò lông vüt (Vietnam), djawan (Indonesia), bayokibok, daua daua (Philippines), sambau (Malaysia). A cultivated variety *frumentacea* is called Japanese millet.

Rating

	+++	Thai, Viet, Msia, Indo, Phil
21	++	Camb, Sing
	+	Laos, Brun
	•	Myan

Origin

E. crus-galli is said to be a native of Europe and India (Holm et al. 1977), but possibly more likely the latter than the former.

Distribution

It is now widely cosmopolitan and occurs throughout the tropical and temperate regions of the world from latitude 50°N to 40°S.

Characteristics

An erect, clumped, C4, annual grass up to 1.5 m high, stems often branching near the base and rooting when decumbent, leaves flat, tapering to a point, hairless, or with a few hairs on the margins near the broad base. Inflorescence with up to 15 greenish (often tinged with purple) spikelets. Flowering occurs year-round in the Philippines, seeds tan to brown, with 2000 (in the Philippines) or far more per plant. Reproduction is exclusively from seed. Some seeds germinate immediately, although others remain viable for several years. *E. crus-galli* is a very variable species with a number of ecotypes around the world. Maun and Barrett (1986) have reviewed the characteristics and biology of this weed.

Importance

E. crus-galli is a common and very important weed of most agricultural areas of the world, with the strange exception of most of Africa where it does not seem to be a problem. It is important in 36 crops in 61 countries (Holm et al. 1977). It prefers wet soils and continues to grow when partially submerged. It is a weed of swamps, but grows in drier soils where it is not as tall and has fewer tillers and seeds. It normally occurs at low or medium altitudes and grows best in rich, compact, moist soils with a high nitrogen content, but can grow well on sands and loams. It prefers sunshine and at short photoperiods the plants flower early and are considerably shorter than under long photoperiods. In their early growth stages both *E. crus-galli* and rice are similar in appearance and their seedlings are often transplanted at the same time. In direct-seeded rice the weed also germinates at about the same time (5 to 6 days), grows at the same rate for the first few weeks, but the weed then becomes taller. Dense stands of *E. crus-galli* can remove 60 to 80% of available nitrogen and its fibrous root system favours it benefitting more than rice from fertilisers.

In heavy competition with *E. crus-galli*, tillering in rice is reduced by up to 50% and the height of the rice plant and the number and weight of the grains diminished. When the weed was transplanted at a density of 20 plants per sq m with rice seedlings in the Philippines, rice yields were reduced by 18% and at a density of 40 weeds per sq m by 30% (Lubigan and Vega 1971). Yields are severely reduced in various countries in many other crops including bananas, cassava, citrus, coffee, cotton, groundnuts, jute, maize, millet, potatoes, sorghum, sugarcane, taro, tea, tobacco and vegetables (Holm et al. 1977).

E. crus-galli can accumulate nitrate in its tissues at levels high enough to be toxic to farm animals (Schmutz et al. 1968).

Natural enemies

Barnyard grass is attacked by a number of (mostly polyphagous) insects, fungi and viruses but, curiously, there are only three references to nematodes (Tables 4.6.1 to 4.6.3). Vengris et al. (1963) suggested that the widespread North American weevil *Listronotus humilis* might be of interest as a biological control agent. Its larvae attacked the growing points in the crown of *E. crus-galli* seedlings, the young tissue around the growing points and the new shoots of intercalary growth in Massachusetts USA. Up to 90% of plants were attacked and young plants were often killed. Maize, *Digitaria sanguinalis* and *Setaria glauca* growing nearby were not attacked.

The only other insects listed that merit further investigation are the gall midge *Lasioptera echinochloa*, reported from USA (Felt 1916, 1918), the thrips *Haplothrips ganglbaueri* from India and *Emmalocera* sp. from Japan and Malaysia. *Lasioptera echinochloa* was reared from the crown and lower portions of the stems of *E. crus-galli* (Felt 1916) and has not been recorded from any other host. Larvae of the moth *Emmalocera* bore in the stems of four species of *Echinochloa*, one of which, *E. picta,* is a perennial. They did not attack *E. colona* or rice (Goto 1992).

With so few natural enemies reported from its presumptive vast area of origin (Europe to India), it is not yet possible to postulate what the prospects for biological control are.

Table 4.6.1 Natural enemies of *Echinochloa crus-galli*: insects.

Species	Location	Other hosts	References
Orthoptera			
GRYLLIDAE			
Euscyrtus concinnus	Philippines	rice, many grasses	Barrion & Litsinger 1980
Hemiptera			
ALYDIDAE			
Leptocorisa oratorius		rice, many weeds	Morrill et al. 1990
APHIDIDAE			
Aphis fabae	Turkey	polyphagous	Gürsoy 1989
DELPHACIDAE			
Laodelphax striatellus	China	rice	Lei et al. 1983
Nilaparvata lugens	China	prefers rice to *E. crus-galli*	Lei et al. 1983
Sogatella furcifera	China	rice	Lei et al. 1983
Sogatella vibix (= *S. longifurcifera*, = *S. panicola*)	China, USA	prefers *E. crus-galli* to rice	Chen et al. 1989a,b, Lei et al. 1983
Tagosodes (= *Sogatodes*) *pusanus*	Malaysia	said to be specific	Itoh 1991a,b
MIRIDAE			
Cyrtorhinus lividipennis	Malaysia	a predator, lays more eggs on *E. crus-galli* than on rice or other nearby weeds	Sivapragasam 1983
PENTATOMIDAE			
Scotinophara latiuscula	Philippines	rice, many weeds	Barrion & Litsinger 1987
Thysanoptera			
PHLAEOTHRIPIDAE			
Haplothrips ganglbaueri	India	many cereals	Ananthakrishnan & Thangavelu 1976
Stenchaetothrips (= *Baliothrips*) *biformis*	India	rice	Ananthakrishnan & Thangavelu 1976
Coleoptera			
CHRYSOMELIDAE			
Dicladispa armigera	India	rice, *Echinochloa colona*, *Paspalum distichum*, *Cynodon dactylon*	Dhaliwal 1979
CURCULIONIDAE			
Listronotus humilis	USA		Vengris et al. 1963
Lissorhoptrus oryzophilus	USA	rice	Maun & Barrett 1986
Diptera			
AGROMYZIDAE			
Agromyza parvicornis	USA	maize, *Panicum miliaceum*	Spencer 1990, Spencer & Steyskal 1986

(continued on next page)

Species	Location	Other hosts	References
Agromyza proxima	USA	*Echinochloa walteri*, *Panicum dichotomiflorum*	Spencer 1990, Spencer & Steyskal 1986
Cerodontha muscina	Europe, North America	many grass genera	Spencer 1990, Spencer & Steyskal 1986
EPHYDRIDAE			
Hydrellia griseola	USA	rice	Maun & Barrett 1986
CECIDOMYIIDAE			
Lasioptera echinochloa	USA	merit investigation	Barnes 1946, Felt 1916, 1918
Orseolia sp. nr *oryzae*	India	merit investigation	Gagné 1985
Lepidoptera			
NOCTUIDAE			
Mythimna (= *Pseudaletia unipunctata)*	Canada, USA	maize, wheat	Borror et al. 1981
Sesamia botanephaga	Ghana	rice, sugarcane	Sampson & Kumar 1986
Sesamia calamistis	Ghana	rice, sugarcane	Sampson & Kumar 1986
Sesamia penniseti	Ghana	rice, sugarcane	Sampson & Kumar 1986
PYRALIDAE			
Chilo agamemnon	Egypt	rice, *Agropyron repens*	Ahmed 1980
Chilo zacconius	Ghana	rice, sugarcane	Sampson & Kumar 1986
Cnaphalocrocis medinalis	Philippines	rice, many grasses	Abenes & Khan 1990
Cnaphalocrocis (= *Marasmia) patnalis*	Philippines	rice, many grasses	Abenes & Khan 1990
Elasmopalpus lignosellus	Cuba	rice, maize	Perez & Lopez 1980
Eldana saccharina	Ghana	rice, sugarcane	Sampson & Kumar 1986
Emmalocera sp.	Japan, Malaysia	*E. oryzicola*, *E. picta*, *E. utilis*: possibly specific to *Echinochloa* (but does not attack *E. colona*)	Goto 1992, Itoh 1991b

Table 4.6.2 Natural enemies of *Echinochloa crus-galli*: nematodes and fungi.

Species	Location	References
NEMATODES		
Hirschmaniella oryzae	India	Mathur & Prasad 1973
Meloidogyne graminicola	India	Rao et al. 1970
Paratylenchus spp.	USA	Gast et al. 1984
FUNGI		
Cochliobolus lunatus	Netherlands	Scheepens 1987
Drechslera dictyoides	Canada	Shoemaker 1962
Fusarium roseum	Brazil	Reis 1982
Helminthosporium spp.	Turkey, USA	Gürsoy 1989, Vengris et al. 1963
Helminthosporium turcium	Romania	Perju 1989
Pyricularia oryzae	Turkey	Togashi 1942, Gürsoy 1989
Rhizoctonia spp.	Brazil	Reis 1982

(continued on next page)

Table 4.6.2 (continued)

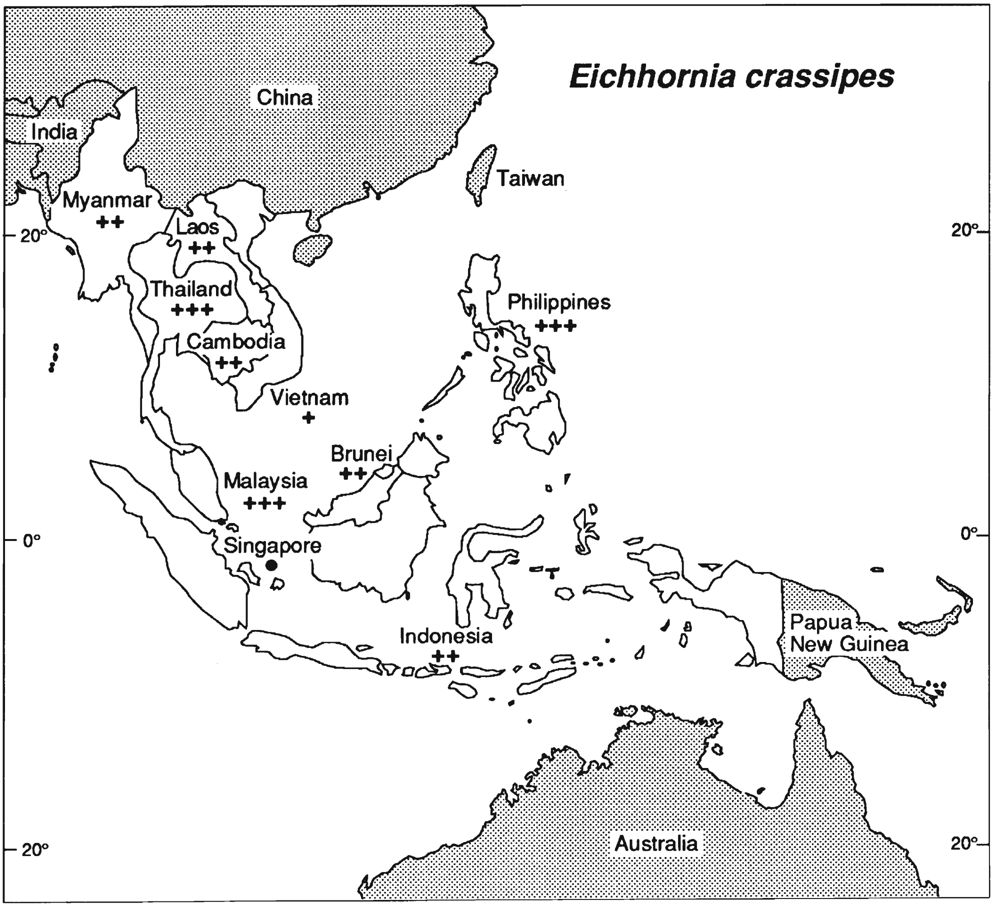
Species	Location	References
Tolyposporium bullatum	Canada, USA, New Zealand	Conners 1967, Fischer 1953, Fullerton 1977
Ustilago crusgalli	Canada, USA	Conners 1967, Fischer 1953, Fullerton 1977
Ustilago tricophora	New Zealand	Togashi 1942, Gürsoy 1989

Table 4.6.3 Natural enemies of *Echinochloa crus-galli*: bacteria and viruses.

Species	Location	References
BACTERIA		
Xanthomonas translucens	Australia	Moffett & McCarthy 1973
VIRUSES		
barley stripe mosaic	Hawaii	Holm et al. 1977
lucerne dwarf	Hawaii	Holm et al. 1977
maize dwarf mosaic	SE Asia	Conti 1981, Lee 1964
oat pseudorosette	Hawaii	Holm et al. 1977
panicum mosaic	Hawaii	Holm et al. 1977
rice dwarf	SE Asia	Shinkai 1956
rice tungro	SE Asia	Watanakul 1964
sugarcane mosaic	Hawaii	Holm et al. 1977
wheat streak mosaic	Hawaii	Holm et al. 1977

Eichhornia crassipes

(after Holm *et al.* 1977)



Map 4.7 *Eichhornia crassipes*

Eichhornia crassipes is a perennial aquatic weed, originating in Amazonia.

There have been many attempts at biological control, with a steadily increasing record of substantial successes, although these have generally been slow in emerging.

The most important natural enemies include two weevils (*Neochetina eichhorniae* and *N. bruchi*), two moth larvae (*Sameodes albiguttalis* and *Haimbachia infusella*), a mite (*Orthogalumna terebrantis*) and a fungus (*Cercospora rodmanii*). However, there are many other natural enemies that could be investigated if required.

Experience in a number of countries indicates that the establishment of several of the above organisms is highly likely to bring about a significant reduction in the abundance of water hyacinth. Control is generally slow in developing and, in some situations, all of the above organisms (and perhaps even others) may be required to provide an adequate level of suppression.

4.7 *Eichhornia crassipes* (Martius) Solms-Laubach

Pontederiaceae

water hyacinth; beda bin, ye padauk (Myanmar), kamplauk (Cambodia), keladi bunting (Malaysia), ècèng, etjeng padi (Indonesia), phak top chawaa, sawah (Thailand), luc bình (Vietnam)

Rating

	+++	Thai, Msia, Phil
20	++	Myan, Laos, Camb, Brun, Indo
	+	Viet
	•	Sing

This account brings up-to-date the chapter on *E. crassipes* in Waterhouse and Norris (1987) and increases its relevance to Southeast Asia. It supplements the valuable review by Harley (1990).

Origin

The centre of origin of water hyacinth is Amazonia, Brazil, with natural spread to other Central and South American countries (Barrett and Forno 1982, Forno and Wright 1981, Harley 1989, Little 1968, Penfound and Earle 1948).

Distribution

Water hyacinth occurs in lakes, slow moving rivers and swamps in most countries of the world lying between 40°N and 45°S. In addition to the Southeast Asian countries listed above, these include Pakistan, India, Bangladesh, Sri Lanka, China, Australia, Pacific islands, USA and much of Africa. It was imported to the Bogor botanical gardens in Indonesia in 1894 as an ornamental and fishpond cover (Soerjani et al. 1987). It was first recorded in eastern Australia about 1894, probably having been introduced as an aquarium plant. By 1900 it was firmly established and by 1979 it was widely distributed throughout coastal eastern Australia and also near Darwin and Perth (Ashton 1973, Bill 1969, Forno and Wright 1981, Mitchell 1978, Parsons 1963).

Characteristics

Eichhornia crassipes is a perennial, herbaceous, aquatic plant. It is usually free floating, whereas other members of the Pontederiaceae are always firmly rooted in the substrate. The leaves are arranged in a rosette and the petioles vary from spongy and bulbous to slender and non-bulbous. The latter are typical of plants from dense infestations, whereas the former are typical of open water and spreading infestations. The roots are long and sometimes dark, because of the purple anthocyanin pigment they contain (Holm et al. 1977). Three style forms are known in the lilac to blue flowers (Barrett and Forno 1982), two of which occur, often together, in Australia (Forno and Wright 1981). Flowers set up to 300 seeds, with or without pollination by insects. Seeds sink following release from the seed capsule and remain viable for 5 to 20 years, usually germinating along shorelines with fluctuating water level (Forno and Wright 1981). However, the usual form of reproduction is vegetative, by means of stolons, which produce plants at the apices. The new plants rapidly produce roots and become independent on decay or breakage of the connecting stolon. Plant doubling time can be as short as 5 days (Perkins 1973a). A mat of medium-sized plants may contain 2 million plants per hectare with a wet weight of 270 to 400 tonnes (Holm et al. 1977).

Importance

Water hyacinth is considered by Holm et al. (1977) to be the world's most serious water weed and a threat to all still or slowly moving bodies of fresh water in the tropics and subtropics. This view has been confirmed over some decades by most countries into which it has been introduced.

Water hyacinth is tolerant of considerable variation in nutrient content and pH, but dies in water of salinity higher than 0.06% (Penfound and Earle 1948). Optimal growth conditions are a pH of about 7, a phosphorus concentration of 20 ppm (Chadwick and Obeid 1966, Haller and Sutton 1973) and adequate nitrogen. Plants will grow in mud and can survive for months on a substrate of low moisture content. Although frost causes dieback of the leaves, water hyacinth plants are known to survive harsh winter conditions in Japan (Sastroutomo et al. 1978) and the United States (Penfound and Earle 1948). In any case, seeds can survive cold conditions (Ueki and Oki 1979). The optimum temperature range for growth is 28°C to 30°C (Knipling et al. 1970).

E. crassipes is generally the dominant plant where it occurs outside its native range and it can bring about the reduction or elimination of other species. In Australia it can outcompete the native floating plants *Lemna* spp. and *Azolla* spp. and also the introduced water weeds *Salvinia molesta* and *Pistia stratiotes* (Forno and Wright 1981). It forms dense mats in natural watercourses, natural and man-made lakes, irrigation and flood mitigation channels and dams. It impedes boat traffic, interferes with or even prevents recreational use of the water and complicates problems during flooding by banking up against bridges, culverts, fences etc., thereby obstructing water flow and increasing flood levels. By reducing the penetration of light and affecting growth of phytoplankton, it lowers the pH and the concentration of dissolved oxygen and increases the level of carbon dioxide. The evapotranspiration rate is reported to be two to eight times that of evaporation from a free water surface (Holm et al. 1977) and it is estimated that one tenth of the average water volume was lost from the Nile every year due to evapotranspiration by water hyacinth (Hamdoun and Tigani 1977).

Although water hyacinth generally affects agriculture only indirectly, it is a problem in some areas in rice and taro fields. Moreover, it is regarded as being of considerable epidemiological importance in many countries because it provides a suitable habitat for the mosquito vectors of malaria, encephalitis and filariasis (Forno and Wright 1981).

Water hyacinth is not entirely without its virtues. For example, many people regard its massed spikes of striking blue flowers as attractive, and this has contributed to its wide and rapid dispersal. In China, Vietnam and some other countries it is harvested locally for animal feed (principally for pigs), although it contains 95% water. In India, it is also used for the production of paper and biogas, as a compost and, after drying, as a fuel. It has the ability to remove nutrients from waters receiving sewage effluents and thus to aid in water purification. At an armed services centre in the United States it is used to harvest silver salts from the effluent of photographic processing laboratories. However, the costs of harvesting, transporting, drying and processing make it uneconomic to utilise water hyacinth infestations for agricultural and other purposes in Australia and many other countries (Bennett 1982b, Forno and Wright 1981).

Natural enemies

In its native range in South America where it is attacked by a number of organisms, water hyacinth occurs in the coastal lowlands, along the margins of lagoons and in slowly moving water along the edges of rivers and streams. It is common in the Amazon and other mighty rivers of Brazil. However the mats formed are seldom as dense as those in countries where it is an introduced plant; and, in its native region, water hyacinth tends to be just one member of a mixed community of floating and anchored plants. Where mats do form they are often destroyed before long by a combination of biological and hydrological forces (Forno and Wright 1981).

Exploration for natural enemies of water hyacinth was first undertaken in Uruguay in the early sixties (Silveira-Guido 1971). In 1967 the Commonwealth Institute of Biological Control began studies in northern South America and the West Indies, in 1968 the United States Department of Agriculture began work in Argentina (Vogt and Cordo 1976), and from 1978 Australia undertook studies in Brazil and adjacent countries. As a result, a great deal of information is available about the organisms that attack water hyacinth in its native range (Harley and Wright 1984). Furthermore, there are a number of reports of generally non-specific organisms attacking water hyacinth in countries to which it has been introduced. Information has been published for Uruguay (Silveira-Guido 1971), Trinidad (Bennett 1967, 1968, 1972; Bennett and Zwolfer 1968), Argentina (DeLoach 1975) and Florida (Charudattan et al. 1974, Delfosse 1978a,b, Delfosse et al. 1976, Perkins 1973a,b, 1974, 1977b). Divakar and Manoharan (1978) and Perkins (1973a) listed more than 70 species of arthropods that feed on water hyacinth in South America, USA and India. This list includes those reported from South America by Bennett (1970), Bennett and Zwolfer (1968), and Silveira-Guido (1971). A widespread dolichopodid fly in South America and Trinidad, *Thrypticus* sp., was regarded as promising, but somewhat less so than those chosen for attention (Table 4.7.1) (Bennett and Zwolfer 1968, 1969). Two species of phytoseiid mite *Amblyseius glorius* and *A. pederosus* (El-Banhawy 1979) and an eriophyid mite *Flechtmannia eichhorniae* (Keifer 1979) have been reported attacking water hyacinth in Brazil. A description of the life cycle and limited host-specificity studies of a root-feeding moth *Argyractis subornata* have been reported (Forno 1983). In addition to attack by invertebrates and fungi, water hyacinth is also eaten by two kinds of vertebrates, manatees *Trichechus* spp. (Anon. 1973), and the white amur or grass carp *Ctenopharyngodon idella* (Baker et al. 1974, Delfosse et al. 1976). These vertebrates do not prefer water hyacinth to many other aquatic plants and do not cause much damage to dense stands of the weed.

Table 4.7.1 Promising agents for the biological control of water hyacinth (after Harley 1989).

Agent	Type of damage
INSECTS	
Coleoptera	
CURCULIONIDAE	
Neochetina bruchi	adults feed on foliage and petioles; larvae tunnel in petioles, stolons and crown
Neochetina eichhorniae	as for *N. bruchi*
Lepidoptera	
NOCTUIDAE	
Bellura densa	larvae tunnel in petioles and crown
PYRALIDAE	
Haimbachia infusella	larvae tunnel in laminae and petioles
Sameodes albiguttalis	larvae tunnel in petioles and buds
MITES	
GALUMNIDAE	
Orthogalumna terebrantis	immatures tunnel in laminae
FUNGI	
HYPHOMYCETES	
Cercospora rodmanii	punctate spotting and chlorosis of laminae and petioles; necrosis of laminae

There are six species of the weevil genus *Neochetina* in Central and South America, all of which are semiaquatic and have adaptations to the aquatic environment, including water-repelling hairs and scales. Two species, *N. eichhorniae* and *N. bruchi*, feed on *Eichhornia crassipes*, the related *E. azurea* (anchored water hyacinth) and *Pontederia cordata*. The other four species are not known to be important enemies of water hyacinth (DeLoach 1975, O'Brien 1976).

Three insects (the beetles *Neochetina eichhorniae* and *N. bruchi* and the moth *Sameodes* (= *Epipagis*) *albiguttalis*), a mite (*Orthogalumna terebrantis*) and a fungus (*Cercospora rodmanii*) are each established in at least one major region of the exotic range of water hyacinth (Table 4.7.2) (Harley and Wright 1984). Brief accounts of these and other promising organisms follow. Specificity tests are summarised by Bennett (1982a) and Harley (1989) and methods for evaluating effectiveness of releases by Harley (1982).

Attempts at biological control

Table 4.7.2 summarises the results of introductions of eight organisms employed so far for the biological control of water hyacinth. The dates of first release are given, although there were often subsequent releases. It is possible that some of these organisms will yet be recovered in countries from which establishment has not so far been reported.

Table 4.7.2 Introductions for the biological control of *Eichhornia crassipes*.

Species	Country	Liberated	Result	References
INSECTS				
Coleoptera				
CURCULIONIDAE				
Neochetina bruchi	Australia	1990	+	Julien 1992
	Benin	1992	?	K.L.S Harley pers. comm.
	Honduras	1990	+	Julien 1992
	India	1984	+	Jayanth 1987, 1988, Pawar & Gupta 1984
	Malaysia	1992		A.D Wright pers. comm.
	Panama	1977	?	Bennett 1984, Parris 1980
	Papua New Guinea	1993	?	M.H. Julien pers. comm.
	Solomon Is.	1993	?	M. Vagalo pers. comm.
	South Africa	1989	+	Cilliers 1991a
	Sudan	1979	+	Beshir 1983, 1984 Beshir & Bennett 1985, Irving & Beshir 1982
	Thailand	1991	+	A.D. Wright pers. comm.
	USA	1974	+	Center & Durden 1986, Center et al. 1989
	Zimbabwe		+	I.W. Forno pers. comm
Neochetina eichhorniae	Australia	1975	+	Wright 1981, 1982
	Benin	1991	+	K.L.S. Harley pers. comm.
	Egypt	1980	?	Julien 1992
	Fiji	1977	+	Singh et al. 1981, Waterhouse & Norris 1987
	Honduras	1990	+	Julien 1992
	India	1983	+	Julien 1992, Misra et al. 1992
	Indonesia	1979	+	Kasno & Soerjani 1979
	Malaysia	1983	+	Julien 1992
	Mexico	?	?	Harley 1989
	Myanmar	1979	?	Napompeth 1984
	Papua New Guinea	1985	+	Laup 1987a
	South Africa	1985	+	Cilliers 1991a
	Solomon Is	1982	–	Waterhouse & Norris 1987
		1988	+	Julien 1992
	Sri Lanka	1981	?	Napompeth 1984
		1988	+	Room & Fernando 1992
	Sudan	1978	+	Beshir 1983, 1984, Beshir & Bennett 1985
	Thailand	1978	+	Napompeth 1982, 1984, 1990a
	USA	1972	+	Center & Durden 1986, Center et al. 1989
	Vietnam	1985	?	Julien 1992
	Zambia	1971	?	Bennett 1974, 1984, CIBC 1972
	Zimbabwe	1971	?	Bennett 1974
Lepidoptera				
PYRALIDAE				
Haimbachia infusella	Australia	1981	–	Wright 1982

(continued on next page)

Species	Country	Liberated	Result	References
Sameodes albiguttalis	Australia	1977	+	Wright 1981, 1982
	Panama	1977	?	Parris 1980
	South Africa	1990	+	Cilliers 1991a
	Sudan	1980	+	Beshir 1983, 1984, Beshir & Bennett 1985, Irving & Beshir 1982
	USA	1977	+	Center et al. 1989
	Zambia	1971	?	Bennett 1974, 1984
MITES				
GALUMNIDAE				
Orthogalumna terebrantis	Cuba	?	?	Harley 1989
	Egypt	1971	?	Julien 1992
	India	1986	+	Jayanth 1987, Jayanth & Visalakshi 1989
	Jamaica	?	?	Harley 1989
	Mexico	?	?	Harley 1989
	South Africa	?	?	Harley 1989
	USA	pre 1900	+	Waterhouse & Norris 1987
	Zambia	1971	?	Wright 1981
FUNGI				
Acremonium zonatum	USA	?	+	Harley 1989
Cercospora rodmanii	South Africa	1992	?	C.J. Cilliers pers. comm. 1993
	USA	?	+	Harley & Wright 1984
FISH				
Ctenopharyngodon idella	Fiji	1968	+	Singh et al. 1981
	USA		+	Waterhouse & Norris 1987

It appears from the records that the nucleus material of *Neochetina eichhorniae* that has been distributed to other countries has come from an area of southern USA that was stocked from collections made in a single area in Argentina in the early seventies. Material with a wider genetic basis may extend the usefulness of this species.

AUSTRALIA

The weevil *N. eichhorniae*, from colonies in Florida that had originated from Argentina, was subjected to confirmatory host-specificity trials, mass reared and released in 1975 near Brisbane. During the following 3 years further releases of laboratory-reared insects were made, and further dispersal was later made of field-collected insects. Successful establishment has followed liberations of as few as 200 adults, and natural dispersal has been quite extensive. Where high populations of the weevil developed the leaves were killed and heavily attacked plants died and sank, unless temporarily supported by the floating mat. Lush stands of water hyacinth supported the fastest growth of *N. eichhorniae* and suffered the most dramatic collapses, but there has also been a general attrition of less healthy plants. Reductions in the area of a number of water hyacinth infestations have occurred and, at some sites once completely covered by the weed, there is now a significant amount of open water and a reappearance of native water lilies and water fowl. The weevil has produced a higher level of control in northern Australia than in the southern regions, where its activity and breeding is slowed during the cooler months of the year (Wright 1979, 1982). Because it was thought that there might be competition for pupation sites between *N. bruchi* and *N. eichhorniae* the former was not introduced (Harley and Wright 1984), although studies now indicate that the action of the two weevils is complementary and a higher level of control has been achieved where both species have been established (Harley 1989). *N. bruchi* was therefore released in 1990, became established, and is spreading steadily (Julien 1992).

Sameodes albiguttalis from laboratory stocks sent from USA was propagated and liberated from 1977 to 1979 and infested plants distributed thereafter. The adult moth disperses freely and, by the end of 1982, the species could be observed at most water hyacinth infestations in Australia. Heavy damage by young larvae has occurred on young plants with bulbous petioles, but rarely on tall plants with slender petioles unless they are very lush. The heaviest damage by *Sameodes* larvae has thus been to plants on the advancing front of dense infestations, and these can be greatly reduced in abundance. Rapid growth of moth populations has often occurred following treatment of water hyacinth infestations with 2,4–D, which reduces leaf hardness and increases nitrogen content (Wright and Bourne 1990). A lagoon in Queensland that was about 85% covered with water hyacinth in November 1978 had only 5% cover by June 1980. Weed recovery to about 65% followed by November 1981, but by May 1982 the cover had declined to about 25% (Wright 1984). Heavy damage by *S. albiguttalis* does not occur on plants under heavy attack by *N. eichhorniae*, although the two species can co-exist. The weevil causes greatest damage during the warmer months and the moth during the cooler months or in the absence of high populations of the weevil. Adult *N. eichhorniae* prefer to feed on the youngest water hyacinth leaves, which release higher quantities of chemical attractants, but are not affected by cuticle hardness which, however, is increased by their feeding: on the other hand, *Sameodes albiguttalis* larvae are adversely affected by cuticle hardness, which may explain their diminished populations when *Neochetina* is present. Petiole hardness is usually lower in winter than summer and liberations of *S. albiguttalis* more often resulted in successful establishment during winter (Center and Durden 1981, Wright 1987, Wright and Bourne 1986).

Haimbachia infusella, obtained from Brazil, appeared to become established after liberation of laboratory stocks in 1981 (Wright 1982), but has not been recovered more recently (Sands and Kassulke 1983) and must be assumed not to have survived.

In summary, the biological control of water hyacinth in Australia has been encouraging, but many infestations have not yet been reduced to an acceptable level (Wright 1984).

FIJI

The white amur or grass carp *Ctenopharyngodon idella* was established in the Rewa river in 1968 and was mass reared and released for many years thereafter (Singh et al. 1981). The mite *Orthogalumna terebrantis* was considered for release in 1975, but not liberated because of fears that it might be a carrier of the fungus *Acremonium zonatum*, a pathogen known to attack several species of *Ficus* (Kamath 1979). The aphid *Rhopalosiphum nymphaeae* has been recorded from water hyacinth in Fiji (Hinckley 1963).

Neochetina eichhorniae from Australia was mass produced and liberated from 1977 to 1978 and soon became established in a number of areas of Viti Levu (Singh et al. 1981). Although damage caused by adult and larval attack is apparent in all areas, this has not caused the degree of weed death reported from Australia and USA. In the Navua area it is possible that the application of insecticides to rice has suppressed nearby weevil populations. When water hyacinth and *Salvinia molesta* were introduced into an artificial pond to which fertiliser had been added, *N. eichhorniae* damaged the dominant water hyacinth, whereupon *S. molesta* soon formed a thick surface mat. This experimental demonstration emphasises the need to proceed simultaneously with the biological control of *Eichhornia* and *Salvinia* if both species are present (Singh et al. 1982).

INDIA

Releases of *Neochetina eichhorniae* began in 1983, of *N. bruchi* in 1984 and of *Orthogalumna terebrantis* in 1986 (Nagarkatti 1982) and all three are established (Harley 1989, Jayanth 1988, Jayanth and Visalakshi 1987, Misra et al. 1992, Pawar and Gupta 1984).

INDONESIA

N. eichhorniae was introduced from USA, released in 1979 and became established at a site at Bogor (Kasno and Soerjani 1979). It now occurs widely in Java.

MALAYSIA

In 1980 water hyacinth covered 470 ha of irrigation waterway surface in the Mada area and 37 km out of 497km of canals in the Krian District. Some $M10 million p.a. is needed to maintain all waterways (Mohamed et al. 1992). *N. eichhorniae* from Australia was introduced in 1983 and has become established (Table 4.7.2).

PAPUA NEW GUINEA

Releases of *Neochetina eichhorniae* from Australia were made in June 1985 (Laup 1987a) and of *N. bruchi* in 1993 (M.H. Julien pers. comm.).

SOLOMON IS

Three hundred adult *Neochetina eichhorniae* from Australia were released directly into the field in 1982 (Macfarlane 1984). It is well established on Guadalcanal near Honiara and, although it has reduced the abundance of water hyacinth, this remains a weed. More recently, *N. bruchi* and *Sameodes albiguttalis* have also been released.

SOUTH AFRICA

N. eichhorniae was first released in 1985. It became established and has spread widely in subtropical and temperate areas, but only slowly into cooler, high altitude areas. *N. bruchi* was liberated in 1989 and is spreading slowly. *Sameodes albiguttalis* has become established as a result of releases in 1990 and is still being distributed. The pathogens *Cercospora piaropi* and *Alternaria eichhorniae* were found to be present and have since been distributed widely. *Cercospora rodmanii* was released in 1992, but is not known to have become established. Chemical and biological control are being used together in the high altitude areas to provide adequate control (Cilliers 1991a, C.J. Cilliers pers. comm. 1993).

MYANMAR

Releases of *N. eichhorniae* from Thailand were made in 1980 and establishment observed around Yangon (B. Napompeth pers. comm.).

SRI LANKA

N. eichhorniae was liberated in 1988 and was well established by 1991 (Room and Fernando 1992).

SUDAN

Neochetina eichhorniae was released in 1978 and is now distributed throughout the White Nile system in Sudan. *N. bruchi* was liberated in 1979 (Irving and Beshir 1982) and became established, but is the least effective of the three natural enemies now there (Beshir 1984). *Sameodes albiguttalis* was liberated in 1980 and now occurs along the White Nile from the junction of the Sobat River to Kosti (Beshir 1983). By 1981 *Neochetina* spp. were widespread and nearly every water hyacinth plant bore feeding marks of the adult weevils (Harley 1989). Plants became less vigorous, had a lower dry weight, floated lower in the water and, before long, few were reaching Khartoum.

THAILAND

Water hyacinth was introduced from Indonesia in 1896 and is considered to be among the most important water weeds in Thailand. Three species of grasshopper (*Atractomorpha crenulata*, *Gesonula punctifrons* and *Oxya minuta*), two cutworms (*Spodoptera litura* and *S. mauritia*) and a sphingid moth (*Hippotion echeclus*) were found attacking water hyacinth. The latter moth also attacked *Monochoria hastata* and *M. vaginalis*. The grasshopper *G. punctifrons* is widely distributed in China, India, Myanmar and Taiwan (Sankaran et al. 1966) and in Thailand it is widespread on water hyacinth, causing obvious leaf damage when populations are high. Although the other insects mentioned are polyphagous and some are known crop pests, *G. punctifrons* was found to feed to only a limited extent on *Colocasia* spp., *Caladium* spp. and *Ipomoea aquatica* and was not known to be an important pest of these crops in the field (Burikam and Napompeth 1980). Among plant pathogens were the fungi *Alternaria eichhorniae*, *Myrothecium roridum* and *Rhizoctonia solani*, but only *A. eichhorniae* was specific to water hyacinth. However it mainly attacked older plants and did not act as a useful control agent (Napompeth 1982, 1984, Napompeth et al. 1977, Ponnappa 1976). Releases of *N. eichhorniae* started in 1978 and, after initial failures, the weevil is now established widely (Napompeth 1984) and significant reduction of water hyacinth has been observed in all major bodies of water. Those utilising water hyacinth for handicrafts are complaining of poor quality plants. Where water hyacinth is now under a significant measure of control other aquatic weeds are becoming important.

N. bruchi was introduced from Australia in 1990 and is now established, but its complementary effects are yet to be realised. *Sameodes albiguttalis* is under quarantine screening (B. Napompeth pers. comm. 1993).

USA

Water hyacinth was introduced as an ornamental plant at least as early as 1884. USA was the first country to start implementing a biological control program, although not until 1972 (Bennett 1965). The total area of the weed in Louisiana is reported to have been reduced by about 75%. At one site in Florida, the area of water covered by the weed has diminished from about 90% in 1974 to about 25% in 1980. In some Florida sites water hyacinth had disappeared by 1976 (Center and Balciunas 1982). These effects have been ascribed mainly to *N. eichhorniae* and *N. bruchi*, although the other agents have undoubtedly helped. In southern Florida, where both species occur, *N. eichhorniae* comprised 70% of the weevil populations: *N. bruchi* developed flight muscles and the capacity to leave declining water hyacinth infestations more readily than *N. eichhorniae* (Center and Dray 1992). *Sameodes albiguttalis* is well established in Florida and in isolated instances it is devastating stands of water hyacinth (Center and Balciunas 1982). The mite *Orthogalumna terebrantis* was an accidental introduction from South America, dating perhaps from the time when water hyacinth entered USA. In combination with the fungus *Acremonium zonatum* the mite can have a severe local effect. The native noctuid moth *Bellura densa*, the native host of which is *Pontederia cordata*, can cause severe damage to water hyacinth in southern USA and the possibility of mass rearing and periodical release to control water hyacinth is being investigated (Baer and Quimby 1981). However, it has been reported as a pest of dasheen (taro) *Colocasia esculenta* and it would thus be unsuitable for release in the Pacific or Africa where this crop is grown (Habeck 1974).

Major natural enemies

INSECTS

Bellura densa Lepidoptera: Noctuidae

Thirty to 40 eggs at a time of *B. densa*, which is native to southern USA, are laid in up to 9 clusters on the leaf surface. Young larvae feed on tender basal stems and foliage and older larvae usually make shallow burrows in the crown. Advanced larvae, which may attain a length of 6 cm, bore deep into the primary stem and may penetrate 30 cm below the water surface (Baer and Quimby 1981). Some final instar larvae enter diapause for up to 4 months. Pupation generally occurs above water in the basal part of the stem. In Florida *B. densa* also attacks *Pontederia cordata* (Baer and Quimby 1981, Harley 1984, Vogel and Oliver 1969) and the roots of dasheen *Colocasia esculenta* (Habeck 1974). Different populations may vary considerably in feeding preferences and great care should be taken in selecting a strain if the introduction of *B. densa* into a taro-growing region is contemplated.

B. densa is attacked by hymenopterous parasitoids, bacteria and microsporida (Bennett 1982a).

Haimbachia infusella Lepidoptera: Pyralidae

Formerly known as *Acigona infusella*, larvae of this moth, which occurs from Argentina to southern Mexico, are specific to the family Pontederiaceae (Bennett 1979, DeLoach et

Table 4.7.3 Duration (approximate in days) of developmental stages of six natural enemies of water hyacinth (Ganga-Vislakshy and Jayanth 1991, Harley 1989, Harley and Wright 1984).

	Bellura densa	*Haimbachia infusella*	*Neochetina bruchi*	*Neochetina eichhorniae*	*Orthogalumna terebrantis*	*Sameodes albiguttalis*
Egg	6	6	8	11	8	4
Larva	41	48	32	83	15	21
Prepupa	3		7	17		
Pupa	15	9	23			7
Generation time	65	64	96	120	26	34

al. 1980, Silveira-Guido 1971). They cause extensive damage to water hyacinth plants having slender petioles. On average 680 eggs are laid by each female. Oviposition occurs at night on the petioles and the resulting larvae tunnel into the petioles and subsequently into the rhizomes, attaining a length of 20 mm. Pupation occurs in the petiole. Speed of development is shown in table 4.7.3. Plants are frequently killed by *Haimbachia* larvae, although they may have produced daughter plants before this happens. In the field *H. infusella* attacked four species of Pontederiaceae (*E. crassipes*, *E. azurea*, *Pontederia cordata* (pickerel weed) and *P. rotundifolia*) but has never been reported feeding on near-by rice, maize or any other beneficial plant in Argentina (DeLoach et al. 1980). In the field in Argentina *Haimbachia* larvae are heavily attacked by braconid wasps, including *Apanteles fluitantis* and *A. cordoi*, and also by pathogens.

Neochetina bruchi Coleoptera: Curculionidae

This weevil occurs naturally from Argentina to northern Brazil. Adults are nocturnal and feed preferentially on the narrow upper third of the petiole and on the upper surface of the lamina, consuming the epidermis and a few layers of underlying cells to produce small sub-circular scars. Up to 8.5 eggs are laid per female per day into the middle third of older, bulbous petioles. Eggs of *N. bruchi* develop at lower temperatures than those of *N. eichhorniae* and the generation time (Table 4.7.3) is also shorter. During the day, adults usually hide inside young rolled leaves in buds near the base of the plant. Newly hatched larvae tunnel in the petioles towards their base and into the crown where they excavate small pockets which may join. Fully grown larvae leave the crown and pupate underwater in a cocoon constructed of root hairs. There are 3 generations a year in Argentina (DeLoach and Cordo 1976a,b). The two *Neochetina* species are able to coexist in very similar ecological niches because of differences in oviposition behaviour and seasonal abundance. *N. bruchi* has a very narrow host range (DeLoach 1976, 1977, Harley 1989, Perkins and Maddox 1976).

Neochetina eichhorniae Coleoptera: Curculionidae

This weevil lays most of its eggs (a maximum of 7 per female per day) in the tender central leaf just below the epidermis and the remainder mainly in the fleshy sheath at the base of each petiole or in adult feeding scars. Larvae enter the petioles and tunnel towards the crown and also into the rhizomes, where they feed, before pupating among the submerged roots. Additional damage is caused by the rotting that accompanies tunnelling. Adults are nocturnal and begin feeding soon after emergence, making characteristic sub-circular feeding scars, particularly on the narrow upper third of the petiole and the upper surface of the leaves. During the day they usually hide near the base of the leaves. There are three generations a year. Adult weevils are attracted to water hyacinth plants that have been damaged physically or by spraying with 2,4–D. This is due to a volatile chemical released by the damaged plant (Forno 1981, Perkins et al. 1976, Perkins 1977a, Delfosse and Perkins 1977). Host specificity data are summarised by Harley (1989).

The weevil's natural range extends from Argentina to southeast Mexico and west to the Andes, so that its distribution overlaps that of *N. bruchi* (O'Brien 1976). Adults are capable of dispersing at least 25 km by flight in summer (Harley 1982).

Sameodes albiguttalis **Lepidoptera: Pyralidae**

The larvae of this moth, which is widespread in South America, are specific to the family Pontederiaceae, but have a preference for *E. crassipes* (DeLoach and Cordo 1978) and particularly for the form with bulbous petioles. On average 300 eggs are laid per female on the leaves, usually in injuries. On hatching, larvae tunnel in the petioles and crown, inflicting considerable damage, which is augmented by the rotting that accompanies tunnelling. Larvae generally pupate in the bulbous petioles and their speed of development is shown in table 4.7.3. Attack may be heavy but sporadic. *S. albiguttalis* is easily established where water hyacinth is healthy and vigorous, but not on less vigorous plants. It has also become established more readily from releases during the cooler months of the year (Center and Balciunas 1982, Center and Durden 1981, Center et al. 1982). Host specificity data are summarised by Harley (1989).

In its native range *S. albiguttalis* is heavily parasitised by the braconid wasp *Hypomicrogaster* sp. and a microsporidan *Nosema* nr *invadens* (DeLoach and Cordo 1978). Both organisms were eliminated before this species was liberated in Australia (Forno and Wright 1981).

MITE

Orthogalumna terebrantis **Acarina: Galumnidae**

This mite is widespread in South America. Usually one, but sometimes two or three eggs at a time are laid in a round hole made by the female's mouthparts in the lower surface of the younger central leaves and the larvae and nymphs mine between the veins, tunnelling towards the leaf apex. The life cycle is completed in 25 to 27 days. Adults live up to 79 days and females lay on average 59 eggs (Ganga-Vislakshy and Jayanth 1991). The mite occurs throughout the native range of *E. crassipes*. It also attacks *E. azurea* and occasionally *Pontederia lanceolata*.

The Argentinian populations may be more host specific than those in Florida (Cordo and DeLoach 1975, 1976, Delfosse 1978a,b, Perkins 1973b). The tunnelling damage caused by the mite provides suitable conditions for attack by the pathogenic fungus *Acremonium zonatum*. The combined effects of these two organisms cause serious damage to water hyacinth (Delfosse 1978b), and the combined effects of *Orthogalumna* and *N. eichhorniae* are also very damaging (Delfosse 1978a,b). The mite is attracted by the chemicals produced by damaged water hyacinth.

FUNGI

Cercospora rodmanii

This fungus, which occurs in Florida and Louisiana, is specific to *E. crassipes*. It produces small punctate spotting and chlorotic and necrotic areas on the leaves, followed by tip necrosis and a spindly appearance of the petioles. It is capable of inflicting significant damage when climatic conditions are favourable (Conway 1976, Conway and Freeman 1977, Conway et al. 1974, 1978, Freeman 1977). A closely related species *C. piaropi* occurs on water hyacinth in Australia and South Africa.

Uredo eichhorniae

This rust fungus occurs widely in southern Brazil and Argentina (Charudattan et al. 1974, Forno and Wright 1981) and its potential for causing damage suggests that it merits study.

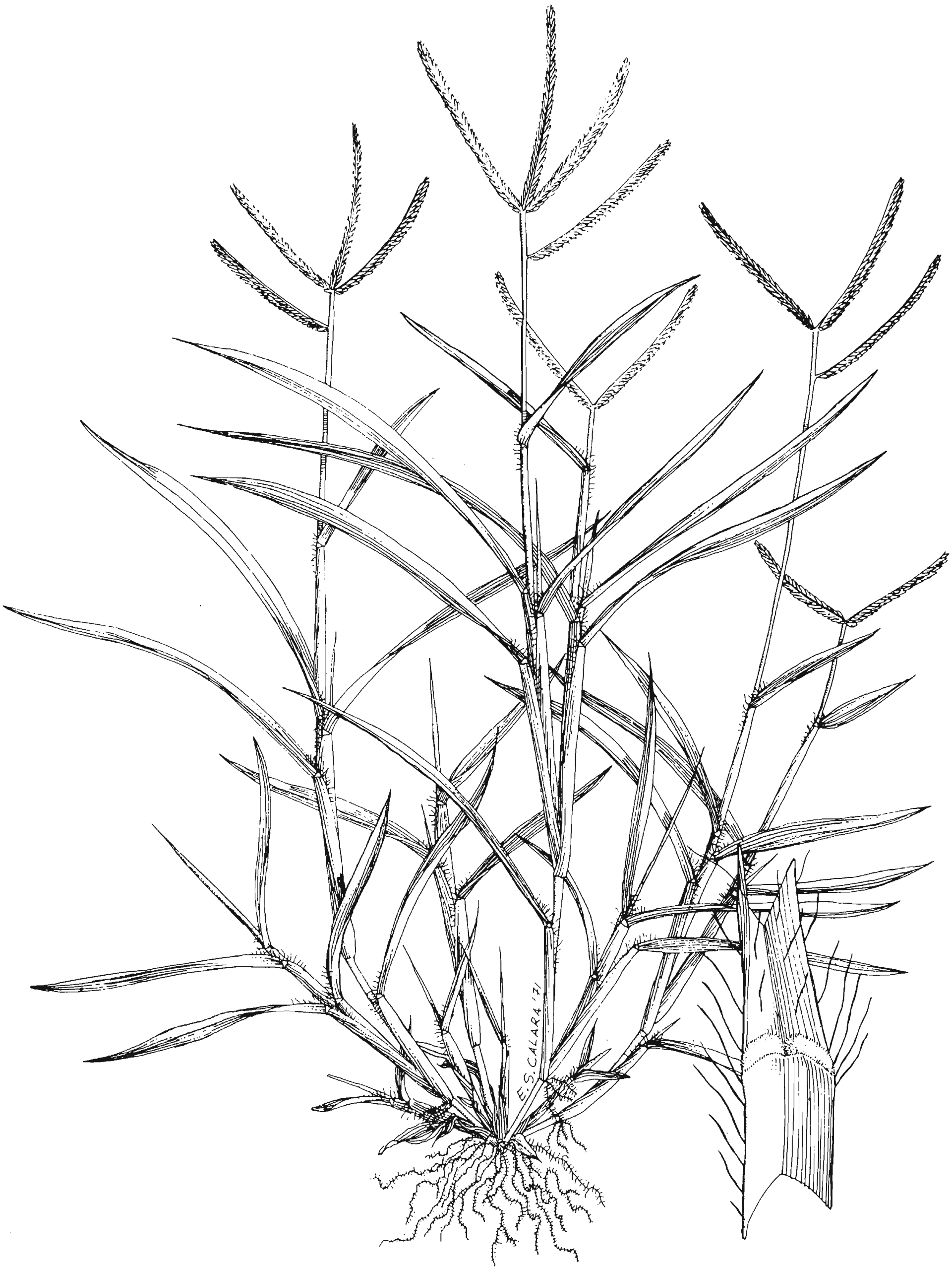
Comments

Its biological control agents generally cause a gradual deterioration in water hyacinth vigour, with decreased flower and seed production. In addition to climate, plant quality (and hence insect nutrition) influences the speed at which damage takes place leading to plant death. Adequate control rarely occurs rapidly, with substantial effects generally taking five or more years after the establishment of insects.

Although many infestations have eventually been brought under control in Australia, there are others, especially in the cooler parts of water hyacinth's distribution, where there has been little impact on an infestation or where greater control is desirable. It is hoped that the recent liberation of *Neochetina bruchi* will deal with these situations. In Texas, *N. bruchi* alone achieved 90% control of an infestation on a reservoir (Cofrancesco 1984). In Louisiana, *N. bruchi* and *N. eichhorniae* together reduced the total area of water hyacinth by 320000 ha (Cofrancesco et al. 1985) and in Florida they controlled infestations (Wright and Stegeman 1990). In Sudan, they prevented the usual annual build-up of more than 100 km^2 of floating mat behind the Jebel Aulia Dam near Khartoum (Beshir and Bennett 1985). These and results from other countries suggest that these two weevils should be introduced first in any biological control project. Next, perhaps, should be the moth *Sameodes albiguttalis*, with its marked preference for bulbous plants and cooler periods of the year. The potential of the moth *Haimbachia infusella*, which prefers plants with slender petioles, has not yet been adequately examined. By itself, the mite *Orthogalumna* may be of limited value. However, when *N. eichhorniae* or pathogens are present, their combined effectiveness is greatly enhanced (Delfosse 1978a,b).

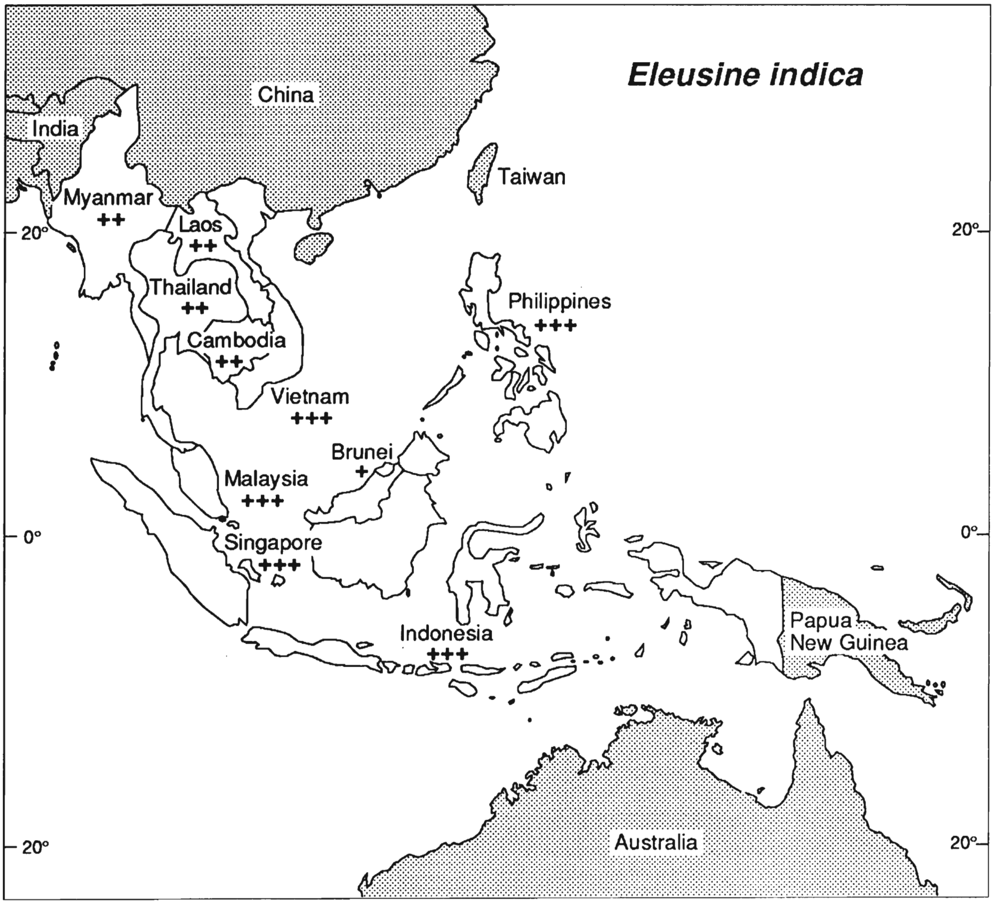
The fungus *Cercospora rodmanii* is capable of severely damaging water hyacinth when climatic conditions are favourable. It is available in USA as a commercial spray.

Valuable advice on procedures for establishing the organisms is given by Harley (1982, 1989) and detailed life history and other data by Center and Balciunas (1982).



Eleusine indica

(after Holm *et al.* 1977)



Map 4.8.1 *Eleusine indica*

Eleusine indica is of African origin and, except for finger millet, *E. coracana,* is not closely related to graminaceous crop plants. Finger millet is a staple crop in India and some parts of Africa, but relatively unimportant or not grown elsewhere. Little is known about the insect or other enemies of *E. indica* in Africa and, elsewhere, almost all records are of pests with a wide host range. Because it is a major weed (5th) in Southeast Asia and is only distantly related to crop plants a search for specific natural enemies in Africa must be regarded as an attractive proposition.

4.8 *Eleusine indica* (L.) Gaertn.

Poaceae

crowsfoot grass, goose grass; sin ngo let kya, sin ngo myet (Myanmar), yah teenka (Thailand), smao choeung tukke (Cambodia) cò mân trâù (Vietnam), rumput sambou (Malaysia), rumput belulâng (Indonesia), sabung sabungan (Philippines)

Rating

	+++	Viet, Msia, Sing, Indo, Phil
24	++	Myan, Thai, Laos, Camb
	+	Brun

Origin

Africa (Phillips 1972), replacing an alternative view that it was India (Holm et al. 1977, Waterhouse 1993a).

Distribution

Throughout the tropics, sub-tropics and temperate regions of the world, including Africa, Asia, SE Asia, Australia, the Pacific and the Americas.

Characteristics

E. indica is a tufted, annual, C4 grass attaining a height of 0.6 m. Its flower spikes mostly have 2 to 7 spikelets, producing a characteristic windmill-like appearance.

Importance

The genus *Eleusine*, contains nine annual or perennial grasses all native to Africa except for the South American *E. tristachya* (Hilu and Johnson 1992, Phillips 1972). It belongs to the subfamily Chloridoideae, which is but distantly related to all except one of the principal grain crops. That exception is finger millet, or ragi, *E. coracana* (2n = 36), which is believed to have arisen from *E. indica* (2n = 18) (Hilu and de Wet 1976, Hilu and Johnson 1992, Hiremath and Salimath 1992) and is an important staple cereal in India and some regions of eastern Africa (Rachie and Peters 1977). However, it is worth noting that *E. coracana* is regarded as a minor weed in some Southeast Asian countries (Thailand, Vietnam) (Waterhouse 1993a) and that it is nowhere important in this region. The genera *Eleusine* and *Dactyloctenium* are closely related.

E. indica is an important weed in more than 60 countries in at least 46 crops and, in these, has the status of a serious weed in 30 countries and 27 crops. It was evaluated as the fifth worst weed in the world (Holm et al. 1977) and also rated fifth in a recent survey in Southeast Asia (Waterhouse 1993a). It was rated 15th in 1992 in the oceanic Pacific (Waterhouse, unpublished). It grows well in sunny or somewhat shaded places, in marshlands, wastelands, roadsides, along borders of irrigated fields and canals, in lawns and in pastures, and prospers and is particularly troublesome on arable land. It ranges from near the seashore to an altitude of at least 2000 m and is a major problem in almost all forms of agriculture between the tropics of Capricorn and Cancer.

E. indica grows and flowers well in all seasons and a single plant may produce more than 50 000 small seeds, which move readily by wind, in mud on the feet of animals and in the tread of machinery. The seeds are eaten by wild and domestic animals and are occasionally grown for grain in Africa and India, but *Eleusine coracana*, finger millet, with somewhat larger seeds is far better for this purpose. Although sometimes claimed to be palatable to grazing animals, crowsfoot grass becomes fibrous too early in the season to be a satisfactory pasture grass. The seed heads may contain high levels of cyanogenic glycosides and are believed to be responsible for occasional cases of stock poisoning (Everist 1974).

Natural enemies

Natural enemies restricted to the genus *Eleusine* and its close relatives might well be considered for biological control of *E. indica* except in India or other regions where finger millet is an important cereal.

E. indica is reported in the literature to be attacked by more than 50 insects, nematodes, fungi, bacteria and viruses, all except 6 in continents other than Africa (Tables 4.8.1 to 4.8.4). Further, with few exceptions, all of these organisms are known to have wide host ranges and to attack important agricultural crops. Indeed, of those recorded, only one cecidomyiid gall fly and possibly one or two fungi could be considered further for classical biological control. Figliola et al. (1988) consider that, where they already occur, two fungi, *Bipolaris setariae* and *Magnaporthe (=Pyricularia) grisea* hold promise as bioherbicides for *E. indica*, although their host range is a little too wide for classical biological control.

It is not surprising that the organisms attacking an economic crop, finger millet, *E. coracana*, have been investigated in greater detail than those of a weedy relative. Finger millet is believed to have been domesticated in the East African highlands by 3000 BC or earlier and archaeological data suggests that it may have been introduced to India as early as 2000 BC (Hilu et al. 1979). Since *E. coracana* and *E. indica* are closely related, Wapshere (1990b) argues, probably correctly, that most or all of the more specific organisms infesting finger millet are also likely to attack *E. indica*. It is very disappointing, therefore, that almost all of the natural enemies of finger millet so far recorded (again mostly from outside Africa) have wide to very wide host ranges and are not potential biological control agents. The very few species that may prove to have a limited host range are shown in table 4.8.5. Wapshere (1990b) has listed 40 insects that attack *E. coracana* and at the same time belong to groups known to have species restricted to a single grass genus (and there are also many other insects from groups with a wider host range that attack *E. coracana*). In addition to the undescribed *Orseolia* gall midge attacking *E. indica* in India, only three insects (two cecidomyiid gall midges, one from Uganda and one from Nigeria and an aphid from India), a nematode (*Heterodera delvii*) from India and a smut fungus (*Melanopsichium* (= *Ustilago*) *eleusinis*) may, if shown to attack *E. indica* also, prove to be sufficiently host specific to be considered for classical biological control. It is relevant that cecidomyiid gall flies are believed to have a high degree of specificity to their host grass genera (Barnes 1946, K.M. Harris pers. comm. 1993, Wapshere 1990a).

Comment

It has been pointed out above that the majority of records for natural enemies of both *E. indica* and *E. coracana* come from outside Africa and that almost all of these organisms have a wide host range. Indeed, this is to be expected if both *Eleusine* species are of African origin. Except for any specific enemies that may have accompanied them, it is inevitable that they will be attacked in new countries by non-specific natural enemies that, hitherto, were attacking other plants. Of course, the possibility exists that natural enemy species in the new country may have evolved a degree of specificity in the four or five thousand years that the *Eleusine* species have existed outside Africa.

It is significant that there has not so far been any detailed search in Africa for natural enemies of *E. indica* to establish whether or not adequately specific species occur there. A two year (or longer) survey of *E. indica* in several regions of Africa would probably be required, together with observations on whether the organisms found attacking *E. indica* also attack *E. coracana*, nearby grasses or other plants. The relevant regions for study in Africa and Madagascar are indicated in map 4.8.2 based on the distribution data of Phillips (1972).

If (i) the African cecidomyiid gall midges (*Contarinia* (= *Stenodiplosis*) spp.) (Tables 4.8.1, 4.8.5) do not already occur in Southeast Asia (they are not known in Australia), (ii) they prove to be adequately host specific and (iii) the Ugandan species attacks *E. indica* in addition to *E. coracana*, they would appear to be the most promising of known species for introduction elsewhere. The undescribed species from northern Nigeria (Table 4.8.1) was collected from *E. indica* at Zaria in July 1959 and July 1960 (K.M. Harris, pers. comm. 1993). Larvae of the Indian *Orseolia* sp. nr. *fluviatilis* probably induce galls on young shoots of *E. indica*, so would affect vegetative growth rather than having a direct impact on seed production. It is as yet known only from India.

To sum up, for an attempt at classical biological control of a grass weed, *E. indica* would appear to be the one with most positive factors combined except that, so far, few adequately specific, natural enemies are known. However, almost nothing is known about the natural enemies in Africa, not only its centre of origin but also that of the genus *Eleusine*. It would, indeed, be most surprising if several natural enemies having a restricted host range were not discovered during a thorough survey there.

Table 4.8.1 Natural enemies of *Eleusine indica*: insects.

Species	Country	Portion attacked	Comments: other hosts	References
Hemiptera				
APHIDIDAE				
Chaetogeoica graminiphaga	India		beans and a number of grasses	Raychaudhuri 1983
Geoica lucifuga	India		also on rice, *Eleusine coracana* and many weeds including *Cynodon dactylon*, *Cyperus rotundus*	Raychaudhuri et al. 1978

(continued on next page)

Species	Country	Portion attacked	Comments: other hosts	References
Hysteroneura setariae	Hawaii		rice, maize, wheat sorghum, sugar cane	Beardsley 1962
Schizaphis (= *Toxoptera*) *graminum*			rice, sorghum, maize and a very wide host range	Patch 1939
Sitobion avenae (= *Macrosiphum granarium*)			rice, wheat, a very wide host range	Patch 1939
Sitobion (= *Macrosiphum*) *miscanthi*	India		on a very wide range of crop plants and weeds	Raychaudhuri 1983
Stegophylla (= *Anoecia*) *querci*			maize and several weeds	Patch 1939
Tetraneura basui	India		on rice, *Echinochloa colona*, *Paspalum conjugatum* and other weeds	Raychaudhuri 1983
Tetraneura nigriabdominalis (= *T. hirsuta*)	India		rice, maize, sugarcane *Eleusine coracana* and a very wide range of weeds	Patch 1939, Raychaudhuri 1983
CERCOPIDAE				
Prosapia (= *Monecphora*) *bicincta fraterna*	Cuba		also on *Paspalum notatum*, *Brachiaria subquadripara*, *Andropogon annulatus*, *Cynodon dactylon*	Plana et al. 1986
CICADELLIDAE				
Nephotettix malayanus	Philippines		rice, many weeds	Khan et al. 1991
Nephotettix nigromaculatus (= *N. nigropictus*)	Philippines		rice, many weeds	Khan et al. 1991
Nephotettix virescens	Philippines		rice, many weeds	Khan et al. 1991
Recilia dorsalis	Philippines		rice, many weeds	Khan et al. 1991
DELPHACIDAE				
Laodelphax striatellus	China		wheat, barley, oats, sorghum etc	Zhang et al. 1981
Peregrinus maidis	India		transmitter of *Eleusine* mosaic virus (see table 4.8.4); very wide host range	Cherian and Kylasam 1937, Patch 1939, Rao et al. 1965
Sogatella furcifera	China		can complete development also on 17 other species of crops and weeds including rice, barley, wheat, *Echinochloa crus-galli*	Huang et al. 1985

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Table 4.8.1 (continued)

Species	Country	Portion attacked	Comments: other hosts	References
LYGAEIDAE				
Blissus leucopterus	USA	lower stem	damages sorghum and many grasses including *Cynodon dactylon* and *Dactyloctenium aegyptium,* but particularly damaging to *E. indica*	Ahmad et al. 1984, Lynch et al. 1987
Thysanoptera				
PHLAEOTHRIPIDAE				
Haplothrips ganglbaueri	India		rice, wheat, sorghum	Ananthakrishnan & Thangavelu 1976
Diptera				
AGROMYZIDAE				
Liriomyza marginalis	N&S America		*Panicum miliaceum*, *Digitaria*, *Paspalum* (primary host), *Euchlaena*	Spencer 1990, Spencer & Steyskal 1986
Pseudonapomyza spicata	Australia	leaf	maize, sugarcane, grasses	Kleinschmidt 1970
CECIDOMYIIDAE				
Orseolia sp. nr *fluviatilis*	India	stem	undescribed gall midge resembling (but not) the rice stem gall midge *Orseolia* (= *Pachydiplosis*) *oryzae*; no host other than *E. indica* known	Barnes 1954a,b, 1956, Gagné 1985, Hegdekatti 1927, Rachie and Peters, 1977
Stenodiplosis sp.	Nigeria	seed heads	undescribed species	K.M. Harris pers. comm. 1993
Lepidoptera				
ARCTIIDAE				
Cnaphalocrocis medinalis	Philippines	leaf folder	rice, many weeds	Abenes & Khan 1990
Cnaphalocrocis (= *Marasmia*) *patnalis*	Philippines	leaf folder	rice, many weeds	Abenes & Khan 1990
Creatonotos (= *Amsacta*) *gangis*	Philippines	leaves	rice, many weeds	Catindig et al. 1993
NOCTUIDAE				
Spodoptera frugiperda	USA		wide range of crops and weeds	Pencoe and Martin 1982
PYRALIDAE				
Ostrinia furnacalis	Guam		wide range of crops and weeds	Schreiner et al. 1990

Table 4.8.2 Natural enemies of *Eleusine indica*: nematodes.

Species	Country	Comments	References
Ditylenchus destructor	South Africa	groundnut, several weeds	De Waele et al. 1990
Hirschmaniella spinicaudata	Cuba	has other weed hosts including *Cyperus iria*	Fernandez and Ortega 1982
Meloidogyne sp.	China	rice root knot nematode (damage up to 50%); also attacks wheat, and *Echinochloa colona*	Guo et al. 1984, Holm et al. 1977
Meloidogyne arenaria	Cuba, Philippines, USA	*Echinochloa crus-galli*, *Portulaca oleracea*, tobacco	Tedford and Fortnum 1988, Valdez 1968
Meloidogyne graminicola	India	wheat, *Panicum* spp, tomato, capsicum, etc	Rao et al. 1970
Meloidogyne incognita	Cuba, USA	*Ageratum conyzoides*, *Croton lobatus*, *Cynodon dactylon*, tobacco	Acosta et al. 1986
Meloidogyne javanica	Brazil	attacks tomato and weeds including *Bidens pilosa*, *Euphorbia heterophylla*, *Galinsoga parviflora*	Lordello et al. 1988
Pratylenchus pratensis	Hawaii	also attacks *Cynodon dactylon*	Holm et al. 1977
Pratylenchus zeae	S. Africa, Cuba	*E. indica* is a moderately good host of the maize nematode; has other weed hosts, including *Cyperus iria*	Fernandez and Ortega 1982, Jordaan et al. 1988
Rotylenchulus reniformis	Hawaii		Linford and Yap 1940

Table 4.8.3 Natural enemies of *Eleusine indica*: fungi and bacteria.

Species	Country	Comments	References
FUNGI			
Bipolaris setariae (as *Drechslera setariae*)	USA (not recorded in Australia)	heavy attack on *E. indica*, light on maize, sorghum, none on dicotyledons	Figliola et al. 1988 Hiremath and Sulladmath 1985
Corticium sasakii	India	rice, many weeds including *Commelina benghalensis*, *Cynodon dactylon*, *Fimbristylis miliacea*	Roy 1973
Drechslera gigantea	Brazil	no hosts other than *E. indica* mentioned	Muchovej 1987
Helminthosporium sp.	Thailand		Chandrasrikul 1962
Helminthosporium holmii	India	also on *Echinochloa colona*, *Chloris gayana*	Singh and Misra 1978
Helminthosporium maydis	China	attacks 21 other weeds including *Imperata cylindrica*, *Digitaria ciliaris* and *Echinochloa crus-galli*	Wu and Liang 1984

(continued on next page)

Table 4.8.3 (continued)

Species	Country	Comments	References
Helminthosporium nodulosum (as *Bipolaris nodulosa* or *Cochliobolus nodulosus*)	Africa, Australia, India, Japan, Philippines, USA	also infests maize, *Eleusine coracana*, wheat, barley, oats and weeds including *Dactyloctenium aegyptium*; causes seedling blight leaf stripe and sooty heads in *E. indica*	Rachie and Peters 1977, Wapshere 1990b
Magnaporthe (= *Pyricularia*) *grisea*	Africa, Australia, India, USA, Georgia	heavy attack on *E. coracana*, *Rottboellia cochinchinensis*, light attack on maize	Chauhan & Verma 1981, Figliola et al. 1988, Heath et al. 1990, 1992, Shetty et al. 1985, Valent et al. 1986, Vodianaia et al. 1986, Wapshere 1990b,c
Pellicularia rolfsii	Australia, India	causes wilt disease of *E. coracana* and infests many grasses and dicotyledonous plants	Wapshere 1990b
Phyllachora eleusines	Africa, Australia	only recorded on *Eleusine* and *Eragrostis* in Africa; in Australia only on *Eragrostis*	Parbery 1967, Ramakrishran 1963
Pyricularia oryzae	Brazil, China	attacks rice	Prabhu et al. 1992, Teng 1932, Valent et al. 1986
Sclerophthora macrospora	India	attacks maize, wheat, oats, rice: attacks *E. coracana* and many grasses, but not *E. indica* in Australia; there may be host specific strains	Rachie and Peters 1977, Ullstrup 1955, Wapshere 1990b
Sclerotium rolfsii	Australia, India	attacks many dicotyledonous crop plants and a wide range of grasses	Reddy 1983, Safeeulla 1976
Ustilago sp.	China		Mundkur 1939
Ustilago eleusinis (as *Melanopsichium eleusinis*)	Africa, Asia	smut fungus of *Eleusine* and *Dactyloctenium*, but only on *D. radulans* in Australia	Simmonds 1966, Zundel 1953
BACTERIA			
Pseudomonas glumae	Japan	an important rice pathogen: attacks a wide range of weeds	Miyagawa et al. 1988
Pseudomonas plantarii	Japan	attacks rice, wheat, sorghum, maize and many weeds	Miyagawa et al. 1988

Table 4.8.4 Natural enemies of *Eleusine indica*: viruses.

Virus	Country	Other hosts	References
cereal chlorotic mottle	Australia	oats, barley, wheat, maize, *E. coracana*, *Digitaria ciliaris*, *Echinochloa colona*; transmitted by *Nesoclutha pallida*	Greber 1979
corn leaf gall	Philippines	maize	Agati and Calica 1950
corn stunt	USA	several other weeds	Pitre and Boyd 1970
Eleusine mosaic	India	maize, sorghum, *E. coracana* and many other hosts	Rao et al. 1965
groundnut rosette	Malawi	groundnut	Adams 1967
maize dwarf mosaic	USA	maize	Lee 1964
maize streak	Nigeria	maize, but not all cultivars *Cicadulina triangula* is the vector	Ekukole et al. 1989, Rossel et al. 1984
rice leaf gall	Philippines	rice	Agati and Calica 1950
rice orange leaf	Philippines	rice	Watanakul 1964
rice ragged stunt	China	rice, *E. indica* and 4 other weeds	Xie et al. 1984
	Philippines	rice, *Echinochloa glabrescens*, *Monochoria vaginalis*, *Paspalum distichum*	Salamat et al. 1987
rice tungro bacilliform	Philippines	rice, many weeds	Khan et al. 1991
rice tungro spherical	Philippines	rice, many weeds	Khan et al. 1991
rice yellow mottle	Kenya	rice, two grasses	Okioma et al. 1983
sugarcane mosaic	India	sugarcane	Chona and Rafay 1950
sugarcane streak	Hawaii	sugarcane	Holm et al. 1977
tungro	Philippines	rice	Watanakul 1964
wheat rosette	China	oats, barley, sorghum, wheat etc. *Laodelphax striatellus* is the vector	Zhang et al. 1981

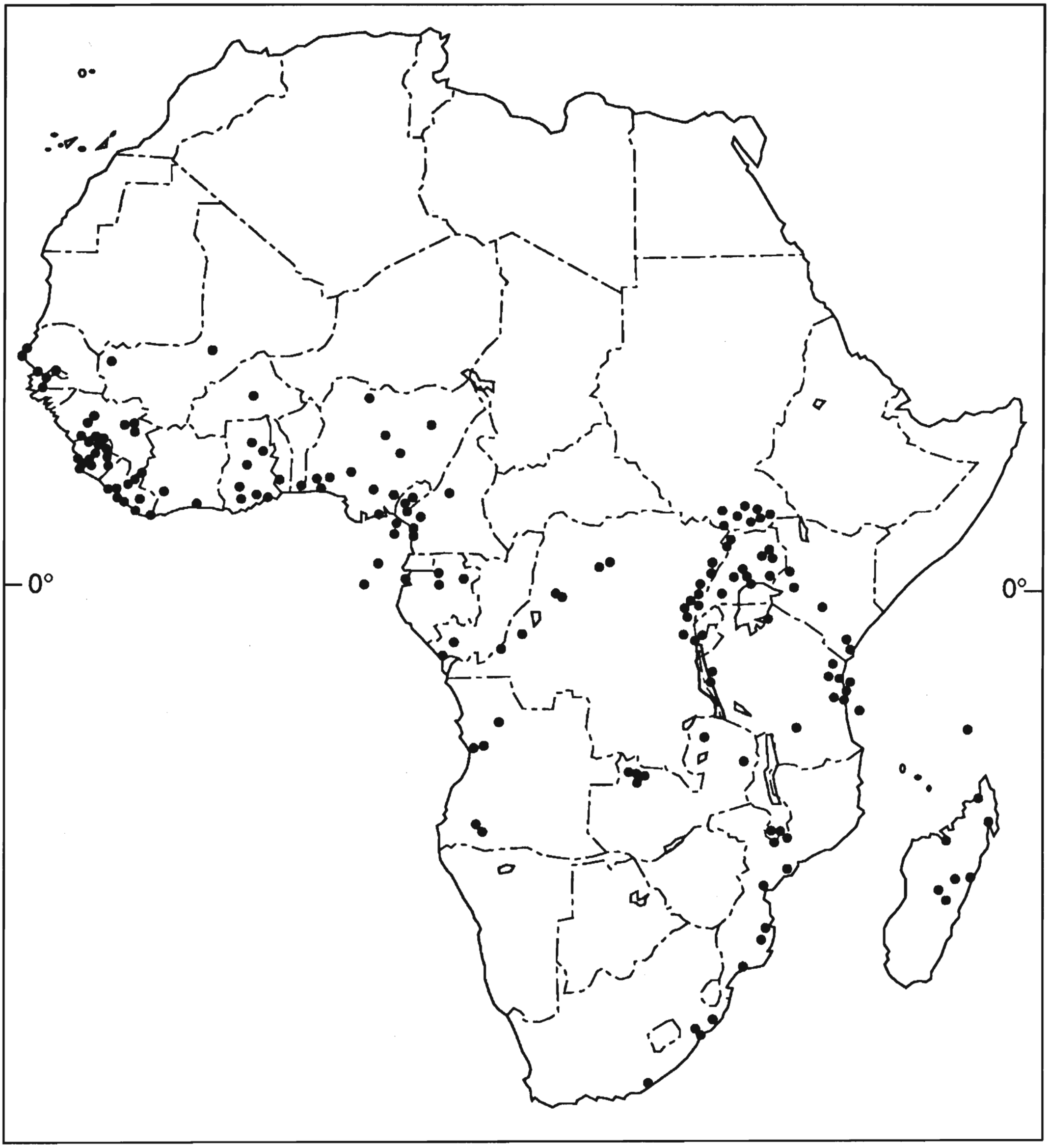
Table 4.8.5 Natural enemies of *Eleusine coracana* which may prove to have a limited host range.

Species	Country	Portion attacked	Comments	References
INSECTS				
Diptera				
CECIDOMYIIDAE				
Contarinia sp.	Uganda	inflorescence	**not** the same as the sorghum midge *Contarinia sorghicola*: the same or a similar species attacks the common fallow weed *Sorghum verticilliflorum*	Barnes 1946, 1954a,b, 1956, Geering 1953, Rachie & Peters 1977

(continued on next page)

Table 4.8.5 (continued)

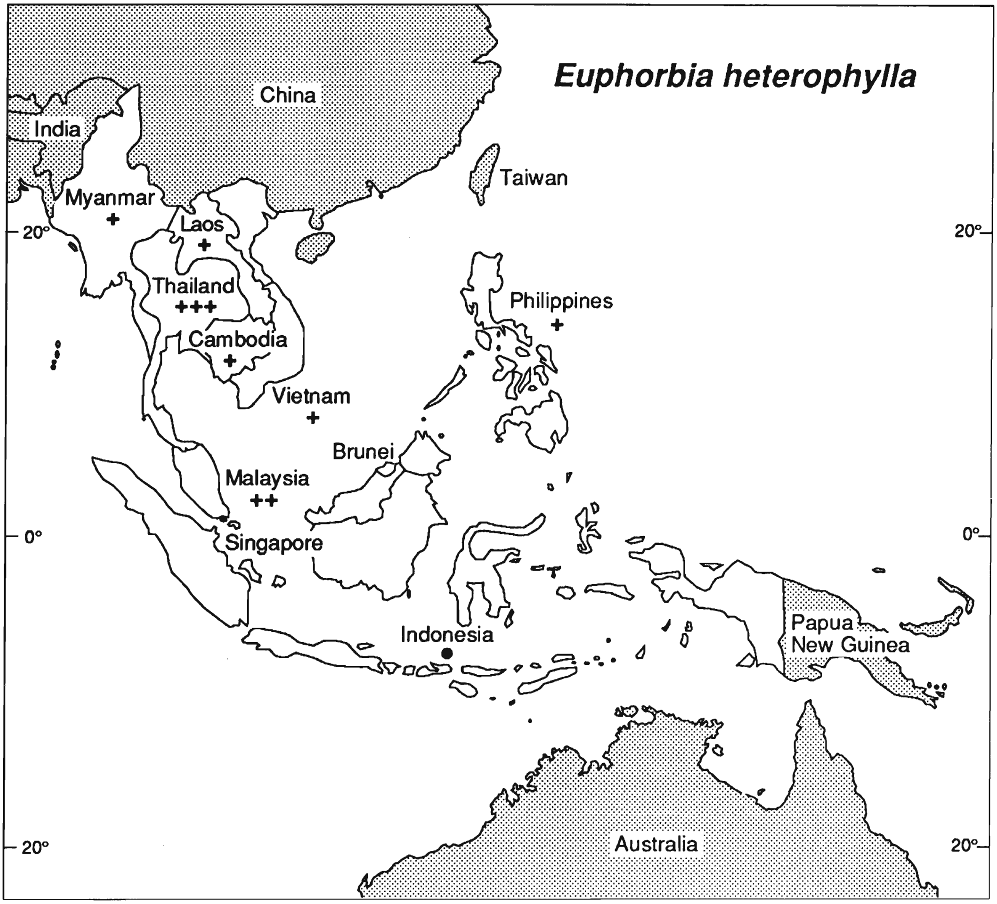
Species	Country	Portion attacked	Comments	References
Hemiptera				
APHIDIDAE				
Sitobion (= *Macrosiphum*) *leelamaniae*	India (not in Australia)		attacks several millets in India including pearl millet *Pennisetum glaucum* (=*P. typhoideum*), also *Andropogon vulgare*	Raychaudhuri 1983
NEMATODES				
Heterodera delvii	India	root cysts	no other hosts mentioned	Jairajpuri et al. 1979
FUNGI				
Melanopsichium eleusinis(= *Ustilago eleusinis*)	Asia, Africa		a smut fungus: only from *Eleusine* and *Dactyloctenium*: tentatively identified from *D. radulans* in Queensland, but not from *E. indica*	Simmonds, 1966, Wapshere 1990c, Zundel 1953



Map 4.8.2 Distribution of *Eleusine indica* in Africa (after Phillips 1972)

Euphorbia heterophylla

(after Barnes and Chan, 1990)



Map 4.9 *Euphorbia heterophylla*

There are very few records of natural enemies other than fungi attacking *Euphorbia heterophylla* and no study has been made in tropical America where it evolved. However, from the sparse records of insects attacking species of *Euphorbia* in Brazil it is likely that adequately host specific insects do occur. Nevertheless *E. heterophylla* is regarded as an important weed in southern Brazil.

4.9 *Euphorbia heterophylla* L.
(= E. geniculata = E. prunifolia)

Euphorbiaceae

painted spurge, Mexican fire plant; yaa yaang (Thailand)

Rating

	+++	Thai
10	++	Msia
	+	Myan, Laos, Camb, Viet, Phil
	•	Indo

Origin

Tropical and sub-tropical America.

Distribution

Widespread as a weed in the tropical and subtropical regions of the world, notably in Southeast Asia, but apparently not in Kalimantan or Sulawesi (Indonesia) (Soerjani et al. 1986).

Characteristics

An erect annual, up to about 1 m tall; stem cylindrical, hairy; lower leaves alternate; stems and leaves with milky latex. The simple or lobed leaves are crowded towards the top of the stem, with a flat, dichotomously-branched, terminal inflorescence of small yellow flowers and large leafy bracts, often with a bright red or cream patch at the base. The inflorescence consists of many small, short-stalked flowers lacking petals but with conspicuous glands (Wilson 1981). Reproduction is by seeds which are shed with an explosive mechanism.

Importance

A weed of increasing importance in upland fields of rice and many other crops; also in wastelands, roadsides, boundaries of coffee plantations; very abundant locally. Seeds persist in the soil until favourable conditions allow germination and rapid growth, giving rise to large populations of the weed. It is an important weed in 23 tropical countries and present in at least 37 others. Its rapid growth enables it to compete successfully with crops, quickly forming a dense canopy over young crop plants. Dense populations of the weed, with its white sticky latex, may make it impossible to harvest the crop.

The young leaves are sometimes used as a vegetable, but are laxative if too much is eaten. The plant is said to have caused poisoning in livestock (Wilson 1981).

Natural enemies

Except possibly for *Alternaria* sp. and *Helminthosporium* sp. which have not been shown to be pathogenic to crop plants (Yorinori 1985), there are no records of apparently host specific organisms attacking *Euphorbia heterophylla* (Table 4.9.1). However, it is known that a number of insects do attack it in Brazil, but this observation was incidental to a study of fungi and none of the insects were identified (E.G. Fontes, pers. comm. 1992). Although periodic collections were made in Trinidad in the early 1970's, no promising insects were encountered (Yaseen 1972).

There are few records (19 only) of insects attacking members of the genus *Euphorbia* in Brazil (Table 4.9.2) (d'Araujo e Silva et al. 1968a,b), indicating that little attention has so far been paid to *Euphorbia* spp. in this region. Six of the insects are polyphagous and too little is known about the others to arrive at a conclusion. Even if some are restricted to the Euphorbiaceae, it remains to be determined whether any will attack either *Euphorbia heterophylla* or *E. hirta*.

E. heterophylla is resistant to most herbicides and, in recent years, has become progressively more important in Brazil, particularly in the southern, soybean-producing states (Yorinori 1985), which suggests that its insect enemies, if any, may be heavily parasitised.

A biological control program has been in progress in Canada since the late 1960's against *Euphorbia cyparissias* and *E. pseudovirgata*, involving the introduction of some twenty species of insects from Europe. Several species have become established, with rather localised effects (Julien 1992). It is said that insects are generally unable to attack *Euphorbia* species because of the latex that flows freely from any wound and clogs the mouthparts (Best et al. 1980), but clearly some insects are adapted to deal with this problem.

The best known economic plant in the Euphorbiaceae is cassava, *Manihot esculenta* of South American origin. The insects attacking it there are comparatively well known, a factor that will aid the evaluation of the specificity of insects attacking *Euphorbia* spp. Another species of horticultural importance is poinsettia, *Euphorbia pulcherrima*.

Table 4.9.1 Natural enemies of *Euphorbia heterophylla*.

Species	Location	Other hosts	References
INSECTS			
Orthoptera			
ACRIDIDAE			
Poekilocerus hieroglyphicus	Sudan	beans, melons	Ba-Angood 1977, Ba-Angood & Khidir 1975
Hemiptera			
ALEYRODIDAE			
Bemisia tabaci	Thailand, Venezuela	cotton, polyphagous	Debrot & Centeno 1985, Nachapong & Mabbett 1979
ALYDIDAE			
Leptocorisa acuta	PNG		F. Dori pers. comm. 1993
Leptocorisa oratorius	PNG		F. Dori pers. comm. 1993
Leptocorisa solomonensis	PNG		F. Dori pers. comm. 1993

(continued on next page)

Table 4.9.1 (continued)

Species	Location	Other hosts	References
MITES			
TETRANYCHIDAE			
Tetranychus urticae	Cuba	polyphagous	Perez et al. 1987
FUNGI			
Alternaria sp.	Brazil		Yorinori 1985
Amphobotrys ricini	USA		Holcomb et al. 1989
Elsinoe sp.	Burundi	cassava	Zeigler & Lozano 1983
Helminthosporium sp.	Brazil		Fontes et al. 1992, Gazziero et al. 1988, Yorinori 1985
Macrophomina phaseolina	India		Saxena et al. 1981
Phytophthora palmivora	Sarawak	black pepper	Anon 1979
Puccinia sp.	Brazil		Fontes et al. 1992
Rhizoctonia solani	Brazil		Yorinori 1985
Sclerotinia sclerotiorum	Brazil		Yorinori 1985
Sphaceloma sp.	Brazil, Burundi	cassava	Yorinori 1985, Zeigler & Lozano 1983
Uromyces euphorbiae	Brazil		Yorinori 1985
NEMATODES			
Meloidogyne exigua	Brazil	coffee, many weeds	Luc et al. 1990
Meloidogyne javanica	Brazil		Lordello et al. 1988
Rotylenchulus reniformis	Florida		Inserra et al. 1989, MacGowan 1989
VIRUSES			
Euphorbia mosaic	Brazil, USA, Venezuela		Debrot & Centeno 1985, Kim & Flores 1979, Kim & Fulton 1984, Yorinori 1985

Table 4.9.2 Insects attacking species of *Euphorbia* in Brazil (d'Araujo e Silva et al. 1968a,b).

Insect	Hosts	Feeding habit
Hemiptera		
ALEYRODIDAE		
Bemisia tabaci (= *B. costa-limai*)	*Euphorbia hirtella*, tomato, *Mentha arvensis*	polyphagous
COCCIDAE		
Coccus spp.	Euphorbiaceae, *Acalypha* sp., *Aspidosperma ramiflorum*, *Cassia* sp., *Citrus* spp.	polyphagous

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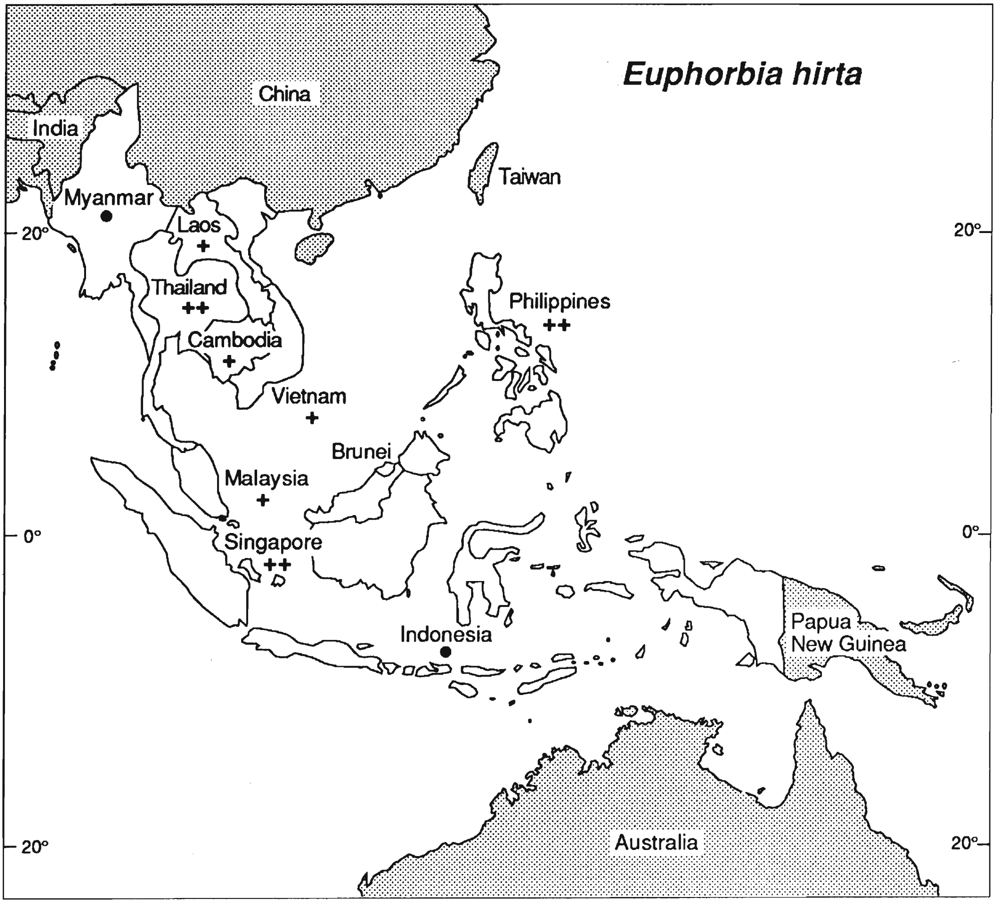
Insect	Hosts	Feeding habit
Eucalymnatus spp.	*Euphorbia capansa*, *Nerium* sp., *Caryota* sp., *Phoenix* sp.	polyphagous
Platinglisia noacki	Euphorbiaceae, *Begonia* sp., *Eugenia* sp., *Grevillea robusta*, *Ilex* sp., *Laurus* sp., *Magnolia pumila*, etc.	polyphagous
COREIDAE		
Chariesterus armatus	*Euphorbia braziliensis*	possibly restricted
TINGIDAE		
Corythuca pellucida	Euphorbiaceae	possibly restricted
Corythuca socia	Euphorbiaceae	possibly restricted
Thysanoptera		
PHLAEOTHRIPIDAE		
Haplothrips gowdeyi	*Euphorbia* sp., coffee, rice, *Crotolaria* sp., *Passiflora* sp., *Buddleia variabilis*	polyphagous
Coleoptera		
CHRYSOMELIDAE		
Caryedes (= *Gibbobruchus*) *pickeli*	Euphorbiaceae	possibly restricted
Disonycha argentiniensis	*Euphorbia pulcherrima*	possibly restricted
Gibbobruchus polycoccus	Euphorbiaceae	possibly restricted
CURCULIONIDAE		
Sternocoelus sp.	Euphorbiaceae	?restricted to Euphorbiaceae
Sternocoelus notaticeps	Euphorbiaceae	?restricted to Euphorbiaceae
Lepidoptera		
LYMANTRIIDAE		
Thagona tibialis	*E. cespitosa*, *E. ovalifolia*, *E. pulcherrima*	?restricted to Euphorbiaceae
NOCTUIDAE		
Spodoptera eridania	Euphorbiaceae, many crops	polyphagous
NYMPHALIDAE		
Didonis biblis	Euphorbiaceae, *Tragia volubilis*	possibly restricted
Dynamine artemisia	Euphorbiaceae	?restricted to Euphorbiaceae
Episcada pascua	Euphorbiaceae	?restricted to Euphorbiaceae
SPHINGIDAE		
Erinnyis oenotrus	*E. ovalifolia*	possibly restricted

Euphorbia hirta

(after Holm *et al.* 1977)



Map 4.10 *Euphorbia hirta*

There is only one record of a natural enemy attacking *Euphorbia hirta* in tropical America where it evolved and only a few of polyphagous species attacking it elsewhere. A survey in Central America would be necessary to determine what species attack it there that might be potential biological control agents.

4.10 *Euphorbia hirta* L.

(= *E. pilulifera*)

Euphorbiaceae

garden spurge, asthma plant; mayo (Myanmar), nam nom raatchasee (Thailand) tuk das khla thom (Cambodia), cò sua lông (Vietnam), ara tanah, hairy spurge (Malaysia) gelâng susu, gèndong âncok (Indonesia), gatas gatas (Philippines)

Rating

	++	Thai, Sing, Phil
10	+	Laos, Camb, Viet, Msia
	•	Myan, Indo

Origin

Tropical America.

Distribution

E. hirta is a weed of the tropics and subtropics.

Characteristics

A small, prostrate, hairy annual, 0.15 to 0.3 m tall, with a tap root; stems much branched from the base, often reddish, bearing brownish stiff hairs and having milky sap; leaves, hairy, opposite, sometimes purple-blotched and with toothed margins; flowers unisexual; reproduction by seeds 0.5 to 1 mm long.

Importance

E. hirta grows well in sunny to lightly shaded cultivated lands, gardens, lawns, waste areas and run down grasslands. It is an early coloniser of bare ground especially under damp or irrigated conditions. It flowers all year round in Southeast Asia producing up to 3000 seeds per plant. When the seed pods mature they explode to disperse the seeds. Its prostrate habit enables it to tolerate mowing and it can be important in lawns. It has been reported from 47 countries as a weed in many crops, including citrus, cotton, groundnuts, maize, pineapples, rice, sorghum, sugarcane, tea and vegetables. Moody (1989) records it as being more widespread in rice than *Euphorbia heterophylla.*

E. hirta is sometimes used in medicines in Fiji, Malaysia, Indonesia, the Philippines and Brazil—the leaves and latex against intestinal diseases, ulcers and bronchitis, and the latex for conjunctivitis. It may have slightly poisonous properties and is useless as fodder for livestock.

Natural enemies

In view of its common occurrence in the tropical and subtropical belt of the world, it is surprising that there are so few records of natural enemies attacking it, and those that do are highly polyphagous (Table 4.10.1). A survey in Central America would be necessary to learn more about its natural enemies that might have potential for biological control.

Table 4.10.1 Natural enemies of *Euphorbia hirta*.

Species	Location	Other hosts	References
INSECTS			
Orthoptera			
ACRIDIDAE			
Chrotogonus trachypterus	India	polyphagous	Chandra et al. 1983
Hemiptera			
APHIDIDAE			
Aphis craccivora	Nigeria, Uganda	polyphagous, a virus transmitter	Booker 1964, Davies 1972, Ofuya 1988
Aphis gossypii	India	polyphagous	Jeritta & David 1986
ALEYRODIDAE			
Bemisia tabaci	India	polyphagous, a virus transmitter	Jeyarajan et al. 1988
DELPHACIDAE			
Tarophagus proserpina	Philippines	polyphagous	Duatin & Pedro 1986
LYGAEIDAE			
Nysius inconspicuus	India	polyphagous	Thangavelu 1978
PSEUDOCOCCIDAE			
Ferrisia virgata	India	polyphagous	Jeritta & David 1986
Thysanoptera			
THRIPIDAE			
Haplothrips euphorbiae	India	possibly host restricted	Jeritta & David 1986
Diptera			
AGROMYZIDAE			
Liriomyza bryoniae	Europe	highly polyphagous	Spencer 1973, 1990
Liriomyza strigata	W. Europe, USSR	highly polyphagous	Spencer 1973, 1990
Lepidoptera			
NOCTUIDAE			
Achaea janata	Indonesia	polyphagous	Kalshoven 1981
FUNGI			
Aecidium tithymali	Thailand		Puckdeedindan 1966
Amphobotrys ricini	USA		Holcomb et al. 1989
Cylindrocladium quinqueseptatum	India		Sulochana et al. 1982
Phytophthora palmivora	Sarawak	black pepper	Anon 1979
PROTOZOA			
Phytomonas sp.	Venezuela		Barreto 1982
NEMATODES			
Meloidogyne incognita	Hawaii		Valdez 1968

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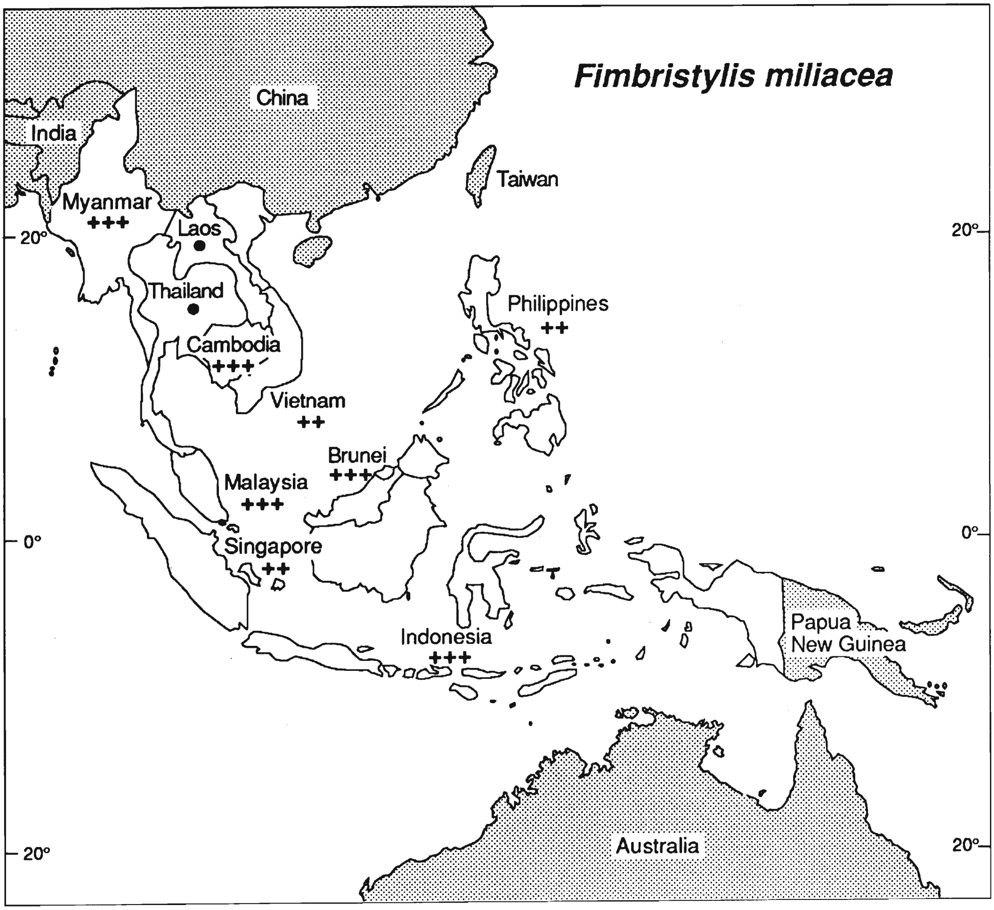
Table 4.10.1 (continued)

Species	Location	Other hosts	References
Meloidogyne javanica	India		Dahiya et al. 1988
Radopholus similis	Zimbabwe	polyphagous	Martin et al. 1969
Rotylenchulus reniformis		Hawaii, USA	Linford & Yap 1940, Inserra et al. 1989
VIRUSES			
groundnut rosette	Hawaii, Nigeria, Uganda		Adams 1967, Booker 1964, Davies 1972
hibiscus yellow vein mosaic	India		Jeyarajan et al. 1988
tapioca mosaic	India		Jeyarajan et al. 1988
tobacco leaf curl	Hawaii		Holm et al. 1977
tomato leaf curl	India		Jeyarajan et al. 1988
urd bean yellow mosaic	India		Jeyaragan et al. 1988

Fimbristylis miliacea

(after Holm *et al.* 1977)



Map 4.11 *Fimbristylis miliacea*

Very few natural enemies of *Fimbristylis miliacea* are known and it would be necessary to carry out a survey in tropical America before it would be possible to evaluate the prospects for its biological control.

4.11 *Fimbristylis miliacea* (L.) Vahl
(= *F. littoralis*)

Cyperaceae

lesser fimbristylis, grass-like fimbristylis; mônhnyin (Myanmar), kak phrèk kdam, smao (Cambodia), rumput bukit, rumput tahi berbau (Malaysia), agor (Thailand), ba bawagan (Indonesia)

Rating

	+++	Myan, Camb, Msia, Brun, Indo
23	++	Viet, Sing, Phil
	•	Thai, Laos

Origin

Tropical America.

Distribution

Central America, West Africa, Asia and Southeast Asia to northern Australia.

Characteristics

An erect annual or perennial sedge, growing up to 0.9 m; flower stems 4 or 5 angled, leaves two-ranked, threadlike, stiff and half as long as flower stems; inflorescence a diffuse compound umbel.

Importance

F. miliacea thrives in damp, open waste places, competing actively with other vegetation following germination during dry periods or shallow water conditions. A layer of water 15 cm deep suppresses germination. Seedlings emerge during the entire growing period of rice with which it competes actively. It is a troublesome weed in 21 countries. In Malaysia it is the first sedge to emerge after rice has been transplanted and the first to recover after ploughing. In the Philippines it flowers all year, plants each producing up to 10000 seeds. In many places there is no seed dormancy.

F. miliacea is one of the most serious and widespread weeds of rice and is also reported from taro (Hawaii), bananas (Taiwan), abaca (Philippines), maize, sugarcane (Indonesia, Taiwan) and sorghum (Malaysia).

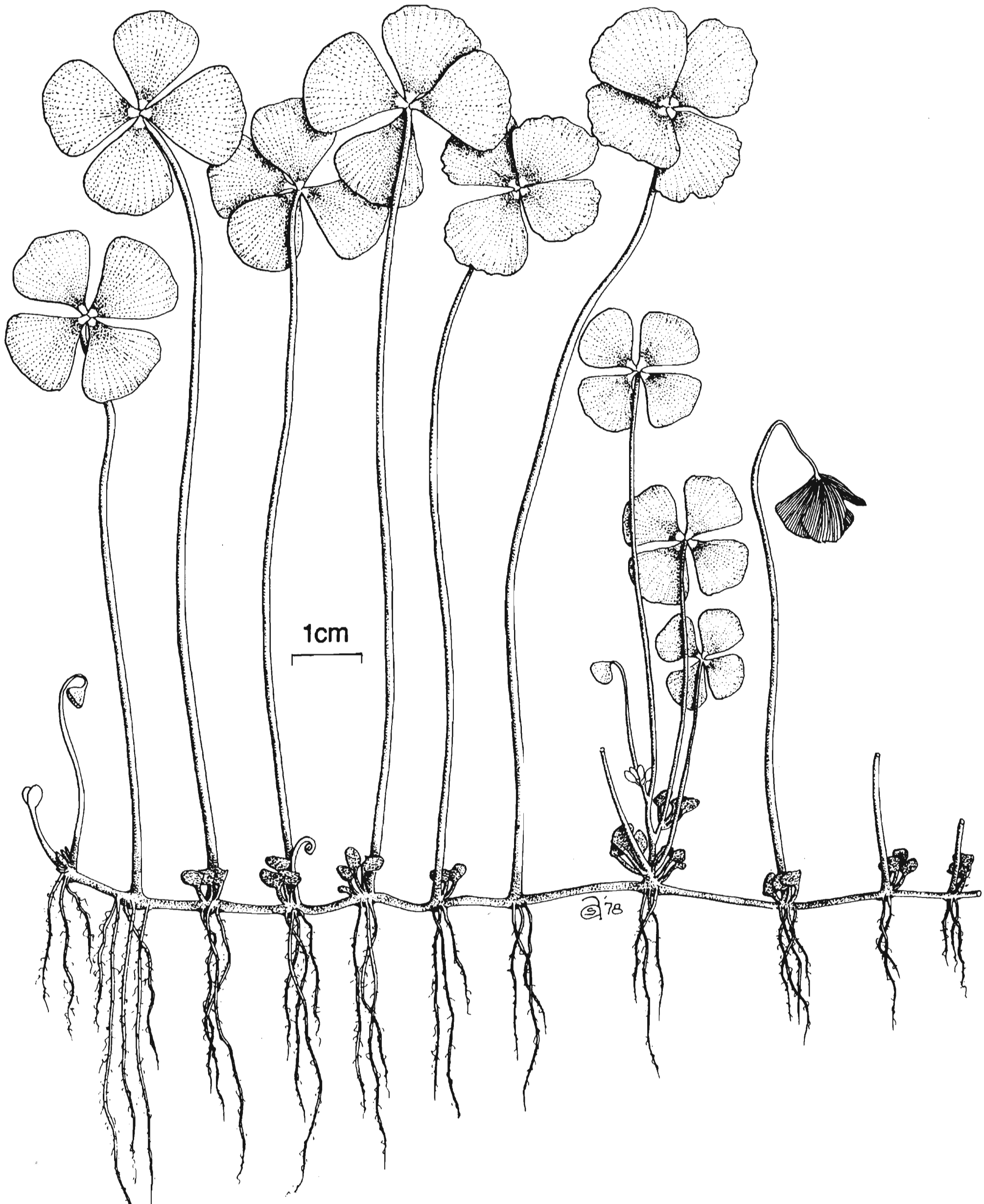
F. miliacea is eaten by cattle, but the seeds are mostly undigested and germinate near the dung.

Natural enemies

So little is known about its natural enemies (Table 4.11.1) that it is not possible to evaluate the prospects for biological control. A survey is necessary in tropical America.

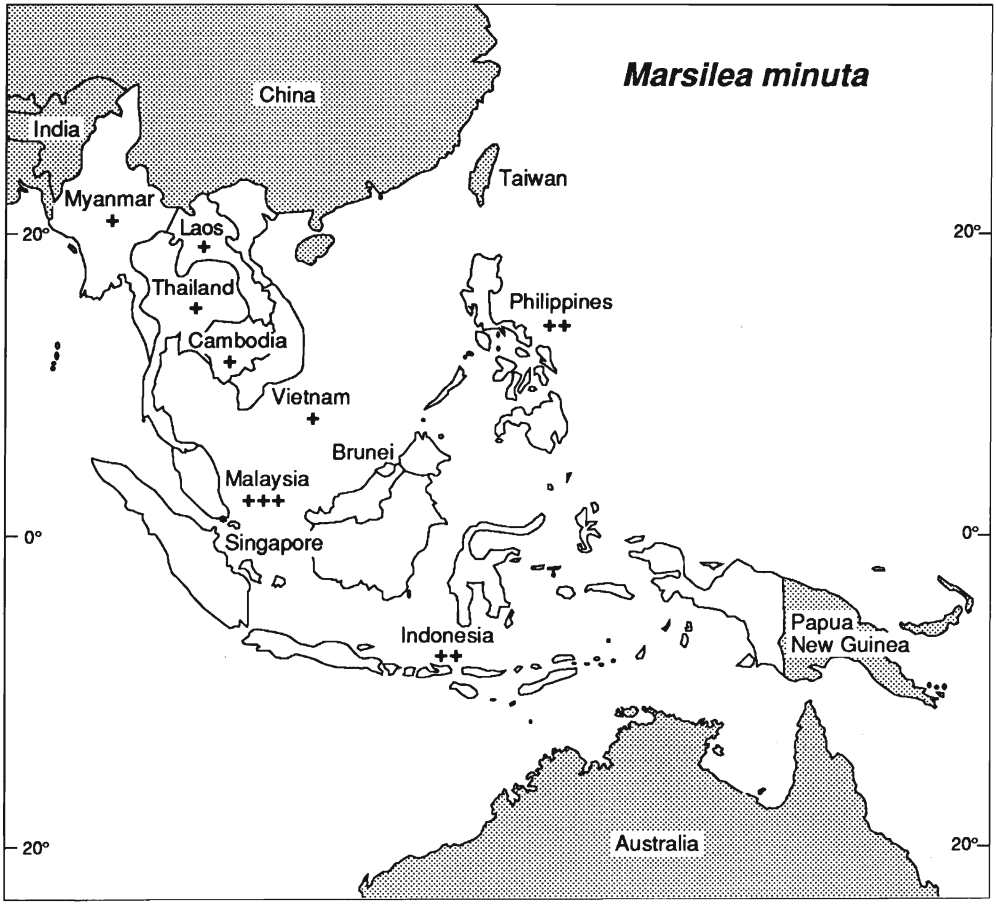
Table 4.11.1 Natural enemies of *Fimbristylis miliacea*.

Species	Location	Other hosts	References
INSECTS			
Hemiptera			
PENTATOMIDAE			
Scotinophara latiuscula	Philippines	rice, *Commelina benghalensis*, *Echinochloa crus-galli*	Barrion & Litsinger 1987
Lepidoptera			
Creatonotos gangis (= *Amsacta*)	Philippines	rice, many weeds	Catindig et al. 1993
FUNGI			
Corticum sasakii	India	*Commelina benghalensis*, *Cynodon dactylon*, *Eleusine indica* and other grasses	Roy 1973
NEMATODES			
Criconemella onoensis		rice, many weeds	Luc et al. 1990
Hirschmaniella spp.		rice, maize, sugarcane, many weeds	Luc et al. 1990
Meloidogyne graminicola	India	rice, many weeds	Luc et al. 1990, Rao et al. 1970
Meloidogyne oryzae	Surinam	rice, plantain, wheat, potato, tomato	Maas et al. 1978
Rotylenchulus reniformis	Trinidad	very polyphagous	Singh 1974



Marsilea minuta

(after Soerjani *et al.* 1987)



Map 4.12 *Marsilea minuta*

Marsilea minuta, water clover, is thought to be of tropical African origin, but no account of its natural enemies there is available. A survey would thus be required to evaluate the prospects for its biological control.

4.12 *Marsilea minuta* L.
(=*M. crenata*)

Marsileaceae

water clover, clover fern, pepperwort; pak vaen (Laos), chuntul phnom (Cambodia), semànggi (Indonesia), phak waen (Thailand), tapah itik (Malaysia) paang itik (Philippines).

Rating

	+++	Msia
12	++	Indo, Phil
	+	Myan, Thai, Laos, Camb, Viet

Origin

Africa or possibly tropical Asia (Jacobsen 1983). It consists of a complex of strains including a diploid (n = 20) and a sterile triploid (2n = 60) (Tryon and Tryon 1982).

Distribution

Marsilea minuta is widespread over most of the African continent and it is pantropical in Asia. The Marsileaceae contains about 65 species, of which 16 occur in Africa and, of these, *M. minuta* is amongst the most widespread (Jacobsen 1983).

Characteristics

A very variable, perennial water fern of aquatic or marshy sites. Its stems are creeping rhizomes rooted in the mud. Leaves are clover-like, with four leaflets borne on a petiole 2 to 30 cm long. Leaflets have fan-shaped, repeatedly bifurcating veins and normally float on the water surface. Sporocarps occur near the base of the petioles and usually occur under the mud or water surface. Reproduction is by spores or rhizomes.

Importance

Although *M. minuta* has a rating of 12 and is widely reported as a weed in Southeast Asia, there are surprisingly few references to it as a weed in the literature except for those dealing with chemical control. In Thailand it is common in rice fields and along canals and other waterways. It is one of the seven most important weeds in the Muda area of Malaysia (Itoh 1991a). It is one of the more important emergent weeds in shallow water rice fields in the central lowlands in Vietnam (Nguyen Van Vuong 1973) and in the lowland area of Vientiane in Laos (Sisounthone and Sisombat 1973). In Indonesia its vegetative growth and reproduction is very rapid. It can grow under water and, after weeding, rapidly re-establishes itself unless well buried in the soil. It is an effective competitor for nutrients, particularly in the early part of the growth period after transplantation of rice seedlings when *M. minuta* rapidly covers the ground surface. In the Philippines it caused 19% crop loss when sown together with rice (Suriapermana 1977).

The young leaves of water clover are sometimes eaten as a vegetable in Indonesia.

Natural enemies

Very little information concerning natural enemies emerged from computer-aided searches of the literature on *Marsilea minuta*, which also included searches of its synonyms: *M. crenata* and *M. erosus* in Asia and *M. diffusa*, *M. perrieriana* and *M. senegalensis* in Africa (Table 4.12.1). In Africa *Marsilea minuta* appears to be regarded, at most, as a minor weed. This is possibly due to the fact that rice is far less important there than in Asia, or it may be due to the presence of effective natural enemies in Africa, although these have not yet been reported.

In the Philippines, larvae of the ephydrid flies *Notiphila latigenis* and *N. similis* are common on emergent *M. minuta* and damage its stems. Their eggs are usually laid on the stems and serve as alternative hosts of *Trichogramma* wasps attacking rice stem borers (Barrion and Litsinger 1986). The contents of upwards of 90% of the sporocarps from *M. minuta* growing under terrestrial conditions in northwestern India were destroyed by larvae of the weevil *Echinocnemus*. The larval and pupal stages are completed in 40 to 45 days (Loyal and Kumar 1977). In Indonesia the case-forming larvae of the widely distributed pyralid moth *Elophila* (= *Nymphula*) *responsalis* attacked *M. minuta* and several other aquatic plants including *Salvinia* spp., *Lemna purpusilla*, *L. polyrhiza*, *Monochoria vaginalis*, *Azolla pinnata* and *Pistia stratiotes*. However, tests have shown that it will not feed on rice. The development period of *Elophila responsalis* ranged from 42 to 56 days. It was attacked by a pupal parasitoid (*Tetrastichus* sp.) and a larval coleopteran predator (Handayani and Syed 1976, Sankaran and Rao 1972, Subagyo 1975). *Elophila responsalis* occurs also in India, Sri Lanka, Myanmar, Japan and Australia.

Comment

A survey for natural enemies attacking *M. minuta* in Africa is required before the prospects for its biological control in Southeast Asia can be evaluated.

Table 4.12.1 Natural enemies of *Marsilea minuta*.

Species	Location	References
INSECTS		
Coleoptera		
CURCULIONIDAE		
Echinochnemus sp.	India	Loyal & Kumar 1977
Diptera		
EPHYDRIDAE		
Notiphila latigenis	Philippines	Barrion & Litsinger 1986
Notiphila similis	Philippines	Barrion & Litsinger 1986

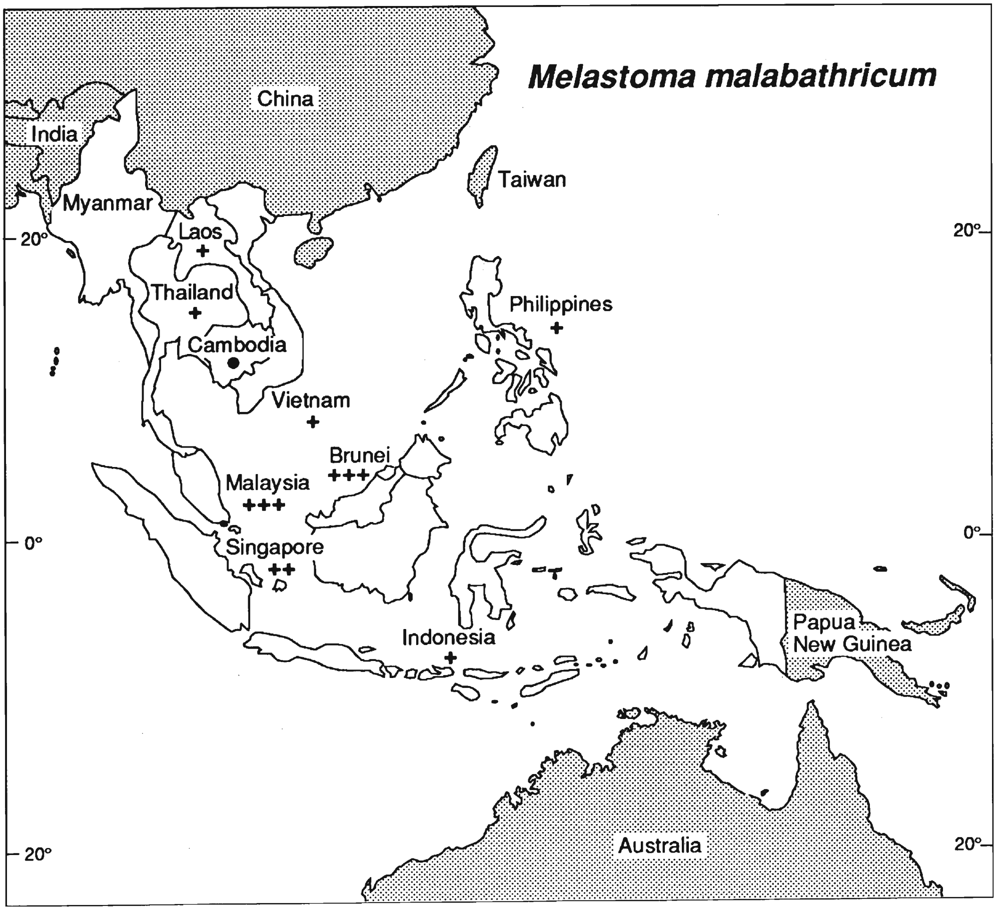
(continued on next page)

Table 4.12.1 (continued)

Species	Location	References
Lepidoptera		
PYRALIDAE		
Elophila (= *Nymphula*) *responsalis*	India, Indonesia	Handayani & Syed 1976, Sankaran & Rao 1972, Subagyo 1975
FUNGI		
Alternaria sp.	India	Menon & Ponnappa 1964
Cercospora marsileae	India	Patil 1975
Phaeotrichoconis crotalariae	India	Menon & Ponnappa 1964
VIRUS		
Pistia virus	India	Menon & Ponnappa 1964

Melastoma malabathricum

(after Soerjani *et al.* 1987)



Map 4.13 *Melastoma malabathricum*

M. malabathricum is a perennial shrub which probably originated in Southeast Asia or neighbouring areas, including Irian Jaya, Papua New Guinea and northern Australia, a region where it is regarded as being of little importance. A survey in this region would reveal whether there are promising natural enemies for biological control.

4.13 *Melastoma malabathricum* L.
(= *Melastoma affine*)

Melastomataceae

melastoma, Indian rhododendron, Straits rhododendron; senduduk (Malaysia)

Rating

	+++	Msia, Brun
13	++	Sing
	+	Thai, Laos, Viet, Indo, Phil
	•	Camb

Origin

Asia, Papua New Guinea, Australia.

Characteristics

M. malabathricum is a perennial shrub growing to 2 m high; its stems are reddish with rough upwardly pointing scales, the leaves are tapered to both ends, are rough to touch and have three distinct ribs. The flowers, which are clustered at the ends of twigs, are pinkish to light violet. The fruit is a berry-like capsule covered with scales.

Importance

Melastoma is common in abandoned clearings, on waste ground and in cultivated lands. In addition to its importance in Southeast Asia, it is a principal weed of rubber in West Africa. It is said to make good firewood. The sweetish black seeds are eaten and chewed leaves are used for burns and against amoebic dysentery. The fruits host a fruit fly species in the *Bactrocera dorsalis* complex which does not attack commercially important fruits (R.A.I. Drew, pers. comm.).

Natural enemies

Krauss (1965) surveyed the natural enemies of species of *Melastoma,* including *M. malabathricum,* in various countries of Southeast Asia and islands of the western Pacific. Twenty six insect species were found on *M. malabathricum* (Table 4.13.1) and a further 34 species on other melastomas. It is very likely that some of the 34 species will also attack *M. malabathricum* and, indeed, the leaf rolling pyralid moth *Ategumia fatualis* does so. After specificity tests *Ategumia fatualis* was liberated in Hawaii and Kauai in 1958 and became established, although it did not become sufficiently abundant to provide effective control (Table 4.13.2) (Krauss 1965).

Another leaf-rolling pyralid *Ategumia adipalis* was liberated in 1965, and was reported to have become established (Davis and Chong 1969), but at low population levels. Next a noctuid moth *Selca brunella* was introduced to Kauai and Hawaii from Malaysia and Singapore in 1964 and was recovered the next year. The larvae feed avidly in flower buds, bore into terminal stems and eat leaves. In heavily infested localities considerable dieback has resulted, at places flowering was prevented and in others up to 50% of fruits were destroyed by larvae. Larvae have been found recently on *Tiboochina urvilleana* and *Heterocentron subtriplinenium* (both Melastomataceae) in Hawaii (C.J. Davis pers. comm. 1993). A braconid wasp *Meteorus* sp. attacks *S. brunella* larvae (Davis 1970, Davis and Chong 1969).

An unidentified grasshopper and an unidentified lepidopterous larva attack *M. malabathricum* in Thailand but not the chrysomelid beetle *Altica cyanea* which is present there and attacks it in Indonesia and Malaysia (Napompeth 1982).

Comment

Although a number of insects are known to attack *M. malabathricum* in Southeast Asia (and especially in Malaysia), they clearly do not reduce its status to the level required and thus are of limited value for classical biological control in that region. However, if as postulated, the area of origin includes Papua New Guinea, (Irian Jaya) and Australia it is possible that there may be useful natural enemies in the region that do not occur in countries to the north and west. Certainly, *Melastoma* is not listed as an important weed in Papua New Guinea.

Table 4.13.1 Natural enemies of *Melastoma malabathricum*.

Species	Country	Food	References
INSECTS			
Hemiptera			
APHIDIDAE			
Aphis sp.	Singapore	leaf	Krauss 1965
CICADELLIDAE			
Tettigella (= *Tettigoniella*) sp.	Malaysia	leaf	Krauss 1965
COCCIDAE			
Rastrococcus sp.	Malaysia	leaf	Krauss 1965
MEMBRACIDAE			
Gargara sp.	Malaysia		Krauss 1965
Leptocentrus taurus	Malaysia	branch; also on *Melastoma polyanthum*	Krauss 1965
Nilautama minutispina	Malaysia		Krauss 1965
Sipylus dilatatum	Malaysia		Krauss 1965
Sipylus sp.	Malaysia	branch	Krauss 1965
Tricentrus sp.	Malaysia	branch	Krauss 1965
	Singapore	branch	Krauss 1965
MIRIDAE			
Helopeltis antonii	Indonesia		Soerjani et al. 1987
Hyalopeplus vitripennis	Malaysia	leaf	Krauss 1965
RICANIIDAE			
Pochazia antica	Malaysia	leaf	Krauss 1965

(continued on next page)

Table 4.13.1 (continued)

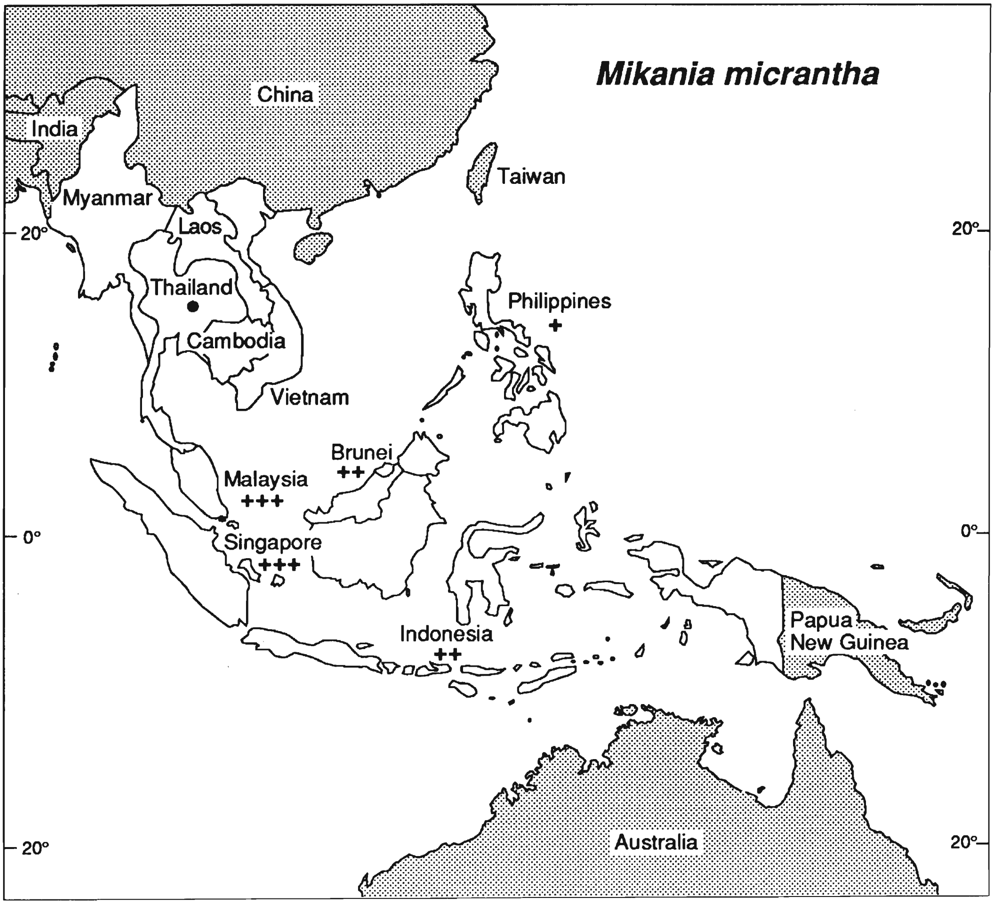
Species	Country	Food	References
Coleoptera			
CHRYSOMELIDAE			
Altica cyanea	Indonesia, Malaysia		Kamarudin & Shah 1978, Napompeth 1982
CURCULIONIDAE			
Alcidodes sp.	Malaysia	shoot	Krauss 1965
Ceutorhynchus sp.	Malaysia	flowers	Krauss 1965
Cryptorhynchus sp.	Malaysia	flowers	Krauss 1965
Imerodes (?) sp.	Singapore	flowers	Krauss 1965
Diptera			
TEPHRITIDAE			
Bactrocera dorsalis (= *B. pedestris*)	Malaysia, Singapore, Sri Lanka	fruit	Krauss 1965
Lepidoptera			
ARCTIIDAE			
Species of Lithosiinae	Malaysia	fruit	Krauss 1965
GELECHIIDAE			
Idiophantis sp.	Malaysia	fruit	Krauss 1965
HYPONOMEUTIDAE			
Argyresthia leuculias	Malaysia	fruit	Krauss 1965
LYMANTRIIDAE			
?Species	Malaysia	flower	Krauss 1965
NOCTUIDAE			
Autoba (= *Eublemma*) *versicolor*	Malaysia	leaf	Krauss 1965
Selca brunella	Malaysia, Singapore	leaf, twig, fruit	Julien 1992, Krauss 1965
PYRALIDAE			
Agrotera basinotata	Malaysia	leaf	Krauss 1965
Ategumia adipalis	Malaysia, Singapore	leaf	Julien 1992, Krauss 1965
Ategumia fatualis	Philippines	leaf	Krauss 1965
TORTRICIDAE			
Archips micaceana	Malaysia	leaf	Krauss 1965
FUNGI			
Phytophthora palmivora	Sarawak	black pepper	Anon 1979

Table 4.13.2 Introductions to Hawaii for the biological control of *Melastoma malabathricum*.

Species	Source	Liberated	Established	References
INSECT				
Lepidoptera				
NOLIDAE				
Selca brunella	Malaysia, Singapore	1965	+	Davis 1960, Davis & Chong 1968, Davis & Krauss 1962, 1966, 1967, Julien 1992, Krauss 1965
PYRALIDAE				
Ategumia adipalis	Malaysia, Singapore	1965	+	Davis & Chong 1969, Julien 1992
Ategumia fatualis	Philippines	1958	+	Davis & Krauss 1966, Julien 1992

Mikania micrantha

(after Holm *et al.* 1977)



Map 4.14 *Mikania micrantha*

Mikania micrantha is a perennial vine, native to Central and South America.

A number of very promising, and probably specific, natural enemies are known in Central and South America where *M. micrantha* is not regarded as a weed. One of these, a thrips *Liothrips mikaniae* has been released in Malaysia and the Solomon Is, but extremely high predation is believed to have prevented its establishment. A bug *Teleonemia* sp., several chrysomelid beetles and an eriophyid mite *Acalitus* sp. warrant serious consideration. A number of other natural enemies, whose specificity has not yet been adequately investigated, also attack *M. micrantha*.

In spite of the lack of success with the thrips, *M. micrantha* appears to be a prime target for the introduction of one or more of the other organisms that attack it in its area of origin.

4.14 *Mikania micrantha* Kunth

Asteraceae

mile-a-minute weed; cheroma, ulam tikus (Malaysia), sembung rambat (Indonesia).

This chapter updates that in Waterhouse and Norris (1987), with special reference to Southeast Asia.

Rating

	+++	Msia, Sing
11	++	Brun, Indo
	+	Phil
	•	Thai

Origin

The weedy species in Southeast Asia and the Pacific is *M. micrantha* from Central and South America and not the North American *M. scandens* or the Old World *M. cordata* (Parker 1972).

Distribution

M. micrantha belongs to a genus containing about 250 species of mostly Central and South American origin. In addition to its native distribution in tropical America, it has spread to Mauritius, India, Sri Lanka, Bangladesh and Southeast Asia (as above). It occurs widely as a weed in the Pacific, including Papua New Guinea (Waterhouse and Norris 1987), but is not yet present in Australia. It was introduced from Paraguay to Bogor Botanic Gardens (Indonesia) in 1949 and, in 1956, was used as a soil cover in rubber: it has since spread throughout Indonesia (Soerjani et al. 1987).

Characteristics

Mikania micrantha is an extremely fast growing, sprawling, perennial vine, with opposite, heart-shaped leaves, longitudinally ribbed, branched and hairless stems and numerous small heads of densely clustered white flowers. It creeps and twines, roots readily at the nodes and produces abundant small (2 mm long) black seeds bearing a terminal tuft of white bristles that aid wind dispersal.

In its natural habitat in tropical America, *M. micrantha* is usually found in disturbed situations. It seldom occurs on poor soils and is most commonly found in damp or swampy places. Typical sites in South America are roadsides in wet forest and the edges of freshwater swamps. Flowering occurs mainly in the dry season and only in sunny situations (Cock 1982a).

Importance

With its rapid growth, ready rooting at nodes, smothering habit and prolific seed production, *M. micrantha* rapidly colonises disturbed habitats, retarding, by competition and through plant inhibitors that it elaborates (Wong 1964), the growth of crops or natural vegetation. In comparison with a nitrogen-fixing legume, it is of restricted value in the role of a cover crop. For example, in Malaysia the girth of rubber trees was 27% less with a cover of *M. micrantha* than of a legume and the yield over the first 32 months of production was 27 to 29% less (Teoh et al. 1985). In many parts of Southeast Asia it is a serious pest of plantation crops (oil palm, coconut, cocoa, tea, rubber, teak). Its climbing habit enables it to reach and then dominate the crowns of bushes or trees up to 10m high, where it is difficult to attack either mechanically or chemically without risk of damaging the crop (Parker 1972). It recovers rapidly from slashing. It is eaten by cattle, but is less valuable as fodder than many of the pasture plants it is able to smother. Nevertheless, it is viewed by some as being useful to control soil erosion, to serve as a mulch when cut, and as being preferable to many alternative plants that might occupy the space vacated by its control. In its native habitat it is seldom a weed.

Natural enemies

MAJOR SPECIES

TROPICAL AND SOUTH AMERICA

Valuable information is available on 9 major and 22 minor natural enemies of *M. micrantha* in its native region as a result of studies by Cock (1982a,b) and Freitas (1991). Several of the major natural enemies are reported to be promising biological control agents (Table 4.14.1) and all these, and probably some of those less extensively studied (Table 4.14.2), are worthy of serious consideration. Details of their biology and possible relevance for biological control are summarised below.

Table 4.14.1 Major natural enemies of *Mikania micrantha* in its native range in Central and South America (after Cock 1982a).

INSECTS

Thysanoptera

PHLAEOTHRIPIDAE

Liothrips mikaniae

Hemiptera

TINGIDAE

Teleonemia sp. or spp. nr *prolixa*

Coleoptera

CHRYSOMELIDAE

Desmogramma conjuncta
Echoma marginata
Echoma quadristillata
Physimerus pygmaeus

APIONIDAE

Apion luteirostre

CURCULIONIDAE

Pseudoderelomus baridiiformis

MITE

ERIOPHYIDAE

Acalitus sp.

Table 4.14.2 Additional natural enemies of *Mikania micrantha*, not known to be polyphagous, from Central and South America (Cock 1982a, Freitas 1991).

Species	Distribution	Feeding location	Host range
INSECTS			
Hemiptera			
LYGAEIDAE			
Xyonysius basalis (= *X. inaequalis* = *X.* sp. nr *ementitus*)	Trinidad, Venezuela	inflorescence	Probably other *Mikania* spp.or other Asteraceae
MEMBRACIDAE			
Entylia sinuata	Colombia, Costa Rica	stems and leaves	*M. cordifolia*
Entylia sp.	Trinidad, Peru, Venezuela Ecuador	stems and leaves	*M. cordifolia*
Micrutalis binaria	Trinidad, Colombia	stems and young leaves	*M. vitifolia* and *M. trinitaria*
MIRIDAE			
Pycnoderes incurvus	Colombia, Ecuador, Costa Rica	leaves	probably specific
TINGIDAE			
Leptocysta sexnebulosa	Venezuela Colombia, Peru	mature leaves	*M. cordifolia*
Coleoptera			
CHLAMISIDAE			
Exema complicata	Trinidad, Peru, Costa Rica, Colombia	leaves	*Mikania* spp., *Chromolaena odorata* and possibly other Asteraceae
CHRYSOMELIDAE			
Longitarsus sp. nr *amazonus*	Colombia, Peru	leaves	probably specific
Sceloenopla sp.	Trinidad	leaves	*M. trinitaria*
Diptera			
AGROMYZIDAE			
Calycomyza mikaniae	Trinidad, Colombia, Costa Rica	leaf miner	*Mikania* spp. and possibly related Asteraceae
CECIDOMYIIDAE			
Neolasioptera sp.	Trinidad, Colombia	flowers	*M. cordifolia*
TEPHRITIDAE			
Xanthaciura insecta	Trinidad	flower head	various Asteraceae
Lepidoptera			
GELECHIIDAE			
Onebala tegulella	Trinidad, Costa Rica	leaf roller	*M. vitifolia*
Recurvaria sp.	Trinidad	flowers	various Asteraceae

(continued on next page)

Species	Distribution	Feeding location	Host range
GEOMETRIDAE			
Chloropteryx sp.	Trinidad	flowers	various Asteraceae
Eupithecia sp.	Trinidad	flowers	various Asteraceae
LYCAENIDAE			
Thereus (= *Thecla*) *palegon*	Trinidad	flowers	various Asteraceae
NYMPHALIDAE			
Tegosa claudina (= *Tegosa similis*)	Brazil, Trinidad, Colombia	leaves	possibly specific
PTEROPHORIDAE			
Adaina bipuncta	Trinidad	flowers	various Asteraceae
PYRALIDAE			
Lamprosema distincta	Trinidad, Panama, Costa Rica	leaf roller	possibly specific
TORTRICIDAE			
Lobesia (= *Polychrosis*) *?carduana*	Trinidad	flowers	various Asteraceae
Phalonidia multistrigata	Trinidad	flowers	various Asteraceae

Acalitus sp. Acarina: Eriophyidae

Feeding on the leaves by this eriophyid mite causes the formation of raised patches (erinea) in which the mites and their immature stages congregate. In Venezuela the patches mostly protrude on the undersurface of the leaf, whereas elsewhere they are mostly on the uppersurface, which may indicate taxonomic differences. At low mite densities the small number of erineum patches appear to have little effect on the growth and vigour of the plant. However, in dense infestations, erineum patches cover all the young leaves and spread into the flower heads, resulting in shortened internodes and reduced flowering. Plant vigour is significantly reduced.

Eriophyid mites are usually restricted to a single plant species. Although erineum patches occur widely on *M. micrantha*, they were not seen on any other species of *Mikania* encountered in Cock's (1982a) studies, suggesting a high degree of specificity. Predatory or scavenger mites occur quite commonly in and around the erineum patches. If field specificity trials with potted plants of closely related Asteraceae placed among heavily infested *M. micrantha* prove negative, this mite would be a promising biological control agent. Similar mites on *Lantana* in South America appear to discourage insect attack (K.L.S. Harley pers. comm.).

Apion luteirostre Coleoptera: Apionidae

Eggs of this weevil are laid in unopened host flower heads. Larvae feed initially on the petals, stigma and stamens and, later, destroy the developing seeds. They pupate in the flower head. The adults make small holes in young leaves.

In extensive field studies *A. luteirostre* larvae were not recorded from *Chromolaena odorata*, although they were found on *M. micrantha* and *M. vitifolia*, but not on *M. cordifolia*. Starvation tests using adults resulted in their feeding on five species of *Mikania* and on *Bidens pilosa*, but not on *Chromolaena odorata*.

Larvae of *Apion luteirostre* are attacked by the non-specific eulophid parasitoid *Horismenus*? *aeneicollis* and the pteromalid *Zatropis* sp. A number of *Apion* species have been used successfully in biological control of weeds programs (e.g. *Emex australis* and *E. spinosa*). Further host specificity trials are needed to evaluate the potential value of *A. luteirostre*.

Desmogramma conjuncta Coleoptera: Chrysomelidae

This chrysomelid beetle occurs widely, but at low density, on *M. micrantha* in Central and South America and a related species *D. bigaria* occurs on *M. micrantha* in Venezuela.

Eggs are laid on the host leaves on which the larvae feed. Pupation occurs in the soil. No field records are available of feeding on plants other than *M. micrantha* and, in limited multiple choice tests, adults offered *Bidens pilosa* (cobbler's pegs), *Chromolaena odorata* and *M. micrantha* (all Asteraceae) attacked only the latter. No natural enemies have been recorded.

The chrysomelid subfamily Chrysomelinae to which this species belongs includes several successful biological control agents such as the *Chrysolina* species on St John's Wort, *Hypericum perforatum angustifolium*. If species of *Desmogramma* are specific to *M. micrantha* they may prove to have potential as biological control agents.

Echoma (= *Omoplata*) *marginata* and *E. quadristillata* Coleoptera: Chrysomelidae

Adults and larvae of these chrysomelid beetles feed openly on *M. micrantha* and *M. cordifolia* leaves and cause general defoliation. *E. marginata* is uncommon, but *E. quadristillata* is quite common around Turrialba (Costa Rica). They appear to have a low reproductive potential (Cock 1982a). In limited-choice tests, *E. quadristillata* fed on *M. micrantha* and *M. cordifolia*, but not on *Bidens pilosa* or *Sonchus* sp. (Asteraceae). In another experiment, no preference was shown between its two host species, but it would not feed on another species of *Mikania*, which was probably *M. vitifolia*.

A tachinid pupal parasitoid *Hyalomyodes triangulifer* is known from *E. marginata* and a chalcidid pupal parasitoid *Brachymeria russelli* from *E. quadristillata*.

Liothrips mikaniae Thysanoptera: Phlaeothripidae

This thrips occurs in Colombia, Costa Rica, Peru, Surinam, Trinidad and Venezuela. The eggs are mainly laid on the undersurface of the host plant leaves or at the base of leaf stalks and the larvae feed there in groups. The prepupae and pupae are found among leaf litter beneath the plant and the adults return to the youngest leaves to feed, mate and oviposit. *L. mikaniae* has been found only on *M. micrantha* growing in full sunshine and it never occurs on plants in shady situations. This limits its potential effectiveness to sunlit stands of the weed. The life cycle (egg to egg-laying adult) takes about 35 days, males living about 28 days, females about 35 days and laying between 21 and 111 eggs (Ooi et al. 1993). The feeding by larvae and adults on the young leaves produces small to moderate-sized lesions on the undersurface, which dry to form brown scars and these cause extensive distortion of the leaves as they grow.

Laboratory studies in Trinidad (Cock 1982b) and field observations (Cock 1981, 1982a,b) show that *L. mikaniae* is restricted to the genus *Mikania* and most probably to

M. micrantha, although *M. cordifolia* and *M. vitifolia* may be fed on to a limited extent in the laboratory. Additional studies carried out in England by CIBC confirmed its host specificity before permission was obtained to introduce *L. mikaniae* to Malaysia. Rearing methods are described by Cock (1982b) and Ooi et al. (1993).

***Physimerus pygmaeus* Coleoptera: Chrysomelidae**

This halticine chrysomelid is one of a group of five *Physimerus* species occurring on *M. micrantha* in South America.

The larval feeding habits are unknown, but they may attack roots. The adults feed on young leaves and petioles, causing the dieback of growing tips, and they may be destructive when in high densities. This species is uncommon in Trinidad, where it is restricted to shady conditions, whereas in Colombia it also occurs in the open.

Adults of *P. pygmaeus* have been found feeding on both *M. vitifolia* and *M. hookeriana*, in addition to *M. micrantha*. Field-collected adults fed on *Bidens pilosa*, but not on *Chromolaena odorata*. No natural enemies have been recorded. Further specificity tests with larvae and adults would be necessary before the potential of this species could be evaluated. Various halticine beetles, *Longitarsus* spp., show great promise for the biological control of ragwort *Senecio jacobaea*, Paterson's curse *Echium plantagineum* and common heliotrope *Heliotropium europaeum*.

***Pseudoderelomus baridiiformis* Coleoptera: Curculionidae**

Larvae of this weevil are not known and may be root or stem gall feeders. The adult burrows into the flowers, damaging the petals, stamens and stigma and prevents seed production from the flowering head it occupies. When common, levels of 25% damage have been recorded.

Adults of *P. baridiiformis* occur mainly in the flowers of M. *micrantha*, but have also been recorded from *M. trinitaria* and *M. vitifolia*. They occur rarely in the flowers of *Chromolaena odorata* and have been recorded once from *Neurolaena lobata*. No natural enemies are known.

Although the level of damage caused may be considerable, further studies of life history and host specificity are required.

***Teleonemia* sp. or spp. nr *prolixa* Hemiptera: Tingidae**

A taxonomic study of the bug genus *Teleonemia* (which contains more than 80 species) is required to enable the determination of correct identity of the one or more species of brown tingid bugs feeding on *Mikania* flowering heads. The species is not *T. prolixa*, which is highly specific to *Lantana camara* (Harley and Kassulke 1975).

The eggs are laid into the flower bracts and the nymphs and adults feed on the flower heads, but do not appear to cause much damage at low densities. Faeces deposited on the opening flowers may be sufficient to prevent seed production, particularly when these serve as a substrate for fungal growth. *T. harleyi* in Trinidad has a similar life cycle and feeding habits in *Lantana camara* flowers (Harley and Kassulke 1975).

Adults and nymphs of *Teleonemia* were found by Cock (1982a) on a number of *Mikania* species (*micrantha*, *vitifolia*, *trinitaria*, *hookeriana*). Although *T. prolixa* has been recorded from *Cinchona* sp. (Drake and Poor 1938), *Lantana camara* (Monte 1939) and *Acacia riparia* (Drake and Ruhoff 1965), the records for *Cinchona* and *Acacia* appear to be in error (Harley and Kassulke 1975). A parasite attacks the eggs of *Teleonemia* and the lygaeid *Xyonysius* sp. in *M. micrantha* flowers. *Teleonemia scrupulosa* has been used in a number of countries to considerable effect to help in the control of *Lantana camara*. If the flower-feeding *Teleonemia* that attack *Mikania* cause similar effects through injection of saliva, they may cause more damage than is apparent at first sight.

MINOR SPECIES

Cock (1982a) and Freitas (1991) list a further 22 species of insects attacking *M. micrantha* in Central and South America (Table 4.14.2). There are 7 species of Hemiptera, 3 Coleoptera, 10 Lepidoptera and 3 Diptera. Five of these are considered at this stage of knowledge to be promising.

Exema complicata Coleoptera: Chlamisidae

Adults and larvae of this beetle are leaf feeders on *Mikania* spp., *Chromolaena odorata* and perhaps other Asteraceae.

Longitarsus nr *amazonus* Coleoptera: Chrysomelidae

Adults of this halticine beetle feed on leaves of *M. micrantha* and larvae probably on roots. *Longitarsus* species generally have a very restricted host range.

Neolasioptera sp. Diptera: Cecidomyiidae

The larvae of this fly feed within the flower head and scar the seed shell, but the effect of this damage on seed viability is unknown. This species is parasitised by a eulophid *Tetrastichus* sp.

Sceloenopla sp. Coleoptera: Chrysomelidae

Adults of this hispine beetle feed on leaves and larvae are leafminers on *M. micrantha* and *M. trinitaria*. *Horismenus*? *aeneicollis* is recorded as a larval parasitoid. Hispine beetles have proved to be very effective against *Lantana camara*.

Tegosa claudina Lepidoptera: Nymphalidae

Earlier referred to as *Tegosa similis*, the larvae of this butterfly are leaf feeders on both *Mikania micrantha* and *M. cordifolia*. Eggs are laid in clusters and larvae are gregarious, passing through six instars (Freitas 1991).

Attempts at biological control

MALAYSIA

An extensive evaluation of natural enemies attacking *M. micrantha* was made in peninsular Malaysia prior to a decision to embark upon a biological control project (Teoh et al. 1985). Of the insects collected from or reared on the host plant, 2506 were classified and separated into commonly found and minor natural enemies (Table 4.14.3).

Although numerous insects were found to attack *M. micrantha*, not only was the extent of damage insignificant, but most of the abundant species were known pests of economic crops. For example, *Halticus minutus* and *Lamprosema diemenalis* are major pests of leguminous cover crops, *Homoeocerus serrifer* attacks rice and *Helopeltis* spp. are serious pests of cocoa. None of the natural enemies recorded in Tropical and South America were found in the survey. A number of fungi were also found, of which *Colletotrichium gloeosporioides* was the most important, comprising 84% of the samples. Other fungi included *Colletotrichium* spp., a non-sporulating brown fungus, *Rhizoctonia* spp., *Curvularia* spp. and *Pestalotia* spp. It was concluded that a strong case existed for the introduction of effective natural enemies.

Table 4.14.3 Insects attacking *Mikania micrantha* in peninsular Malaysia (Teoh et al. 1985).

Species	Effects
MAJOR SPECIES	
Orthoptera	
ACRIDIDAE	
Acrida turrita	holes in leaves
Hemiptera	
APHIDIDAE	
Aphis spiraecola	wrinkled leaves
CERCOPIDAE	
Clovia conifer	yellow spots on leaves and stems
CICADELLIDAE	
Bothrogonia ferrugenea	brown spots on stems
COREIDAE	
Homoeocerus serrifer	brown spots on leaves
Riptortus linearis	brown spots on leaves
MEMBRACIDAE	
Centrotypus flexuosus	necrosis on stems
MIRIDAE	
Halticus minutus	necrotic lesions on leaves
Helopeltis spp.	necrotic lesions on leaves
Lepidoptera	
PYRALIDAE	
Lamprosema diemenalis	
MINOR SPECIES	
Orthoptera	
ACRIDIDAE	
Catantops humilis	
Hemiptera	
APHIDIDAE	
Aphis gossypii	
CICADELLIDAE	
Nephotettix spp.	
Thysanoptera	
THRIPIDAE	
Isothrips spp.	
Microcephalothrips spp.	

(continued on next page)

Table 4.14.3 (continued)

Species	Effects
Parthenothrips spp.	
Thrips hawaiiensis	
Thrips tabaci	
Coleoptera	
CHRYSOMELIDAE	
Dactylispa bipartista	
COCCINELLIDAE	
Coelophora bissellata	
Epilachna indica	
Diptera	
TEPHRITIDAE	
Sphaeniscus atilus	
Lepidoptera	
AMATIDAE	
Amata huebneri	
PYRALIDAE	
Hellula undalis	

Liothrips mikaniae was introduced to Malaysia from Trinidad via England in 1989 for additional host specificity trials. Difficulties were experienced initially in mass rearing, due to unsuitable environmental conditions (lighting, temperature, aeration) low plant nutritional quality and predators (spiders, ants, and particularly a predatory thrips, *Xyloplothrips* sp. which destroyed 90% of the culture). Also, there were differences in the *M. micrantha* plants used. Some were hairless and others hairy. Larvae hatching from eggs along stems of the latter found difficulty in moving among the trichomes and many failed to reach the nearest leaf. Nevertheless, in Trinidad, *L. mikaniae* was found breeding on both plant types. After passing tests with 18 Malaysian crop species, 13 161 adult thrips were released in 25 batches of 99 to 1400 at 5 different sites from April 1990 to June 1991, but no establishment resulted (Table 4.14.4). Further thrips were imported in January 1992 to extend the genetic base of the rearing colony. Two releases were made into a fenced site, 18 000 adults, together with their rearing plants in pots, in May 1992 and 1500 adults about a month later. The pots were watered daily for two months. However, *L. mikaniae* gradually disappeared and, after eight months, none could be found. An ant that made its nest amongst *Mikania* leaves was observed to feed voraciously on adult, larval and pupal stages of *L. mikaniae*, but showed little interest in eggs, whereas a predatory *Haplothrips* sp. preferred eggs. About 20 other potential predators were evaluated, but were not implicated (Liau et al. 1991, 1993, Norman et al. 1992, Teoh et al. 1985, Ooi 1993, Ooi et al. 1993).

SOLOMON ISLANDS

A consignment of *L. mikaniae* was sent from Malaysia to the Solomon Is and released in the field in 1988, but the site was flooded shortly afterwards. Further releases were made, but no establishment has occurred (M. Vagalo pers. comm.). It was suggested that there may be differences in hospitability to *L. mikaniae* of the host plant between the Caribbean and Solomon Is.

PAPUA NEW GUINEA

Part of a consignment of *L. mikaniae* sent to the Solomon Is in 1989 was taken to Papua New Guinea, but there is no information on its fate (Williams et al. 1990), although it is believed to have died in quarantine (F. Dori pers. comm. 1993).

SRI LANKA AND ASSAM

In Sri Lanka and Assam it has been found that the plant parasite *Cuscuta chinensis* will suppress *Mikania* and prevent it spreading into tea plantations, although *C. chinensis* is not sufficiently selective to be used in the plantations themselves (Parker 1972). On Espiritu Santo (Vanuatu) a related species *Cuscuta campestris* is reported to suppress *M. micrantha* (M.J.W. Cock pers. comm.).

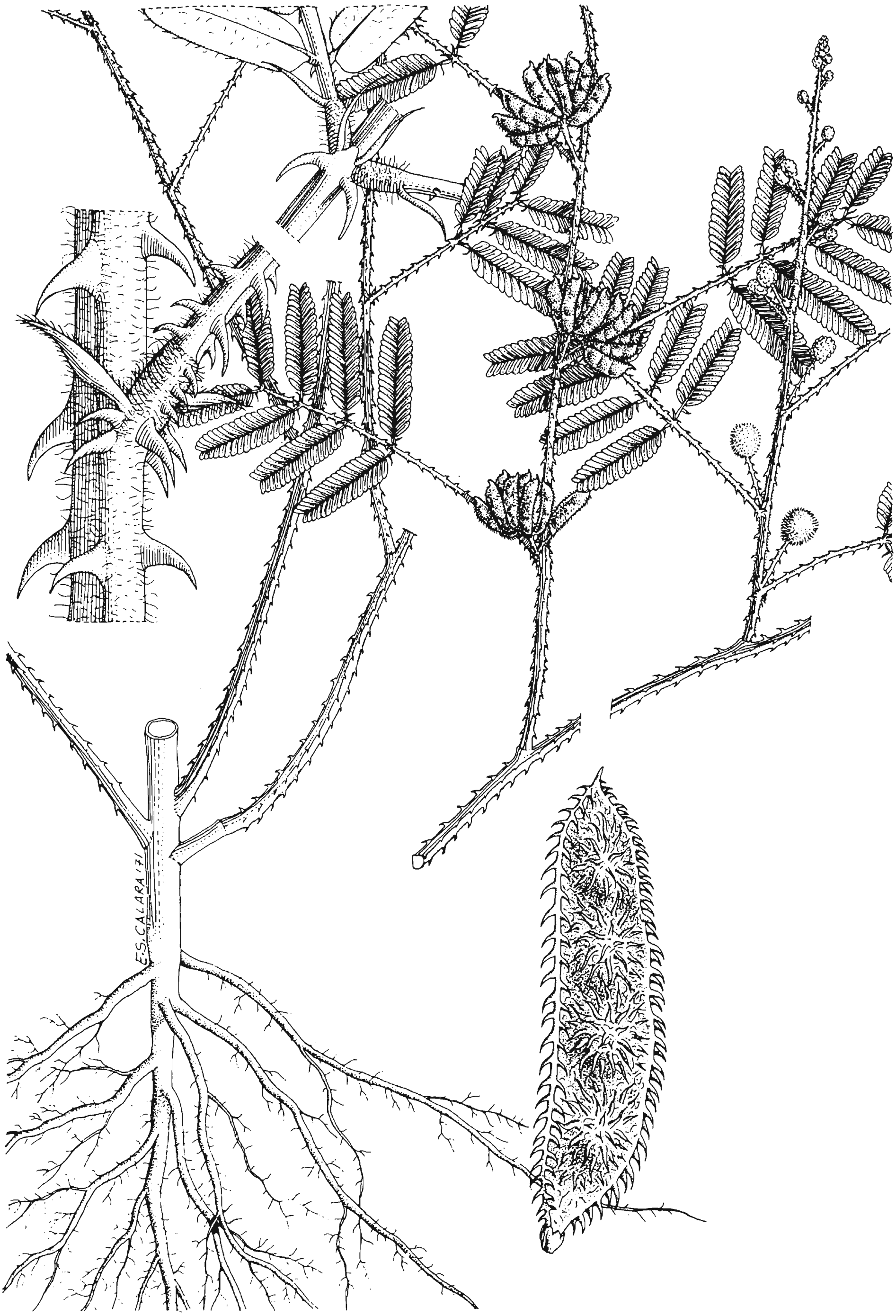
Table 4.14.4 Liberations for the biological control of *Mikania micrantha*.

Species	Where	From	When	Result	References
Thysanoptera					
PHLAEOTHRIPIDAE					
Liothrips mikaniae	Malaysia	Trinidad via UK	1991	–	Liau et al. 1991, 1993, Norman et al. 1992
	Solomon Is	Trinidad via UK	1988	–	M. Vagalo pers. comm., Williams et al. 1990

Comment

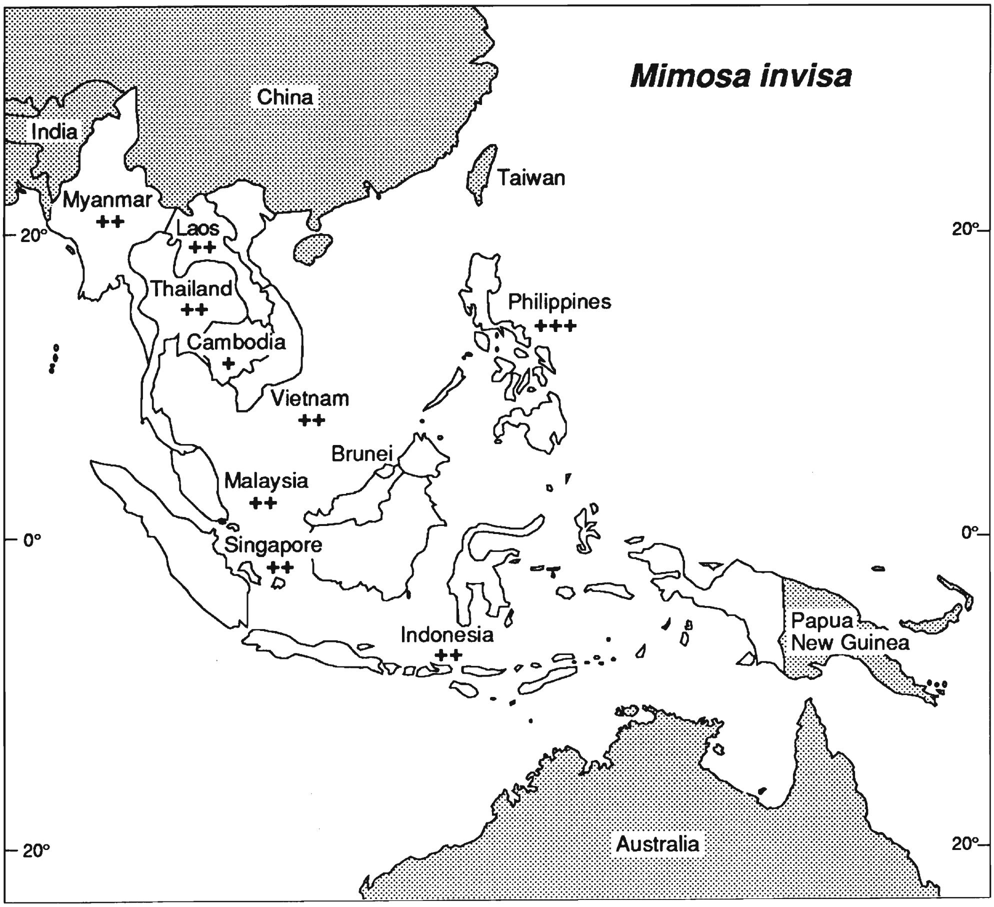
Mikania micrantha is an introduced weed of widespread importance in plantation crops throughout Southeast Asia. It is not a significant weed in its native range in tropical Central and South America, where it is attacked by a wide range of arthropod natural enemies. Several appear to be not only damaging to the weed, but also highly specific. It must be concluded that *M. micrantha* is a highly appropriate target for an attempt at biological control.

The failure of *Liothrips mikaniae* to become established in Malaysia is disappointing. The most probable explanation, partly supported by observations, is that heavy predation was the cause. Although the same guild of predators may be widespread on continental Southeast Asia, the same may not apply to island nations, particularly those in the southern Pacific, which have a far less diverse fauna and releases there might lead to successful establishment.



Mimosa invisa

(after Holm *et al.* 1977)



Map 4.15 *Mimosa invisa*

Creeping sensitive plant, *Mimosa invisa*, is native to Tropical America, where it is not regarded as a weed.

At least 70 species of insects attack it in Brazil and additional species elsewhere. Detailed studies have been made on two Hemiptera (*Heteropsylla spinulosa* and *Scamurius* sp.) and a moth (*Psigida walkeri*). *H. spinulosa* has caused extensive damage to *M. invisa* following its establishment in Australia and promising early results in Fiji, Papua New Guinea and Pohnpei, but disappointing results in Western Samoa. *Scamurius* sp. has failed to become established and *P. walkeri* is still under investigation.

The prospects for biological control of *M. invisa* appear to be good, although additional natural enemies may have to be considered.

4.15 *Mimosa invisa* Martius ex Colla

Mimosaceae

creeping sensitive plant; banla saet (Cambodia), borâng, pis koetjing, rèmbètè (Indonesia), duri semalu (Malaysia), makahiyang lalaki (Philippines), maiyaraap thao (Thailand), cò trinh nu móc (Vietnam)

Rating

	+++	Phil
18	++	Myan, Thai, Laos, Viet, Msia, Sing, Indo
	+	Camb

Origin

Tropical America. In Brazil southwards from Bahia to Paraná and westwards to Paraguay and tropical northeast Argentina; also lowlands of Central America from Veracruz (Mexico) southeastwards to Panama and adjacent Colombia.

Distribution

In addition to the above there are, in the Americas, scattered records from Brazilian Amazonia, the Guianas, Jamaica, Hispaniola and Cuba. *M. invisa* is widely distributed in Southeast Asia and the Pacific, also in Queensland, India, Sri Lanka, Taiwan and Nigeria. It was first recorded in Java in 1900 (Soerjani et al. 1987).

Characteristics

Mimosa invisa is a fast growing, abundantly thorny, biennial or perennial shrub with angular branching stems that become woody with age. The leaves are alternate, bipinnate and compound. The pink to purple globular flowers are borne on a short prickly stalk arising from a leaf axil. The seed pods are covered with stiff bristles and separate at transverse grooves into two to four, single-seeded segments.

The genus *Mimosa* does not occur naturally in Southeast Asia or Australia. *M. invisa* is one of three weedy species of *Mimosa* in this region, all of which are treated in this volume. They may be distinguished (i) by the number of pinnae in the leaves: *M. invisa* 4 to 9 pairs; *M. pigra* 6 to 16 pairs; and *M. pudica* 1 to 2 pairs and (ii) the size of the pods: *M. invisa* 4 seeds per pod, *M. pigra* 12 to 24 seeds. In addition, *M. invisa* stems have a dense covering of small prickles, whereas *M. pigra* stems have a sparse covering of large prickles (Lonsdale 1992).

M. invisa folds its pinnate leaves when touched, but is not as sensitive as some other species, such as *M. pudica*. The leaves fold at nightfall.

Unlike the situation in the more tropical regions, such as the Philippines where *M. invisa* flowers all year round, in central and southern Brazil it only flowers from the end of January to mid April. Seeds mature from February to the end of May and plants then senesce, losing most of their leaves, although a few green leaves remain at the stem base. For two to five months green plants are difficult to find. Senescence is not due to water shortage as well-watered plants in the laboratory also senesce. However, germination occurs when moisture is available, so young plants may appear after showers of rain (Garcia 1982b).

Importance

M. invisa scrambles vigorously over other plants, forming dense tangled thickets up to 2 m high. It is a nitrogen-fixer and its extremely rapid growth smothers useful plants and other weeds. Its sharp, recurved thorns make stock reluctant to graze on it and difficult for them to penetrate the stands. Crops infested with *M. invisa* are difficult to harvest because the thorns puncture and lacerate the hands of the workers. It is common along roadsides and in moist waste places. It causes major problems in coconut, tea and rubber plantations, sugarcane and pineapple fields, crop lands and pastures. It is not a problem in the Americas, western Asia, East Africa or Europe, but is a serious weed in Southeast Asia and the Pacific. A spineless variety, *M. invisa inermis*, has been suggested as a tropical pasture legume, but its tendency to revert to the thorny type and its potential toxicity has discouraged its use (Waterhouse and Norris 1987).

In the Americas, *M. invisa* is most common in the Paraná basin in the State of San Paulo (Brazil), but even there pure stands are not common and it does not appear to invade nearby crops. In forest regions it occurs as thickets among grasses along roads, river banks and in waste places; it occurs more commonly on the fringe of cities (Garcia 1982b).

Natural enemies

Information up to 1986 was summarised by Waterhouse and Norris (1987).

M. invisa is seldom troublesome in Brazil or Argentina and some 70 species of insects and two fungi are known to attack it in Brazil (Table 4.15.1). Additional insects are known in the Americas, but they have not yet been studied. A pathogenic fungus *Corynespora cassiicola* kills *M. invisa* in Australia (Haseler 1984), heavy infestations of scale insects attack it in Fiji (Mune and Parham 1967), a non-specific lymantriid larva feeds on young leaves and flowers in Thailand (Napompeth 1982) and a pierid butterfly *Eurema* sp. breeds on it in Papua New Guinea and New Britain (T.L. Fenner pers. comm.).

More than half of the insects attacking *M. invisa* in Brazil have not yet been identified. Indeed it is probable that most of these are undescribed species and, if so, it follows that there is no published information about them. Where possible, identification, even to a genus, may be valuable. For example, species of the genus *Heteropsylla* are restricted to legumes, with known hosts only in the Mimosaceae or Caesalpiniaceae. Of the 35 described species with recorded hosts, 31 are specific to a single host (Hodkinson and White 1981, Muddiman et al. 1992).

Only a few of the 70 insect species attacking *M. invisa* are known as agricultural pests (Table 4.15.1). From the remainder, preliminary observations on a subgroup of about 10 species led to detailed studies on three, *Heteropsylla spinulosa*, *Scamurius* sp. and *Psigida* (= *Psylopigida*) *walkeri*.

Attempts at biological control

AUSTRALIA

Large numbers of *Heteropsylla spinulosa* were released in coastal Queensland, commencing in 1988 (Table 4.15.2). This involved 33 field sites, averaging thousands of insects per release (M. Ablin pers. comm. 1990). Within two years, the psyllid had dispersed widely into all infestations of *M. invisa* in pastures. Dense clumps of the weed were reduced to small masses of bare stems with stunted growing tips, leading to other vegetation reestablishing itself. Seed production from severely affected plants was reduced by 85 to 100% (Ablin 1992, Anon 1988). It did not attack *M. pudica* plants nearby. A more recent assessment, using insecticide-produced exclusion, found that *H. spinulosa* reduced seed production on average by 80%, growing tip elongation by 77% and the growth rate of tips by 50% (Ablin 1993a). Although *M. invisa* may still produce clusters of seed pods when damage is high, the pods contain very few viable seeds. Mature plants support low populations of *H. spinulosa* during the dry season from July to November. Thereafter, psyllid abundance increases with the onset of summer rains, with peak numbers in April or May (M. Ablin pers. comm. 1993).

Scamurius sp. was liberated in Queensland from 1987 to 1990 and proceeded to kill the tips of many shoots (Anon 1988). However it did not become established. It was also released against *Mimosa pigra* in the Northern Territory where it survived for several months, but fecundity was very low and the colony died out (M. Ablin pers. comm. 1993).

FIJI

H. spinulosa was brought in from both Western Samoa and Australia in 1993 and, after a generation in quarantine, was liberated in Nadi in June. Six weeks later all stages were seen in the field. A mealy bug and *Tetranychus* sp. mites are occasionally found on *M. invisa* in the field (S.N. Lal pers. comm. 1993).

PAPUA NEW GUINEA

Heteropsylla spinulosa from Australia was reared through one generation in quarantine in Port Moresby and released early in 1993 in the Ramu Valley near Lae. Within a few months it had severely damaged *M. invisa* and killed many plants (F. Dori pers. comm. 1993).

POHNPEI

Ten months after release at Palikir, Pohnpei *H. spinulosa* became abundant on *M. invisa* and subsequently killed many plants. Many psyllids were transferred to *M. invisa* in other areas (N.M. Esguerra pers. comm. 1993).

WESTERN SAMOA

A total of 47000 nymphs and adults of *Heteropsylla spinulosa* from Australia were liberated in Western Samoa in 1988 and 1989 and, a year later, the psyllid was reported at some sampling sites to have reduced seed production, although not the area infested (Willson and Ablin 1991).

Scamurius sp. was also liberated in Western Samoa in 1989 and was seen in the field after more than one generation, but not in more recent times. There have been no reports of its effects. *M. invisa* continues to be a serious weed, with more than 85% of villages on the main island of Upolu being infested (Willson and Garcia 1992).

Important Natural Enemies

INSECTS

Heteropsylla spinulosa Hemiptera: Psyllidae

The average development period of this small (2.5 mm long) pale green, Brazilian psyllid is about 28 days. High populations cause severe stunting and distortion of the leaves and growing tips; flowering is reduced or even prevented. A sticky honeydew is produced which encourages a dense growth of sooty moulds. Females attach eggs by means of a pedicel inserted into the plant tissue between overlapping leaflets. Young nymphs live hidden between the leaflets, whereas adults feed on leaflets and shoots.

In Brazil reduviid bugs pierce nymphs with their proboscis and withdraw them from their shelters, whereas larvae and adults of the predatory coccinellid *Eriopis connexa* are only able to capture exposed nymphs. Nymphs are also attacked by an encyrtid wasp *Psyllaephagus yaseeni* (Willson and Garcia 1992). The predatory vespid wasp *Protonectarina sylveiriae* attacks nymphs and an unidentified wasp causes up to 13% parasitisation (Garcia 1985).

In extensive host specificity tests *H. spinulosa* adults and nymphs were unable to live on any plant other than *M. invisa* and its spineless variety *M. invisa inermis*. In the field it did not attack *M. pudica*, even when large infestations of *M. invisa* were destroyed and *M. pudica* was common nearby (M. Ablin pers. comm. 1993). Eggs were laid on 18 other plant species, but only under glasshouse conditions (Garcia 1985, Wild 1987, Willson 1987, Willson and Garcia 1992) and *Heteropsylla spinulosa* was judged safe to liberate in Australia and four other countries (Table 4.15.2)

Psygida walkeri Lepidoptera: Cercophanidae

This moth is widespread in Brazil and Colombia. Females have a wing span of up to 5 cm. When fully grown its greenish, spiny larvae may reach a length of 5 cm. They feed voraciously on leaves, flower buds, tender seed pods and on the top 30 cm of tender stems and branches, preventing both flowering and seed production. The life cycle takes about 2 months and there are 3 generations a year. There is a pupal diapause of up to 4 months in Brazil

Larvae of *P. walkeri* have been found in the field on *M. invisa*, *M. rixosa*, *M. velloziana* and once on *M. somnians*. They have not been found in the field in Brazil on other leguminous plants near *M. invisa* plants bearing larvae, nor on any plants of economic importance (Garcia 1983). However, under artificial conditions larvae can be reared on black wattle *Acacia mearnsii* and may also feed on *Mimosa pudica* and *Leucaena leucocephala*. Although adults will oviposit on *A. mearnsii*, no attack has been observed in the field (Haseler 1984). Further host specificity testing is in progress in Australia.

***Scamurius* sp. Hemiptera: Coreidae**

Both nymphs and adults of this large (up to 2.2 cm) coreid bug feed on the shoots, causing them to collapse, thereby inhibiting vegetative growth and flowering. First instar nymphs moult whether fed or not and, after five instars, mature in about seven weeks. There are about four generations a year, from early summer to autumn, and adults may live for six months or more.

Adults were found to probe many species of plants, but to feed only on species of *Mimosa*. Nymphs were able to develop on *M. invisa* and on two other weedy species, *M. pigra* and *M. pudica*, but not on other plants (Garcia 1984, Wild 1986, 1987). This species was approved for release in Australia and Western Samoa (Table 4.15.2).

FUNGUS

Corynespora cassiicola

This stem spot fungus is very common in hot humid weather in north Queensland, Papua New Guinea (Keravat, Rabaul) and Western Samoa. It can be very damaging to *M. invisa* if environmental conditions are suitable (Willson and Ablin 1991). The strain involved appears to be specific to *M. invisa*, although fungi with the same specific name are reported from cowpea, papaya and tomato. If suitable environmental conditions persist in the field *M. invisa* plants shed their leaflets and stems die back as lesions cover the plant (M. Ablin pers. comm. 1993).

Comments

The use, in the future, of *H. spinulosa* from Brazil against *M. invisa* is complicated by several introductions of natural enemies that have already been made by Southeast Asian countries (eg. Thailand, Philippines). These introductions were of two parasitic wasps (*Tamarixia leucaenae* and *Psyllaephagus yaseeni*) native to the Caribbean and Central America (Noyes 1990) and one or more predatory coccinellids against a pest psyllid *Heteropsylla cubana* which appeared from the Americas in the 1980s. This pest can cause severe damage to *Leucaena leucocephala* which is widely planted for firewood and as fodder. Tests showed that these natural enemies of *H. cubana* would also attack *H. spinulosa* (Baker 1990). As a result, several countries where *M. invisa* is a serious pest (Australia and most Pacific islands, but not New Caledonia) have deferred introducing natural enemies of *H. cubana*.

Several interesting points, relevant to any investigation for natural enemies in South America, emerge from the *M. invisa* project there:

- Before the studies of C.A. Garcia in the early 1980s almost nothing was known about the insects attacking it, yet within a year 57 insects were listed from Brazil (Garcia 1982a,b) and within two years a further 10. No records are available from elsewhere in the Americas, except of a *Heteropsylla* sp. from Colombia (Garcia 1983).
- It has not been possible for taxonomists to assign a specific name (and sometimes not even a generic name) to the majority of insects collected. Some were not previously represented in any museum collections and many are almost certainly undescribed species.

- Only one (*Scamurius* sp.) of the three insects eventually selected for detailed study was recognised in the first survey which yielded 57 species. It is clear that follow up surveys are essential.
- No study has yet been made of the insects attacking *M. invisa* over a very large area of its presumed native range. From brief observations in Colombia Garcia (1983) commented that larvae of Lepidoptera were 'quite similar to those collected off *M. invisa* in Brazil. Coleoptera in general look different'.
- Should existing biological control be considered inadequate, further detailed studies covering the entire native range of *M. invisa* might well reveal additional, adequately specific insects attacking it.
- Examination of the host specificity of more of the insects recorded from Brazil (Table 4.15.1) might also reveal further adequately specific insects.
- *H. spinulosa* does not thrive under either very wet or very dry conditions. Its populations depend upon the availability of green foliage and, in the dry season, are found on pockets of green foliage. A flush of growth after rain leads to a build up in populations to a level that severe damage may be caused, sufficient to kill many *M. invisa* plants.

Table 4.15.1 Natural enemies of *Mimosa invisa* in Brazil (from Garcia 1982a,b, 1983 and his unpublished monthly reports).

Species	Comment
INSECTS	
Orthoptera	
TETTIGONIIDAE	
sp. 1	attacks flowers
sp. 2	attacks leaves
Hemiptera	
CERCOPIDAE	
Tomaspis (= *Zulia*) *enteriana*	
sp.	belongs to Gyopinae
CICADELLIDAE	
sp. 1	common on *Mimosa invisa* and *M. pigra* and colonises *Acacia mearnsii* and *M. scabrella* during the dry season
sp. 2	
COREIDAE	
Scamurius sp. 1	see text
Scamurius sp. 2	
MIRIDAE	
Horciacinus signoreti (= *H. argentinus*)	
Taylorilygus pallidulus	
MEMBRACIDAE	
Ceresa ustulata	an agricultural pest
Enchenopa gracilis	
Micrutalis sp.	

(continued on next page)

Table 4.15.1 (continued)

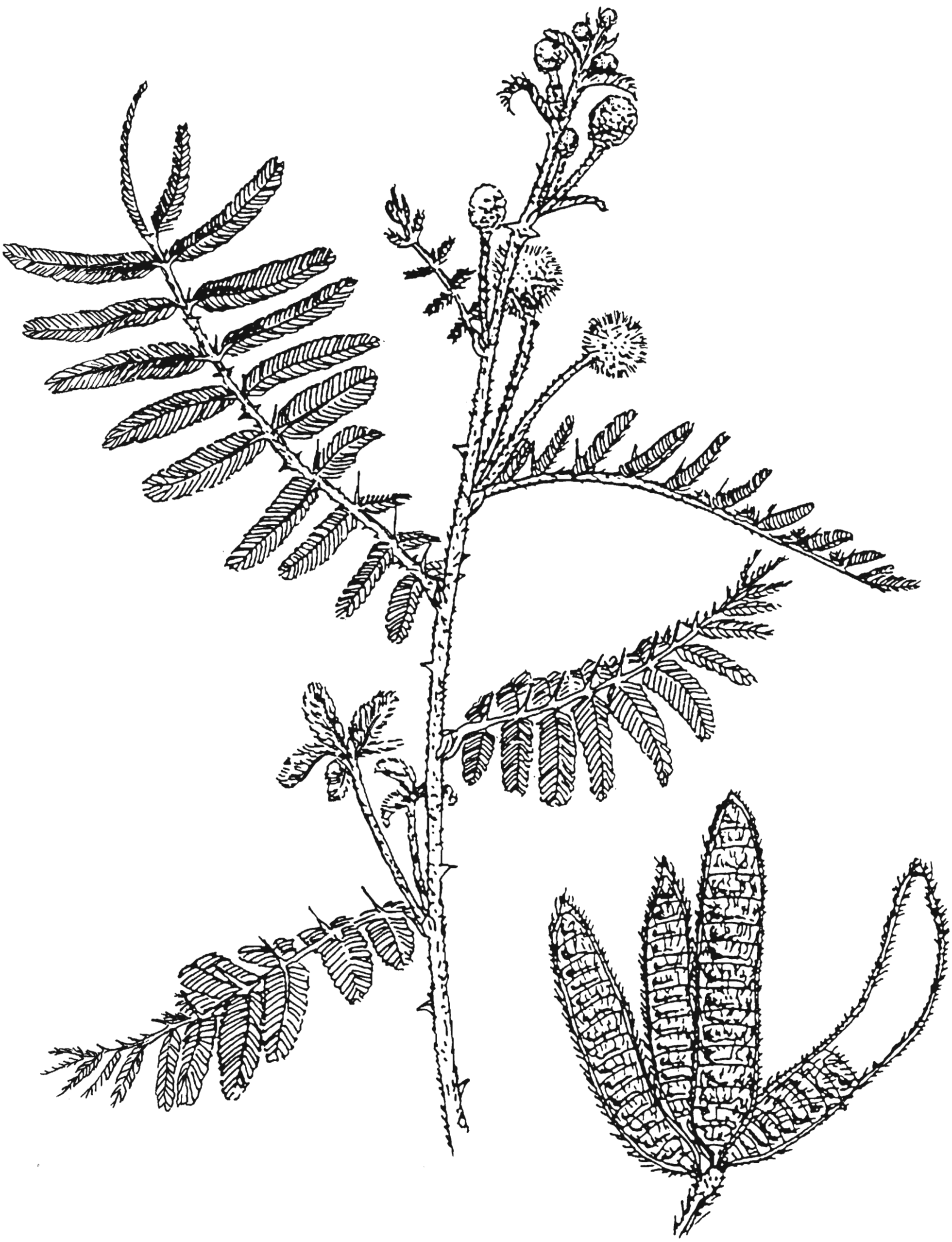
Species	Comment
PENTATOMIDAE	
Acrosternum herbidum	
Dichelops furcatus	an agricultural pest
Edessa meditabunda	an agricultural pest
Euschistus tristigmus cribarius	
Euschistus luridus	
Piezodorus guildinii	an agricultural pest
PSYLLIDAE	
Heteropsylla spinulosa	see text
Heteropsylla sp.	from Colombia
THYREOCORIDAE	
Gyrocnemis sp.	
Coleoptera	
CHRYSOMELIDAE	most Chrysomelidae were present in low numbers.
Colaspis sp.	adults eat *M. invisa* leaves
Cryptocephalus viridiaeneus	
?*Hilax* sp.	excellent defoliator; also attacks *M. pigra*
Lactica sp.	
Lexiphanes ?semicyaneus	
Lexiphanes sp.	
Metaxyonycha pallidula	
Nodonota sp.	
Pachybrachys sp.	
Systena s-littera	
Temmodachrys sp. nr *aphodoides*	
CURCULIONIDAE	
Asynonychus godmani (= *Pantomorus cervinus*)	adults eat leaves and show strong preference for *M. invisa*, but will also attack *M. pudica*, *Calliandra selloi* and *Acacia mearnsii*
Chalcodermus sp.	larvae bore stems, brown adults eat leaves
Chalcodermus sp. nr *segnis*	black adults bore green seeds, but did not attack pods of 7 other legumes
Hypanthus sp.	
Promecops sp. 1	
Promecops sp. 2	
Sibinia aspersa	adults eat ovaries, larvae the seeds; recorded from *Mimosa albida* and *M. quadrivalis*, but would not attack six other legumes including *Leucaena leucocephala*
Sibinia ?subulirostris	*seminicola* group, larvae eat seeds, adults the leaves and ovaries and are also found in *Mimosa rixosa*
Sibinia sp.	
Lepidoptera	
AMATIDAE	
sp.	red hairy larva
CERCOPHANIDAE	
Psigida walkeri	see text
GEOMETRIDAE	
sp. 1	debris-covered larva
sp. 2	twisted larva

(continued on next page)

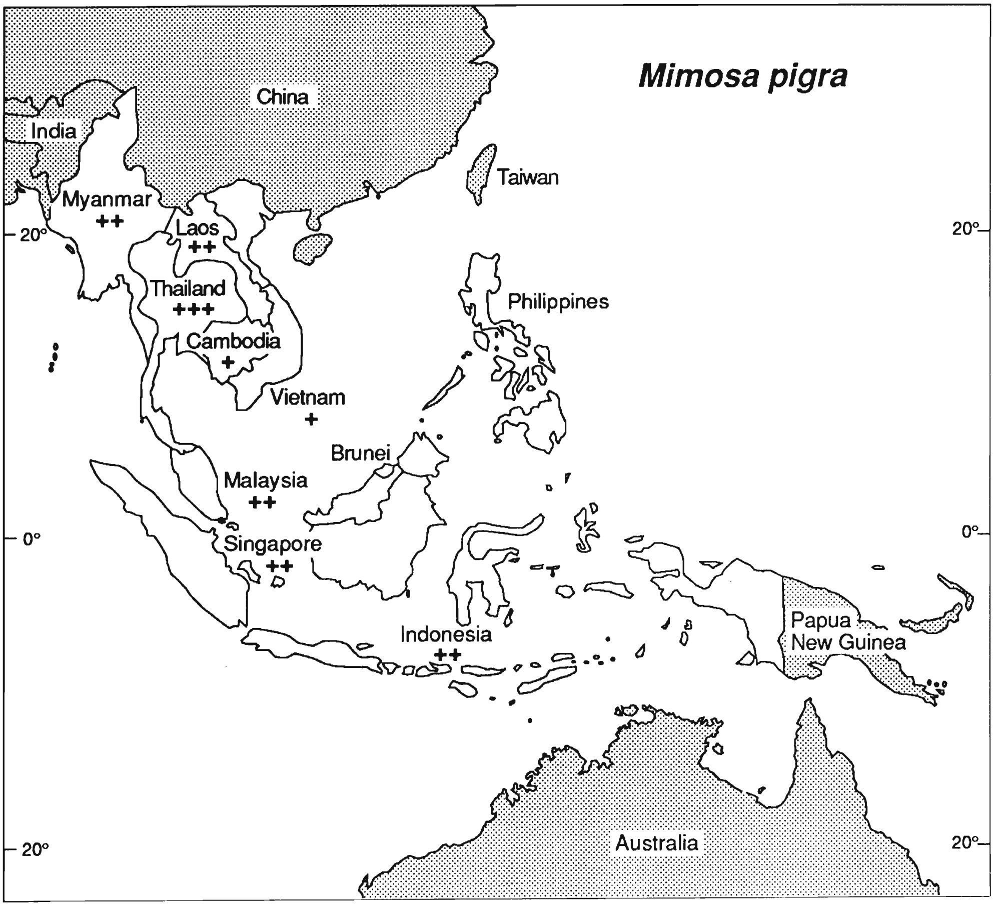
Species	Comment
sp. 3	reddish green larva
sp. 4	common slim larva
sp. 5	thick twig larva
HESPERIIDAE	
Cogia (= *Caicella*) *calchas*	occurs in Mexico and Argentina; eggs laid also on *M. pudica*, *M. scabrella*, *Indigofera anil*, *Skranquia* sp., larvae are heavily parasitised
LYCAENIDAE	
Hemiargus hanno	larvae eat leaves, flowers and seed pods; also *M. pudica* flowers
Tmolus (= *Thecla*) *azia*	larvae eat leaves and flowers; also *M. pudica* and groundnut flowers
NOCTUIDAE	
sp. 1	velvet black larva; also on *M. pudica*, *M. scabrella*, *Acacia mearnsii*, *Calliandra selloi*, *Leucaena leucocephala*
sp. 2	reddish larva
sp. 3	green larva
sp. 4	small green larva
PIERIDAE	
Eurema tenella	occurs in Brazil, Argentina, Paraguay, Bolivia; larvae defoliate *M. invisa*; also eat *M. pudica*, *M. scabrella*, *Acacia mearnsii* and (reluctantly) *Leucaena leucocephala*
TORTRICIDAE	
sp. 1	flower/twig roller
sp. 2	pod eater
sp. 3	larvae eat leaves
sp. 4	larvae roll flowers
FAMILY UNKNOWN	4 species, two bore in the stem tips, 1 eats pods and 1 the flowers
FUNGI	
Cercospora canescens	
Fusarium sp.	
Uredo mimosae-invisae	from Venezuela (H.C. Evans pers. comm. 1992)

Table 4.15.2 Liberations for biological control of *M. invisa*.

Species	From	Liberated	When	Result	References
Heteropsylla spinulosa	Brazil	Queensland	1988	+	Ablin 1992, Anon 1988
		Fiji	1993	?	S.N. Lal pers. comm. 1993
		Papua New Guinea	1993	+	Ablin 1993b, F. Dori pers. comm. 1993
		Pohnpei	1992	+	N.M. Esguerra pers. comm. 1993
		Western Samoa	1988	+	Willson & Garcia 1992
Scamurius sp.	Brazil	Queensland	1987	-	Anon 1988
		Western Samoa	1988	?	



Mimosa pigra
(after CSIRO, 1992)



Map 4.16 *Mimosa pigra*

Mimosa pigra originated in the area extending from Mexico to Amazonia and Venezuela. Four beetles and two moths have been established on *M. pigra* in Australia in the past 10 years. Two stem-boring moths *Neurostrota gunniella* and *Carmenta mimosa* are having a significant effect on the vigour of the weed. *N. gunniella* has spread widely, infests most stems and is reducing seed production. All except *N. gunniella* have been liberated in Thailand. *N. gunniella* was not liberated because it can attack the aquatic vegetable *Neptunia oleracea*. However the two seed-feeding bruchids are destroying up to 20% of the seed in Thailand

A specific, highly pathogenic fungus, *Phloeospora mimosae-pigrae*, has been approved for release in Australia and six insects and a rust fungus are under study.

There are grounds for confidence that a group of natural enemies will become available that, acting together, will cause significant damage to *M. pigra.*

4.16 *Mimosa pigra* L.

Mimosaceae

giant sensitive plant; mai yah raap yak, maiyarap ton, chi yop luang (Thailand); kembang gajah, semalu gajah (Malaysia); trinh nu nhon (Vietnam); putri malu (Indonesia)

Rating

	+++	Thai
15	++	Myan, Laos, Msia, Sing, Indo
	+	Camb, Viet

Origin

Mexico, southern Venezuela, or central Amazon basin.

Distribution

Throughout the tropics and still spreading. It was an early invader of tropical Africa and is spreading aggressively in northern Australia and Southeast Asia. It is not present in the Philippines or the oceanic Pacific. Details of its distribution and time of recognition in various countries are given in Lonsdale (1992).

Characteristics

M. pigra is a perennial leguminous shrub, growing up to 6 m high on a wide range of soils, and found in moist open sites with a rainfall between 750 and 2250 mm in the tropics. Its leaves are bipinnate and sensitive to the touch, through movements of the petiole and pinnules. Petioles bear a slender prickle at the junction of each of the 6 to 16 pairs of pinnae and sometimes have stouter prickles between each pair. The stems bear broad-based, sharp thorns up to 7 mm long. Mature plants have many branches growing from the base, with a skirt of adventitious roots forming in seasonally inundated sites. They have a large central taproot which penetrates 1 to 2 m deep and a lateral root system that extends up to 3.5 m from the stem at a depth of about 5 cm. The flowers are mauve to pink, massed in globular heads 1cm in diameter, with each head containing about 100 flowers. Seed pods are produced in clusters of about 7, are densely bristly, 3 to 8 cm long and break transversely into segments each containing a seed. The bristles facilitate floating and thus rapid spread of the weed along river systems. In regions with pronounced wet and dry seasons, the former is the main period of growth, with flowering mainly from mid to late wet season. Development from flower bud to ripe seed takes about 5 weeks (Lonsdale 1992). Average seed production is about 9000 seeds per plant, but up to 220 000 has been recorded. Although most seeds that lodge on or near the soil surface probably germinate within two years many seeds deeper in the soil lie dormant for long periods (at least 23 years).

Previously, two varieties were recognised var. *pigra* and var. *berlandieri*, of which only *pigra* has spread around the world. Variety *berlandieri* has recently been renamed *Mimosa asperata* (Barneby 1989, Lonsdale 1992).

Importance

In tropical America *M. pigra* usually occurs as small clumps of multi-stemmed plants growing in seasonally flooded habitats. However, in many countries to which it has been introduced, *M. pigra* is a serious weed of wetlands. Dense, prickly thickets compete with pastures, prevent access to water and hinder mustering. The thickets exclude native vegetation and so alter the environment that many native plants and animals are eliminated or seriously affected (Lonsdale 1992). The weed leads to sediment accumulation in irrigation systems and reservoirs and, as the seed segments float, many end up in fallow rice paddies where they germinate rapidly. River sand containing seeds helps to establish new infestations when transported to building sites, road constructions etc.

Cattle and horses occasionally browse on young plants and some wild animals find it acceptable, particularly as a dry-season browse but, in general, it seems to be of low palatability. The leaves contain low levels of the toxic amino acid mimosine. *M. pigra* was introduced to Thailand in 1945 as a green mulch crop and for erosion control in rice paddy irrigation channels, but it was soon found that the problems associated with it far outweighed any advantages (Wara-Aswapati 1983). However it is used still as a source of firewood and bean poles, although it is now regarded as a very serious weed.

Natural enemies

Surveys for natural enemies have been made in Brazil, Mexico, Venezuela (Harley et al. 1983), Honduras (Habeck and Passoa 1982), Costa Rica (Forno 1992) and most recently in Belize and Cuba (I.W. Forno pers. comm.). In Honduras more than 60 species were listed (2 Orthoptera, 27 Hemiptera, 1 Diptera, 15 Coleoptera and 15 Lepidoptera). Although a full list of insects attacking *M. pigra* in its native range has yet to be published, a diverse group of over 200 is known to occur (Forno et al. 1991b). Only 12 species are considered to be pests of agriculture and at least 45 have habits that are likely to lead to restricted host specificity, such as gall forming, leaf mining or stem boring. It is suggested that some 10% may be adequately host specific. These are likely to attack different parts of the plant causing complementary damage, so that the prospects for biological control appear good (Forno et al. 1989b, Wilson et al. 1990).

Six of the tropical American species of insects have been liberated (Table 4.16.1) five more were eventually not released after tests showed (or suggested) that they are insufficiently host specific (Table 4.16.2) and a further six are currently being examined in Australia or Mexico for host specificity (Table 4.16.3). However, the list of potential insects for consideration is far from exhausted. Host testing of agents for *M. pigra* is discussed by Forno and Harley (1992).

Two fungal pathogens of *M. pigra* (*Diabole cubensis* and *Phloeospora mimosae-pigrae*) cause considerable damage in Mexico in spite of being extensively attacked by hyperparasitic fungi. Without these, the pathogens should prove even more damaging. Other, less damaging fungi include *Colletotrichium gloeosporioides*, *Pestalopsis* sp., *Phomopsis* sp. and *Oidium* sp. (Evans 1988, 1990, Evans and Seier 1991, Evans et al. 1993).

Table 4.16.1 Releases for the biological control of *Mimosa pigra*.

Species	Part attacked	Liberated	Result	References
Coleoptera				
APIONIDAE				
Coelocephalapion aculeatum	flower buds	Australia 1992	+	Forno et al. 1994, Wilson et al. 1992
		Thailand 1991	?	Wilson et al. 1992
BRUCHIDAE				
Acanthoscelides puniceus	seeds	Australia 1983	+	Kassulke et al. 1990, Wilson & Flanagan 1991,
		Thailand 1984	+	Harley et al. 1985
		Vietnam 1987	?	Julien 1992
Acanthoscelides quadridentatus	seeds	Australia 1983	+	Forno et al. 1991b, Harley et al. 1985, Kassulke et al. 1990, Wilson & Flanagan 1991
		Thailand 1984	+	Forno et al. 1991b, Harley et al. 1985
		Vietnam 1987	?	Julien 1992
CHRYSOMELIDAE				
*Chlamisus mimosae**	pinnae & stems	Australia 1985	+	Julien 1992
		Thailand 1986	+	Julien 1992
		Vietnam 1990	?	Julien 1992
Lepidoptera				
GRACILLARIIDAE				
Neurostrota gunniella	pinnules & stems	Australia 1989	+	Davis et al. 1991, Wilson & Flanagan 1990
SESIIDAE				
Carmenta mimosa	stem	Australia 1989	+	Forno et al. 1991a,
		Thailand 1991	?	Julien 1992

* Introduced from Brazil, the remaining 5 insects from Mexico.

Host specificity tests indicate that *Phloeospora mimosae-pigrae* is specific to *M. pigra* and Australian authorities have granted permission to liberate this pathogen. Testing of *Diabole cubensis* is still in progress.

Attempts at biological control

AUSTRALIA

M. pigra was probably introduced to Australia at Darwin sometime during the 20 years before 1891 (Miller and Lonsdale 1987, Lonsdale et al. 1989) and, after a slow start, underwent a population explosion in the late 1970s and, by 1992, had already covered some 800 km^2 of wetlands (Lonsdale 1992). In its century of occupation, at least 114 species of phytophagous insects have come to attack it (5 Orthoptera, 3 Isoptera, 49 Hemiptera, 21

Table 4.16.2 Insects tested against *Mimosa pigra*, but not released (after Forno 1992).

Species	Portion attacked
INSECTS	
Coleoptera	
CHRYSOMELIDAE	
Cryptocephalus (= *Diplacaspis*) nr *miserabilis*	leaves
Diplacaspis nr *prosternalis*	stems and leaves
Lexiphanes guerini	young leaves
Syphrea bibiana	seedlings and roots
Lepidoptera	
GELECHIIDAE	
nr *Aroga*	leaves and stems

Table 4.16.3 Natural enemies of *Mimosa pigra* under investigation (I.W. Forno pers. comm. 1993).

Species	Portion attacked	Status
INSECTS		
Coleoptera		
APIONIDAE		
Coelocephalapion pigrae	flower buds and leaves	awaiting approval for release
CURCULIONIDAE		
Chalcodermus serripes	flower buds and immature seeds	in quarantine in Australia
Sibinia fastigiata	immature seeds	in quarantine in Australia
Sibinia ochreosa	flower buds	under study in Mexico
Sibinia peruana	flower buds	in quarantine in Australia
Sibinia seminicola	immature seeds	in quarantine in Australia
FUNGI		
Diabole cubensis	leaves	under host testing
Phloeospora mimosae-pigra	stems, leaves, seed pods	approved for release

Coleoptera and 36 Lepidoptera). Of the 114, 47 species are seldom encountered, 39 are occasionally found and 28 are common. Thirty of the species are known pests of cultivated plants and all except two are thought to be polyphagous. These two (a psyllid and a gelechiid moth) probably feed only on a restricted number of leguminous plants. In this survey no plant pathogens were recorded (Flanagan et al. 1990, Wilson et al. 1990).

In spite of this diverse insect attack there is still an enormous difference, two orders of magnitude, between the bank of *M. pigra* seeds in the soil in Mexico (a mean of 117.5/m^2) and Australia (a mean of 12 380/m^2). This is believed to reflect the differential occurrence of effective natural enemies in each region (Lonsdale and Segura 1987).

The first insects to be liberated—in 1983—for biological control of *M. pigra* were two seed feeding bruchid beetles, *Acanthoscelides quadridentatus* and *A. puniceus*, both of which established readily (Table 4.16.1). They had previously been shown to be adequately host specific (Kassulke et al. 1990). Although these species have become widespread, on average they destroy only 0.8% of mature seed, so are not having much impact. Of the beetles sampled, 97.8% proved to be *A. puniceus* (Forno et al. 1991b, Wilson and Flanagan 1991, Wilson et al. 1992). A parasitoid, *Dinarmus* sp. (Pteromalidae), was reared from field-collected bruchids, but did not appear to be having much influence on beetle populations (C. Wilson pers. comm.).

Next, in 1985, the stem feeding beetle *Chlamisus mimosae* was released and readily became established (Forno et al. 1991b) and in 1992/93 large populations have been found at the Finniss R., Northern Territory and are severely damaging *M. pigra* stems (I.W. Forno pers. comm. 1993).

During 1989, two stem boring moths *Neurostrota gunniella* and *Carmenta mimosa* were released. *N. gunniella* established rapidly and, within a few months, was not only widespread near the release site but damaging a large number of stems (Forno et al. 1991b, Wilson and Flanagan 1990). By 1993, it had spread to all *M. pigra* infestations and is associated with a naturally-occurring, exotic, die-back pathogen (Wilson 1992). There is a strong negative correlation between seed production and moth populations, suggesting that *N. gunniela* can reduce seed numbers by up to 60% (Anon 1992).

Carmenta mimosa is very damaging to young plants and is spreading rapidly in the Finniss R. region where it is severely damaging stems (I.W. Forno pers. comm. 1993, Wilson 1992).

The flower bud weevil *Coelocephalapion aculeatum* was liberated in 1992 and has become established, but its effects remain to be assessed (Forno et al. 1994, Wilson et al. 1992).

THAILAND

M. pigra was introduced from Indonesia to the Chiang Mai province between 1947 and the early 1960s as a cover and green manure crop. When found useless for the purpose, it was employed for the control of irrigation ditchbank erosion, but has now become one of the worst and most aggressive weeds in the country.

Napompeth (1981) reported 5 insect species attacking *M. pigra* but, of these, only the boring beetle *Sagra femorata* caused much damage. A further study (Napompeth 1983) increased the number to 19 insects, but without adding any promising species.

Both *Acanthoscelides puniceus* and *A. quadridentatus* were liberated in 1984 (Table 4.16.1) and are now destroying between 1% and 20% of mature *M. pigra* seeds, which is significantly higher than that recorded for Australia (Forno 1992). The reasons for this different level of effect are not known. *Chlamisus mimosae* was liberated in 1986 and became established, but is not causing significant damage. The moth *Neurostrota gunniella*, which is producing such spectacular damage in Australia, has not been liberated in Thailand because it has been shown to be capable of developing in the aquatic *Neptunia oleracea*, which is used as a vegetable. Two other species, the weevil *Coelocephalapion aculeatum* and the moth *Carmenta mimosa* were liberated in 1991 (Wilson et al. 1992), but there is no information on their establishment or impact.

MALAYSIA

Acanthoscelides quadridentatus and *A puniceus* have become established at Kota Bharu in northern Malaysia adjacent to the region where they are established in Thailand (B. Napompeth pers. comm. 1993).

MYANMAR

Acanthoscelides quadridentatus and *A puniceus* have also become established in Myanmar along the border with Thailand (B. Napompeth pers. comm. 1993).

INDONESIA

M. pigra has been established in Indonesia at least since 1844 but is regarded as a less serious weed than in Thailand (Napompeth 1982, 1983). At least 10 insects were recorded on it and, at times, causing considerable damage in the Bogor area (1 Orthoptera, 3 Hemiptera, 1 Diptera, 2 Coleoptera and 3 Lepidoptera). Only one of these, a cerambycid borer *Milothris irrorata* was regarded as having any potential to cause important damage (Napompeth 1982). As there were doubts about its host specificity (Kalshoven 1981), it was introduced to Thailand for further study but did not survive in culture (Napompeth 1982, 1992b). *Acanthoscelides* spp. have been found in *M. pigra* seed pods collected in Bogor in 1992, although there are no records of releases having been made (B. Napompeth pers. comm. 1993).

VIETNAM

Acanthoscelides puniceus and *A. quadridentatus* from Thailand were liberated in 1987 and *Chlamisus mimosae* in 1990, but there is no information on their establishment (Julien 1992).

Important natural enemies

***Acanthoscelides quadridentatus* Coleoptera: Chrysomelidae**
A. puniceus

These two species occur widely in Mexico and *A. quadridentatus* is also recorded from Texas, Nicaragua and Honduras. There are also two additional species, *A. pigricola* and *A. zebratus*, that are apparently specific to *M. pigra* seeds (Habeck and Passoa 1982). Eggs are laid during the day in or near crevices between pod segments. At 25°C each larva hatches after 10 days and tunnels through the pod into a single seed in which it completes its development. Pupation occurs in a cell and adults emerge by chewing a hole through the seed coat. On average *A. quadridentatus* females live 93 days and lay 65 eggs, whereas *A. puniceus* females live 130 days and lay 178 eggs (Kassulke et al. 1990).

***Carmenta mimosa* Lepidoptera: Sesiidae**

This species is native to Mexico and Cuba. In Mexico the larvae tunnel in the stems of *M. pigra*, thereby weakening the plant. The upper two-thirds of the stems frequently snap off, resulting in spectacular damage. Females lay 1 to 5 eggs at a time (up to a total of about 260) in the axils of the topmost, fully expanded leaves on a stem. At 25°C larvae hatch after 11 days and tunnel into the stem at a node or the swelling at the base of a leaf petiole. They feed on the outer layers of the plant, sometimes ringbarking it, or tunnel through the pith; they are cannibalistic if they meet another larva. They eject frass onto the surface of the stem. Occasionally larvae leave the stem and re-enter below the soil surface, grazing on and in the root, causing damage which sometimes kills the plant. Depending upon plant quality, there are 8 or 9 larval instars in 40 to 99 days before larvae spin a silken cocoon in which they pupate. The duration of the pupal period is 18 to 21 days, giving an average life cycle of 98 days. Larvae can be reared on an artificial diet. In host specificity tests, *C. mimosa* was found to complete its development only on *M. pigra* (Forno et al. 1991a, 1994, Smith and Wilson 1992, Wilson et al. 1992).

Chalcodermus serripes Coleoptera: Curculionidae

This weevil is native to Mexico. Adults feed on young leaves, flower buds and seeds. Eggs are inserted into the ventral side of pods so that they are at the embryo end of a developing seed. They hatch in 6 days and larvae feed on the soft developing seed, destroying the embryo (I.W. Forno, pers. comm.).

Chlamisus mimosae Coleoptera: Chrysomelidae

This species is native to Brazil. Females mate 2 weeks after emergence and then begin to lay eggs. Each egg is enveloped in faecal material and attached to the underside of a leaf by a fine stalk. At 25°C larvae hatch after 3 weeks and construct a conical case which is added to as the larva grows. Larval development time is 83 days and the pupal stage lasts 25 days. Adults live up to 95 days. Adults and larvae graze on the epidermis of the growing tips, on green stems and on leaves. In Darwin (Northern Territory) cultures of *C. mimosae* were attacked by a pupal parasitoid and predatory mites (Wilson et al. 1992).

Coelocephalapion aculeatum Coleoptera: Apionidae

This species is native to Mexico. It lays one egg at a time into a separate flower bud (of which an inflorescence contains up to 100). Larvae hatch after 2 days and feed on the developing flower buds, destroying the reproductive parts and sometimes the pedicel. Larval development takes about 7 days and pupal development 3 days. Preoviposition is about 7 days, adults live at least 3 months and may lay up to 5 eggs per day. Adults chew into the unopened flower buds and feed on the anthers and the pistil (Heard 1992, Wilson et al. 1992). This species could develop satisfactorily only on *M. pigra* (Forno et al. 1994).

Coelocephalapion spretissimum and *C. pigrae* Coleoptera: Apionidae

The life cycle of these species is similar to that of *C. aculeatum*. Adults feed on young leaves as well as on flower buds. The host testing of *C. pigrae* has been completed.

Neurostrota gunniella Lepidoptera: Gracillariidae

This species is widespread in tropical or subtropical, moderately wet to semi-arid habitats wherever *M. pigra* occurs from southern Texas to Costa Rica and Cuba. It has been established in Australia.

Eggs are laid singly on the ventral side of the first or second leaf from the branch tip and hatch about 4 days later. The first and second instar larvae are adapted for mining by being flattened dorso-ventrally, having large blade-like mandibles and no thoracic legs.

Each mines up to 5 leaf pinnules. Third instar larvae are cylindrical, enter the leaf rachis and tunnel to the stem tip. Later instars usually tunnel down the stem. They sometimes leave the stem and re-enter it at a node or near a prickle. Frass is usually visible when a larva is inside a stem. Pupation occurs in a cocoon spun between pinnules or inside the stem. The outside of the cocoon is ornamented with small, pearly-white, frothy balls discharged from the anus.

At 25°C the time from egg to adult is about 30 days and equal numbers of males and females are produced. Females mate on the night of emergence and lay an average of 86 eggs, most on the second night. *N. gunniella* caused very severe damage to *M. pigra* in quarantine trials which demonstrated that, except for attack on *Neptunia* species, it was specific to *M. pigra*. The aquatic *Neptunia oleracea*, which is an important vegetable in Thailand was attacked, so it has not been released there. In Mexico *N. gunniella* larvae are heavily attacked by parasitoids (Davis et al. 1991, Forno et al. 1989a, 1991b).

***Sibinia* spp. Coleoptera: Curculionidae**

S. fastigiata occurs from Mexico to Brazil and Peru, whereas *S. seminicola* occurs from Texas and Mexico to southeastern Brazil and northeastern Argentina. These two *Sibinia* species are larger than the two that follow. Larvae of both species develop in the pods of *M. pigra* and feed on the seeds. Larvae of *S. seminicola* feed on green, immature seeds and pupation occurs within the pods while they are still attached to the plants (Clark 1984).

Sibinia ochreosa occurs in Texas, Mexico, Honduras, Nicaragua, Brazil, Argentina and *S. peruana* occurs in Mexico, Guatemala, Honduras, Costa Rica, Panama, Brazil, Peru, Bolivia and Argentina. Larvae of these two species develop in the flower buds of *M. pigra* and, at least the former species, pupates in the flower head (Clark 1984).

FUNGI

***Diabole cubensis* Fungi: Uredinales**

This rust attacks the leaves of *M. pigra* in Mexico and Cuba. It is particularly common and damaging during the dry season when there are high day temperatures and a significant drop at night leading to dew formation. Five hyperparasitic fungi are consistently encountered, often completely overgrowing the rust (Evans 1988, 1990).

***Phloeospora mimosae-pigrae* Fungi: Coelomycetes**

This fungus causes extensive defoliation during the wet season, particularly in the Gulf coast of Mexico, but also occurs in Trinidad, Venezuela, Colombia and Brazil. It attacks stems, leaves and seed pods. It is host specific to *M. pigra* (Evans 1988, 1990, Seier and Evans 1993).

Comment

The majority of natural enemies of *M. pigra* so far studied are flower or seed attacking insects and there are indications already that considerable amounts of seed are being destroyed—up to 60% from *Neurostrota* alone in Australia and up to 20% by bruchids in

Thailand. However, starting from a seed bank of 9000 per m^2, this degree of reduction is nowhere like limiting.

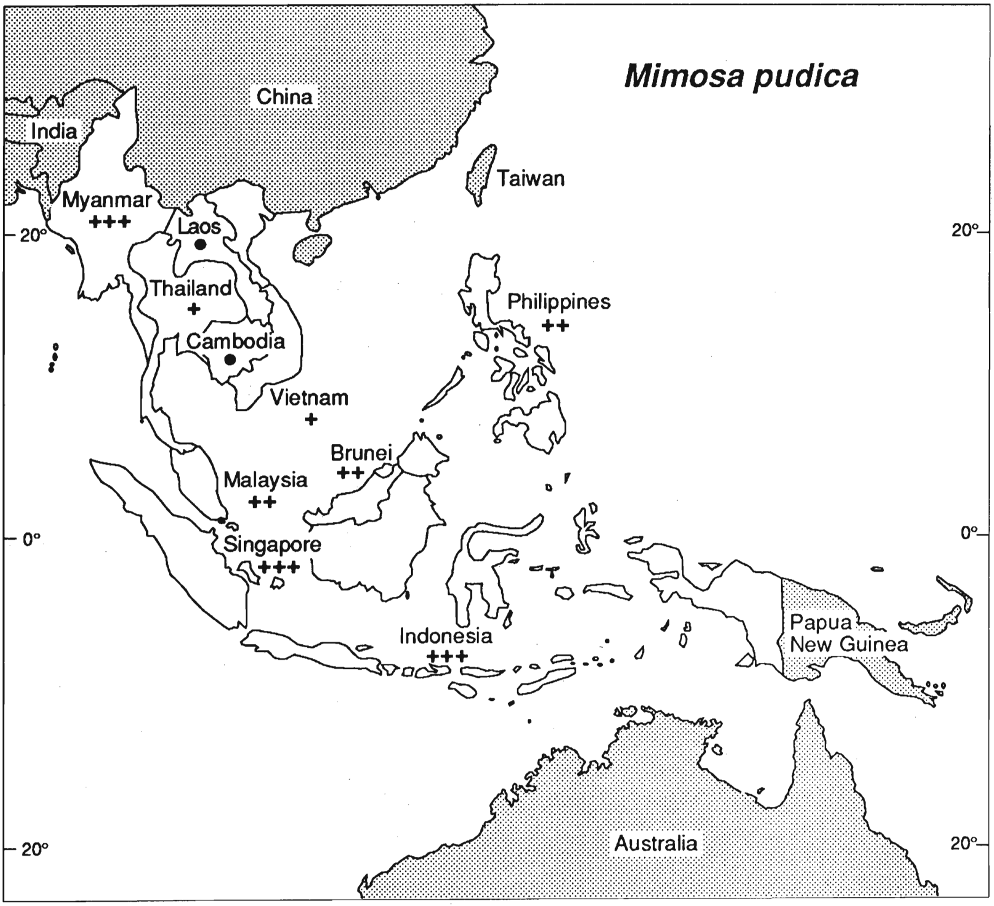
The inhibition to tip growth produced in Australia by *Neurostrota gunniella* is likely to be far more significant and will become even more so if the borer, *Carmenta mimosa*, becomes abundant enough to weaken a considerable proportion of larger stems.

If (when) the two apparently specific fungi are approved for release, it is confidently expected that they will make a major contribution, *Phloeospora mimosa-pigrae* in the wet season and the rust *Diabole cubensis* in the dry.

It is highly probable that a complex of natural enemies will be required to bring about an adequate reduction in competitiveness of *M. pigra*. It is still unclear whether those available or under investigation will be adequate but, if required, there are additional species that could be examined and future priority might well be given to leaf, stem or root feeding species.

Mimosa pudica

(after Holm *et al.* 1977)



Map 4.17 *Mimosa pudica*

Very little is known about the natural enemies of *Mimosa pudica* in its centre of origin in Central America. Most of the species recorded from there or elsewhere are widely polyphagous and few show promise as biological control agents. Since at least three forms of the weed are known it would be desirable to establish which forms are weedy in Southeast Asia so as to enable any searches in Central America to concentrate on that form. On general grounds, it is probable that useful species do exist.

4.17 *Mimosa pudica* L.

Mimosaceae

common sensitive plant; paklab, sampeas (Cambodia), daoen kaget kaget (Indonesia) mala malu (Malaysia), makahiya (Philippines), mai yarap (Thailand) mäc cö (Vietnam)

Rating

	+++	Myan, Sing, Indo
17	++	Msia, Brun, Phil
	+	Thai, Viet
	•	Laos, Camb

Origin

Tropical America.

Distribution

M. pudica is widespread in tropical, subtropical and temperate areas of the world. Its distribution and other relevant aspects were summarised by Waterhouse and Norris (1987). There are at least three distinct varieties (Brenan 1959). *M. pudica hispida* is uncommon in the Americas, but is established in the Philippines (Barneby 1989), the Caroline and Mariana Is, Queensland, India and in African savanna country. *M. pudica unijuga* occurs in Hawaii and probably in other Pacific countries where it is a major weed.

Characteristics

M. pudica is low, much branched, generally perennial, slightly woody at the base, from 15 to 100 cm high and has either an upright or a low trailing habit. Its stiff reddish-brown or purple stems bear scattered thorns. The hairy leaves are alternate, bipinnate and compound. They are sensitive to the touch, the petiole dropping and the leaflets being rapidly drawn back and folded. The pink flowers form small globular heads, each borne on a short hairy stalk arising from a leaf axil. Seeds are produced in pods which split into single-seeded segments bearing bristles, which aid dispersal by animals. In tropical countries the weed flowers all year and each plant may produce up to 700 seeds.

Importance

M. pudica is a weed in 22 crops in 38 countries (Holm et al. 1977). It is common in waste land and is also a weed of lawns, crops, pastures and roadsides. In Southeast Asia and the Pacific it is a serious weed in maize, sorghum, sugarcane, tea, soybeans, upland rice, pineapples and cotton. Because of its tolerance to shading it is an important weed in plantation crops, such as rubber, coconuts, bananas, papaya, coffee, oil palm and citrus. In tropical pastures its dense growth and thorns often deter animals from feeding on suitable forage mingled with it (Holm et al. 1977). The thorns deter hand weeding and, as it survives mowing, it is a very unwelcome component of lawns. Attempts to select thornless types as pasture plants have not been successful.

Natural enemies

Some information is summarised by Waterhouse and Norris (1987). It is interesting that Holm et al. (1977) report *M. pudica* to be a widespread weed in the Caribbean, but far less important to the north and south of this region. This suggests that it evolved elsewhere in the Americas and has not been accompanied into the Caribbean by its full suite of natural enemies. Nevertheless a preliminary survey in Trinidad (Table 4.17.1) revealed 14 insects attacking it, but they are probably polyphagous, with the possible exception of the arctiid caterpillar *Lophocampa catenulata* and the beetle, *Chlamisus* sp. (Yaseen 1971, 1972). Perez et al. (1988) found that the race *filenus* of *Hemiargus hanno* in Cuba appears not to attack plants other than *M. pudica*, although partially grown larvae of the Trinidad race were able to complete their development on *Aeschynomene sensitiva* and *Cajanus cajan* (Yaseen 1972). *H. hanno filenus* feeds readily on *M. pudica* seeds and is particularly active in spring when the weed is producing most seed (Perez et al. 1988). Four additional insects are known from Brazil (Garcia 1982a,b, 1983) but, so far, no species of *Heteropsylla*, although a special search for one might be rewarding. Although *M. pudica* was often encountered in surveys carried out in Mexico and Venezuela for natural enemies of *M. pigra*, casual observation did not suggest that it was heavily attacked, less so indeed than *M. invisa* (I.W. Forno pers. comm. 1993).

It is not known whether there is any differential attack by natural enemies on any of the three or more varieties of *M. pudica*, which have been established on morphological differences alone.

Table 4.17.1 Natural enemies of *Mimosa pudica*.

Species	Country	Portion of plant attacked	References
INSECTS			
Hemiptera			
COCCIDAE			
Coccus longulus	Fiji	stems	Hinckley 1963
CYDNIDAE			
Microporus (= *Microcompsus*) sp.	Trinidad		Yaseen 1972
DIASPIDIDAE			
Hemiberlesia lataniae	Fiji	stems	Hinckley 1963
Pinnaspis strachani	Fiji	stems	Hinckley 1963
MARGARODIDAE			
Icerya seychellarum	Fiji	stems	Hinckley 1963
SCUTELLERIDAE			
2 species	Trinidad	flowers	Yaseen 1971
Coleoptera			
CHRYSOMELIDAE			
Chlamisus sp.	Trinidad	flower buds	Yaseen 1971, 1972

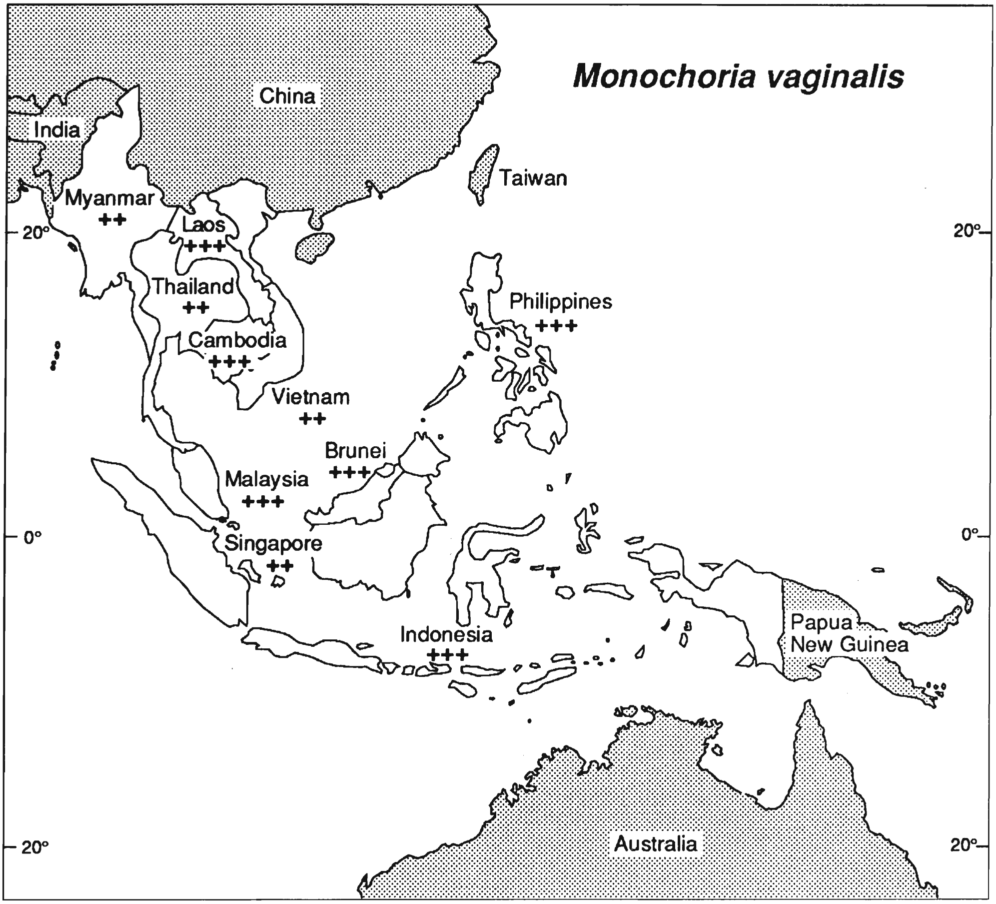
(continued on next page)

Table 4.17.1 (continued)

Species	Country	Portion of plant attacked	References
CURCULIONIDAE			
Chalcodermus sp.	Brazil	seed pods	C.A. Garcia pers. comm.
Promecops ?campanulicollis	Brazil	leaves; mainly on *M. invisa*, see table 4.15.1	Garcia 1982a,b, 1983
An unidentified sp.	Trinidad		Yaseen 1971
Lepidoptera			
ARCTIIDAE			
Lophocampa catenulata	Trinidad	leaves	Yaseen 1971
GEOMETRIDAE			
Ptychamalia perlata	Trinidad	leaves	Yaseen 1972
GRACILARIIDAE			
Neurostrota gunniella	Mexico	leaves, stems	Davis et al. 1991
HESPERIIDAE			
Cogia (= *Caicella*) *calchas* (= ? *Nisoniades bessus)*	Trinidad	leaves, flowers	Cock 1985, Yaseen 1972
?*Staphylus mazans*	Trinidad	leaves, flowers	Yaseen 1972
LYCAENIDAE			
Calephelis sp.	Trinidad	leaves	Yaseen 1971
Hemiargus hanno	Cuba, Trinidad	leaves, flowers, pods also on flowers of *Aeschynomene sensitiva* and *Cajanus cajan* (= *C. indicus*)	Dethier 1940, Perez et al. 1988, Yaseen 1972
Tmolus azia	Trinidad	leaves, flowers also on *Mimosa pudica* and groundnut flowers	Yaseen 1972
NOCTUIDAE			
Spodoptera litura	Fiji	leaves	Hinckley 1963
Sp. 1 (velvet black larva)	Brazil	leaves; also on *M. invisa*	Garcia 1982a,b, 1983
PIERIDAE			
Eurema lisa	Cuba		Dethier 1940
Eurema tenella	Brazil	leaves: mainly on *M. invisa,* see table 4.15.1	Garcia 1982a,b, 1983
TORTRICIDAE			
Platynota rostrana	Trinidad	leaves	Yaseen 1972
NEMATODE			
Meloidogyne sp.	Cuba		Holm et al. 1977, Izquierdo et al. 1987
FUNGI			
Oidium sp.	Mexico	mildew on leaves	Evans 1987
?*Puccinia* sp.	Mexico	rust on leaves	Evans 1987
VIRUS			
unspecified	Germany		Umrath et al. 1979

Monochoria vaginalis

(after Holm *et al.* 1977)



Map 4.18 *Monochoria vaginalis*

Monochoria vaginalis appears to be a major weed only in Southeast Asia and then only in rice. Almost nothing is known of its natural enemies in India and Africa where it occurs, but is not regarded as important. This suggests that a survey in these regions might reveal promising biological control agents.

4.18 *Monochoria vaginalis* (Burm. f.) Presl

Pontederiaceae

monochoria; ka kiad chrach (Cambodia), phak kbiat (Thailand), rau mác lá thon (Vietnam), etjeng padi (Indonesia), biga bigaan (Philippines), kelayar, echeng padi (Malaysia)

Rating

	+++	Laos, Camb, Msia, Brun, Indo, Phil
26	++	Myan, Thai, Viet, Sing

Origin

Tropical Asia and Africa (Holm et al. 1977), but not a pest in Africa or Asia (Soerjani et al. 1987), although it is clearly very important in Southeast Asia.

Distribution

Africa, India, China, Korea, Japan, Southeast Asia to northern Australia, Fiji and Hawaii.

Characteristics

A smooth, fleshy, semi-aquatic annual or perennial, 0.1 to 0.5 m tall; the plant roots in mud and its upper portions grow above water; stemless, base of leaves heartshaped or rounded, shiny deep green; petioles soft, hollow; inflorescence with a large bract and arising about two thirds of the way up the petiole from the base and opposite the leaf; 3 to 25 violet or lilac flowers producing numerous, small seeds throughout most of the year. Seed germination and seedling growth not reduced by submergence. Old plants often form large clumps.

Importance

M. vaginalis occurs in marshy places, freshwater pools, mudflats, ditches, along canal banks and in rice fields. It is a very serious weed of rice in eastern and southern Asia. It is predominantly an annual in flooded ricefields, dying when the fields dry out, but developing again later from seed.

In Taiwan, *M. vaginalis* produced more fresh tissue weight than any other weed in rice, twice that of second ranking *Echinochloa crus-galli* (Lin 1968). However in the Philippines it was outcompeted in rice by *E. crus-galli* (Lubigan and Vega 1971). Only in rice is it reported as a very widespread and important weed, except for its occurrence in taro in Hawaii.

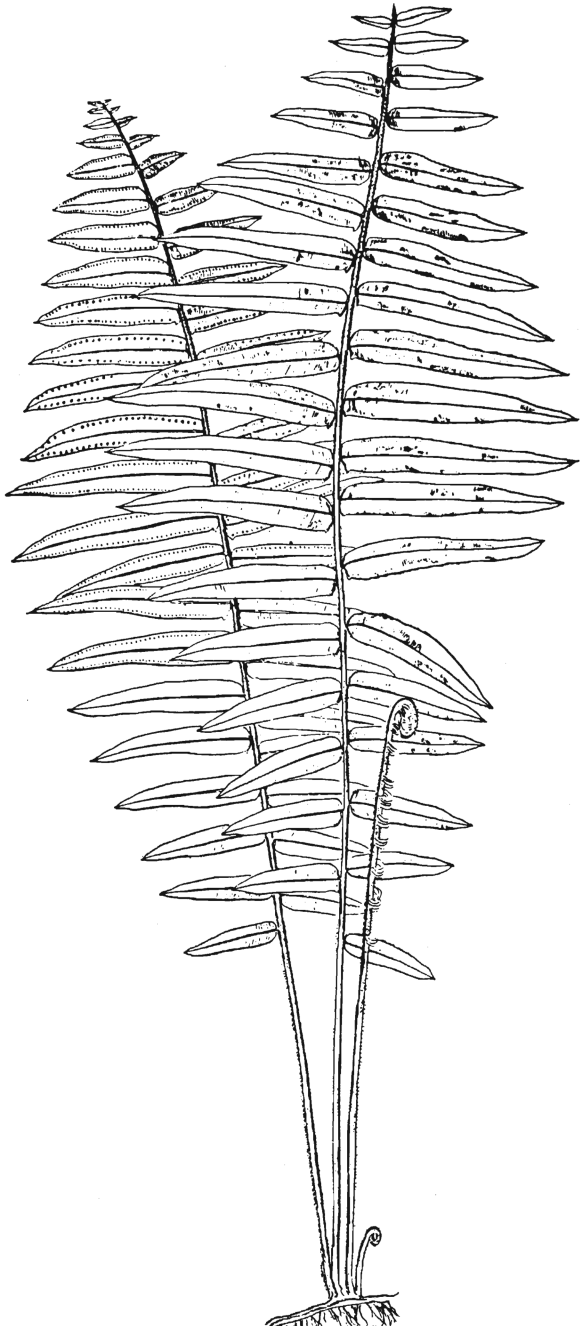
Its leaves are eaten as a pot herb in India and several parts of it are used as herbal medicine, the juice being prescribed for various conditions and the roots for stomach and liver ailments and toothache (Burkill 1935, Soerjani et al. 1987).

Natural enemies

So little is recorded about the natural enemies of *M. vaginalis* (Table 4.18.1) that it is not possible to assess the prospects for biological control. However, the fact that it is apparently not a weed in Africa or western Asia suggests that it would be well worthwhile investigating these regions for suitable agents.

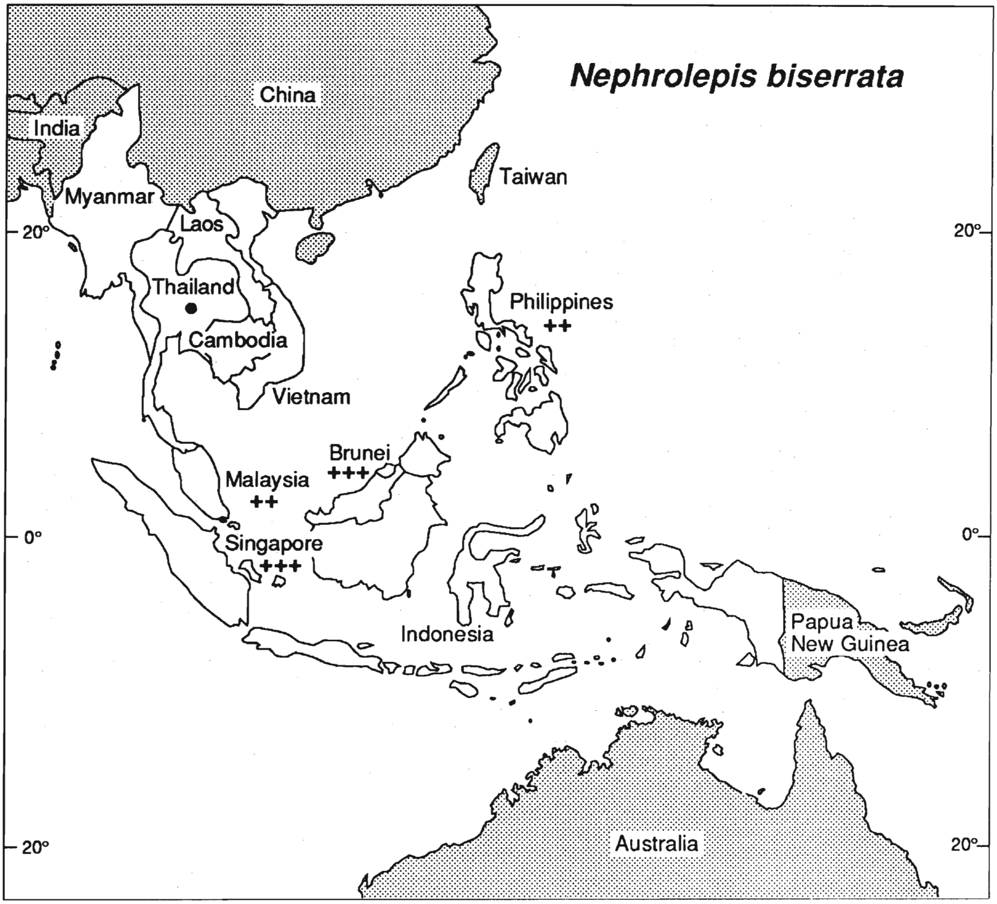
Table 4.18.1 Natural enemies of *Monochoria vaginalis*.

Species	Location	Other hosts	References
INSECTS			
Orthoptera			
ACRIDIDAE			
Gesonula punctifrons	India		Sankaran & Rao 1972
Hemiptera			
CICADELLIDAE			
Macrosteles fascifrons	USA	rice	Way et al. 1983
DELPHACIDAE			
Tarophagus proserpina	Philippines	taro, cassava, sweet potato	Duatin & Pedro 1986
Lepidoptera			
NOCTUIDAE			
Spodoptera litura	India	widely polyphagous	Sankaran & Rao 1972
PYRALIDAE			
Elophila responsalis	Indonesia	*Marsilea minuta, Pistia stratiotes, Salvinia molesta, S. cucullata*	Handayani & Syed 1976, Mangodihardjo 1975
Nymphula fregonalis	India	probably polyphagous	Sankaran & Rao 1972
SPHINGIDAE			
Hippotion echeclus	India	polyphagous	Sankaran & Rao 1972
NEMATODES			
Hirschmaniella spp.		rice, sugarcane, many weeds	Luc et al. 1990
Meloidogyne graminicola		rice, many weeds	Luc et al. 1990
VIRUSES			
rice ragged stunt	Thailand, Philippines	rice	Parejarearn et al. 1988, Salamat et al. 1987
Pistia virus	India		Menon & Ponnappa 1964
FUNGI			
Cercospora sp.	India		Menon & Ponnappa 1964
Doassansia sp.	India		Menon & Ponnappa 1964
Rhizoctonia solani	India	rice, potato	Gokulapalan & Nair 1983
Thanatephorus cucumeris	Philippines	rice	Moody et al. 1987, Mew et al. 1980
a leaf blight	Philippines	*Sphenoclea zeylanica*	Bayot et al. 1992
CRUSTACEA			
Triops cancriformis	Japan	*Veronica peregrina* and some other weeds	Igarashi 1985



Nephrolepis biserrata

(after Barnes and Chan, 1990)



Map 4.19 *Nephrolepis biserrata*

N. biserrata is a widespread fern that probably originated in Tropical Africa. Almost nothing was learnt concerning natural enemies from a literature search. A survey in its area of origin would be required to evaluate whether there were any natural enemies that might be of value for biological control.

4.19 *Nephrolepis biserrata* (Sw.) Schott

Nephrolepidaceae (formerly in the Davalliaceae)
broad sword fern; paku larat (Malaysia)

Rating

	+++	Sing, Brun
10	++	Msia, Phil
	•	Thailand

Origin

Probably Tropical Africa.

Distribution

Pantropical. *N. biserrata* occurs throughout tropical Africa, ranging in the west from Guinea to Angola and in the east from Sudan to Durban (South Africa). It is mainly coastal, but infrequent in the interior. It is most abundant up to 350 m (Jacobsen 1983). In addition to Southeast Asia, it is also known from India, Australia, Japan, the Pacific, USA and Mexico.

Characteristics

N. biserrata is a perennial, terrestrial or epiphytic fern. The rhizome bears abundant scales and produces many long stolons. The fronds are tufted, suberect to arching and green when young, turning brown when old. The pinnae are commonly 15 to 20 cm wide, exceptionally more than 30 cm. Fertile pinnae are narrower than the sterile pinnae and bear sori well clear of the edge. The veins are indistinct and fork once or twice. When rooted in the soil, the fern commonly reaches a height of 2m and, exceptionally in South Africa, up to 4 m.

Importance

N. biserrata is very common in shaded places in the lowlands wherever the conditions are not too dry. It can form dense masses in rubber and oil palm plantations and in orchards and often occurs as an epiphyte on palms. Where pineapples had been grown for up to 10 years in Malaysia, 90% of the viable seeds and spores in the top 15 cm of soil were spores of *N. biserrata* (in particular) and 8 other ferns (Wee 1974), enabling its rapid reappearance after cultivation.

Natural enemies

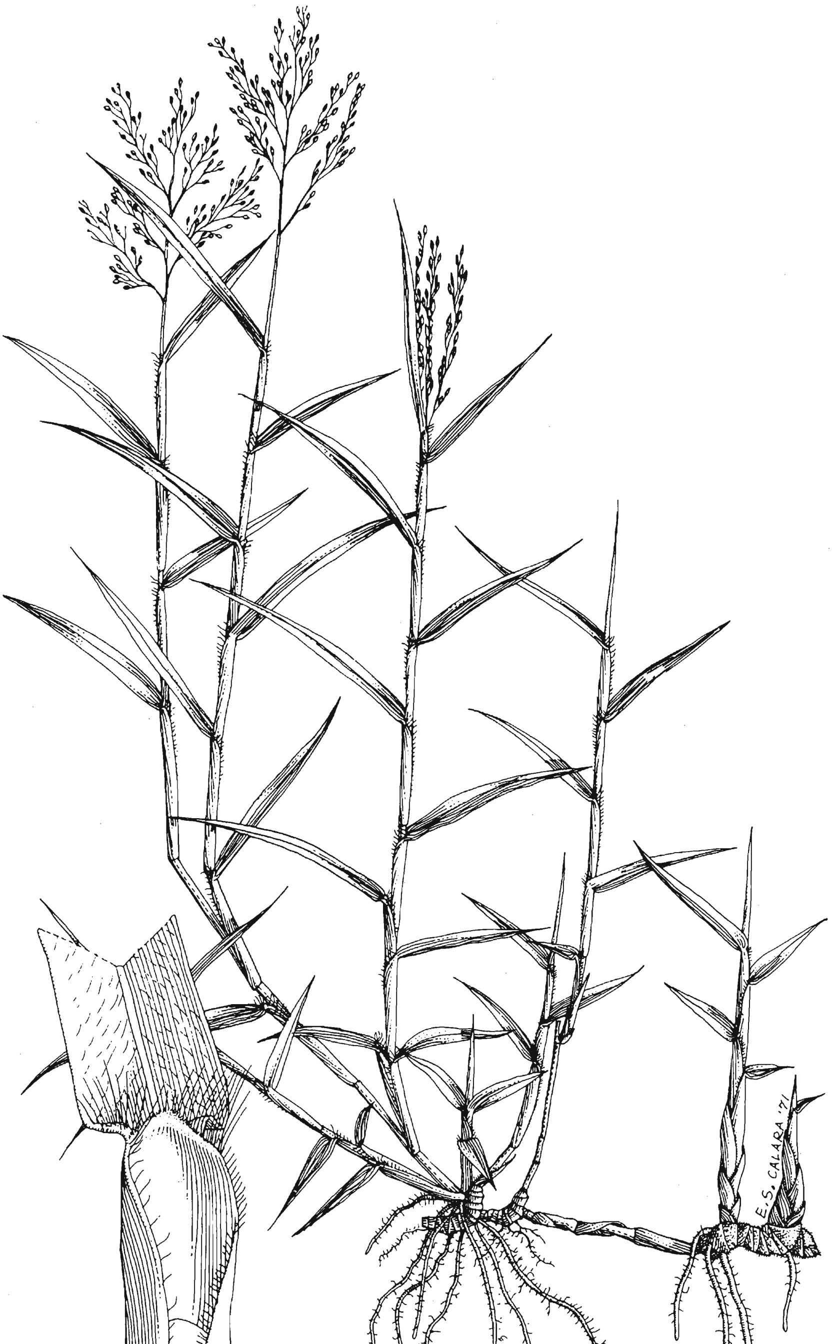
The only records of natural enemies encountered were those of an eriophyid mite on *N. biserrata* in Fiji (Mani and Jayaraman (1987) and of the nematode *Aphelenchoides fragariae* in Hawaii, but there is no evidence that a careful search has ever been made.

Attempts at biological control

There have been none.

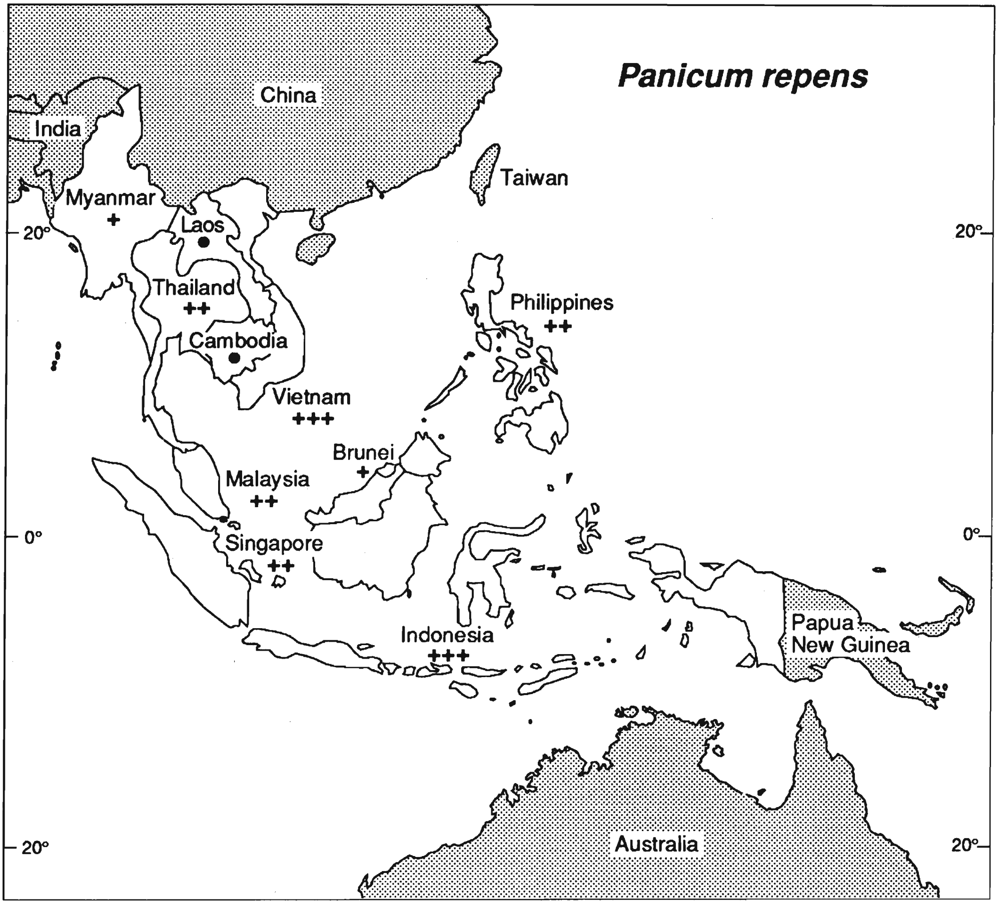
Comment

The genus *Nephrolepis* contains about 20 species (Tryon and Tryon 1982), or 35 species (Jacobsen 1983). It is primitive among the group of oleandroid, davallioid and nephrolepoid ferns to which it belongs and *N. biserrata* and its close allies represents the more primitive element in the genus *Nephrolepis* (Nayar and Bajpai 1976). A survey for natural enemies, particularly in the areas in Africa where it occurs, would reveal whether there are any that might be of value in biological control.



Panicum repens

(after Holm *et al.* 1977)



Map 4.20 *Panicum repens*

P. repens is a major grassy weed in Southeast Asia. It is probably of tropical African/Mediterranean origin, a region where it is not reported to be a problem. Very few natural enemies have been recorded and, without a preliminary survey in its area of origin, it would not be possible to evaluate the prospects for its biological control.

4.20 *Panicum repens* L.

Poaceae

torpedo grass, creeping panic grass; myet kha (Myanmar) yah chan ah kat, yah chanagard (Thailand), chhlong (Cambodia), cò ông (Vietnam), keruong padi, rumput jae jae (Malaysia and Indonesia), luya luyahan (Philippines)

Rating

	+++	Viet, Indo
16	++	Thai, Msia, Sing, Phil
	+	Myan, Brun
	•	Laos, Camb

Origin

Tropical and North Africa, Mediterranean (sometimes said to be native to Asia).

Distribution

Panicum repens is widely distributed in the tropics and subtropics. It was introduced to Java about 1850, but is said not to occur in the Moluccas. No seeds are produced in Indonesia (Soerjani et al. 1987).

Description

Panicum repens is an erect, wiry, creeping, perennial grass, rooting at hairless nodes and bearing flowering stalks 30 to 90 cm tall. It spreads widely (up to 7 m), but does not form dense clumps. Its smooth, sharp-pointed, branched rhizomes are often swollen or knotty and have brownish or whitish scales. Its leaves are alternate. The inflorescence is an open terminal panicle, 6 to 20 cm long, with many tender branches pointing obliquely upwards. The spikelets are pale green or pale yellow and often tinged with purple.

Importance

Panicum repens is one of the most serious grass weeds because of its rapid rate of spread and the persistence and hardiness of its coarse, enlarged rhizomes. It suppresses other plants by its allelopathic (inhibiting) products (Perera et al. 1989). It is primarily a weed of moist, coastal, sandy soils, although it also grows in heavy upland soils (to 2000 m in Indonesia). It thrives in open sunny situations, but can stand partial shade and its rhizomes survive even prolonged dry periods. It tolerates temporary flooding, sometimes forms floating mats, and encroaches upon ditches, drains and watercourses. It is common in cultivated lands, grasslands, roadsides and gardens and is frequently reported as a weed in lawns. In Malaysia it is a serious weed of cocoa, coconuts and rubber, in Indonesia of rainfed and upland rice, cocoa, coconut, maize, rubber, sugarcane and tea and in Thailand of rice and orchard crops. In improved pastures it chokes out more nutritionally valuable grasses. Deep ploughing favours its spread by breaking up and dispersing its rhizomes.

P. repens is quite palatable to stock when young and has the advantage of being able to stand heavy grazing and trampling. However, it contains only 3.3% crude protein and up to 39% crude fibre, so there are other far more nutritious grasses suitable for the same environment (Holm et al. 1977).

Natural enemies

As can be seen in table 4.20.1, very few natural enemies were revealed by an extensive literature search. The only species not known to be both polyphagous and a pest is the mite *Parasteneotarsonemus panici*, recorded so far only from Tamil Nadu, India, where it was found causing rusting symptoms beneath the leaf sheath of *P. repens* (Mohanasundaram 1984).

Absence of attack almost certainly does not represent the true situation, but rather that no relevant surveys have been carried out. For example, there has been little advance in knowledge of cecidomyiid gall flies attacking *Panicum* spp. since the summary by Barnes (1954b) in which were listed at least 13 species (Table 4.20.2). Two of these (the widespread rice stem gall midge *Orseolia* (= *Pachydiplosis*) *oryzae* and *Contarinia* (= *Stenodiplosis) panici* are known to be pests (Hegdekatti 1927). The scarcity of information from Africa points to an important gap in our knowledge and the absence of records from the Mediterranean, where most plants have been studied in some detail for native-insects, suggests that *P. repens* is not native to that region.

Comment

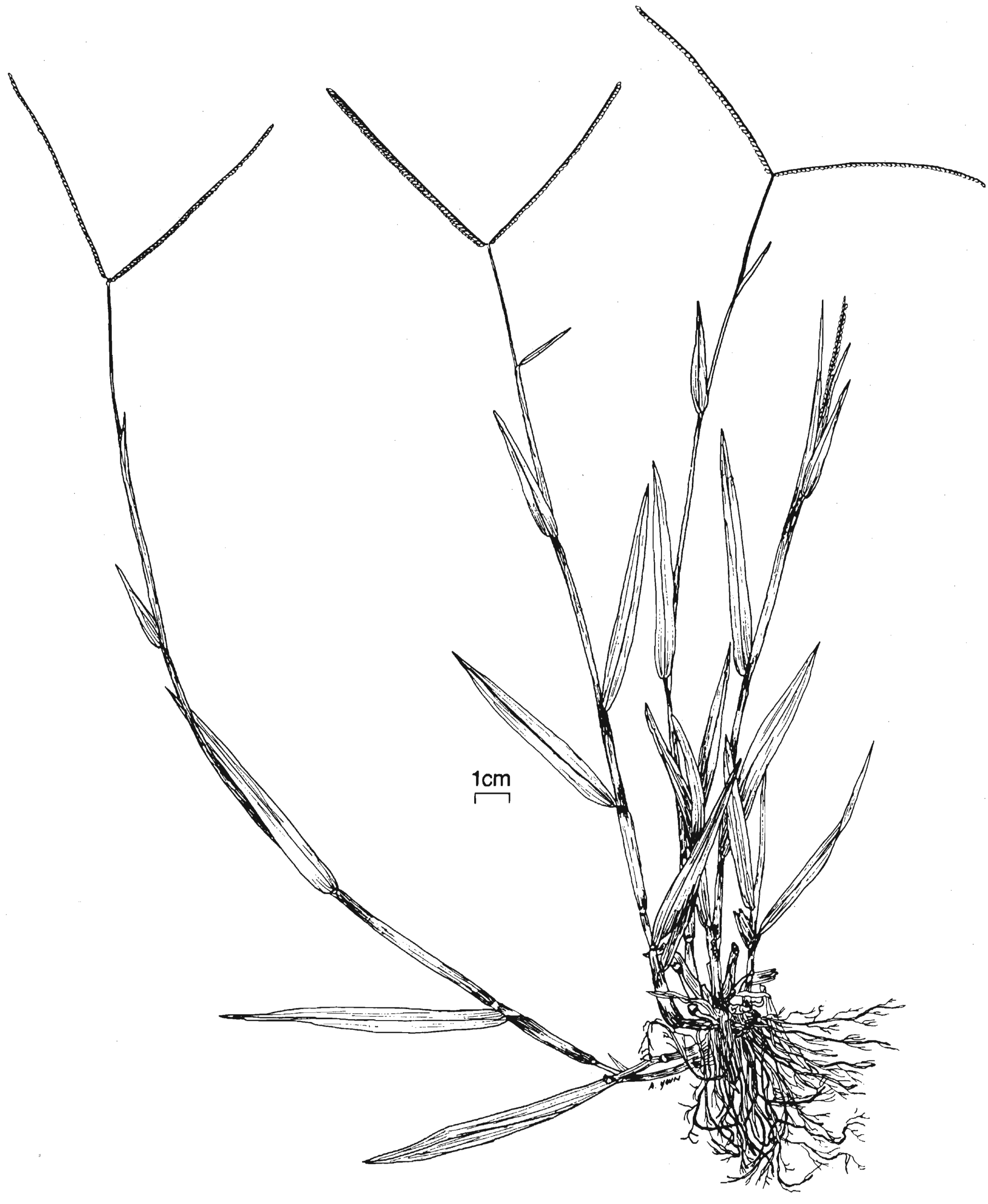
Clearly insufficient information is known about the natural enemies of *P. repens* (although it doubtless must have many) to provide any meaningful assessment of the prospects for its biological control. However, the genus *Panicum* contains a number of good to very good fodder species (e.g. *P. antidotale* (blue panic), *P. bulbosum* (bulbous panic), *P. capillare* (witchgrass), *P. maximum* (guinea grass), *P. paludosum* (swamp panic)) as well as several that are weedy and may cause photosensitivity or poisoning (e.g. *P. coloratum* (coolah grass), *P. luzonense*, *P. miliaceum* (millet panic, or proso), *P. novemnerve*). There are thus likely to be considerable problems in discovering organisms of adequate specificity. Nevertheless, *P. repens* is not reported as a weed of crops in tropical Africa or the Mediterranean (Holm et al. 1977) and a preliminary survey there might well reveal promising natural enemies.

Table 4.20.1 Natural enemies of *Panicum repens*.

Natural enemies	Recorded from	References
INSECTS		
Hemiptera		
CICADELLIDAE		
Thaia oryzivora	Thailand	Leeuwangh & Leuamsang 1967
DELPHACIDAE		
Delphacodes idonea	USA	Ballou et al. 1987
Sogatella kolophon	Australia, Pacific Is, SE Asia, USA, Central & S. America, W. Africa	Ballou et al. 1987
Lepidoptera		
EUPTEROTIDAE		
Nisaga simplex	India	Patnaik et al. 1987
NOCTUIDAE		
Sesamia cretica	Egypt	Ahmed 1980
PYRALIDAE		
Cnaphalocrocis medinalis	Philippines	Abenes & Khan 1990
Cnaphalocrocis (= *Marasmia*) *patnalis*	Philippines	Abenes & Khan 1990
Parapoynx stagnalis (= *Nymphula depunctalis*)	India	Pillai & Nair 1979
MITES		
TARSONEMIDAE		
Parasteneotarsonemus panici	India	Mohanasundaram 1984
FUNGI		
Claviceps sp.	India	Janardhanan et al. 1982
Pyricularia sp.	India	Hilda & Suranarayanan 1976, Holm et al. 1977
Pyricularia oryzae		Paje et al. 1964
Sporisorium overeemi		Rifai 1980
NEMATODE		
Meloidogyne graminicola		Luc et al. 1990

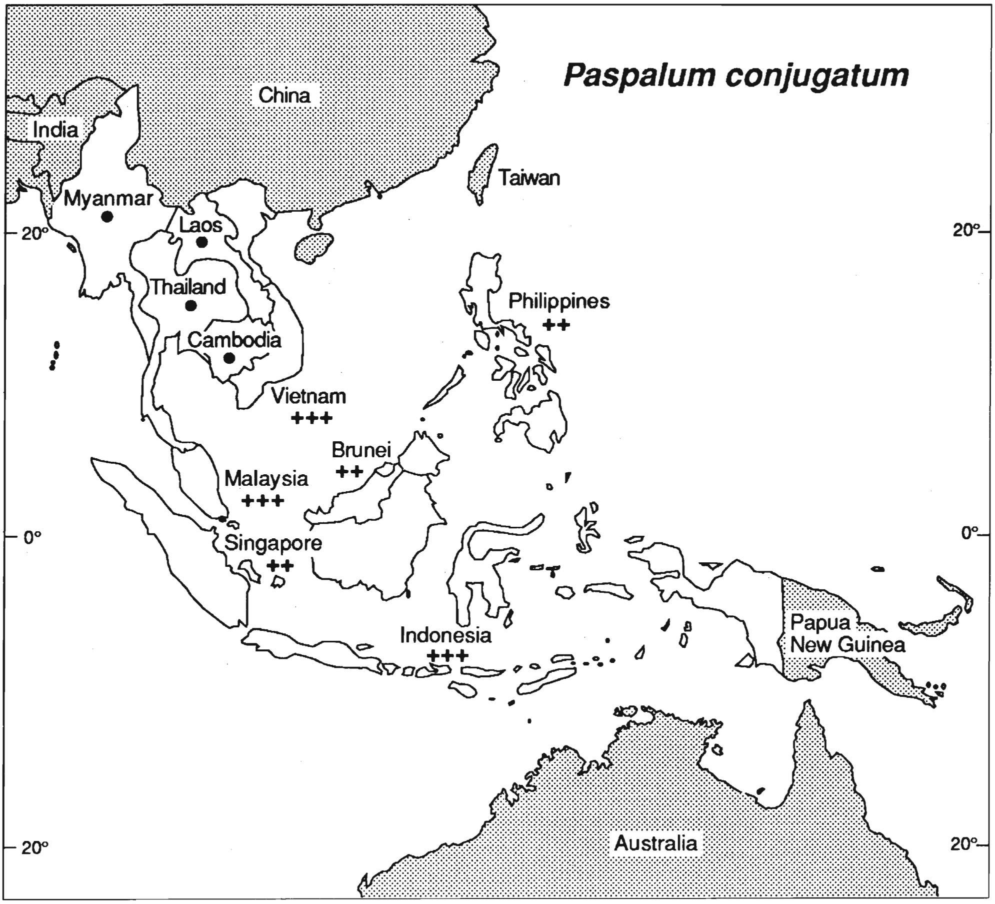
Table 4.20.2 Gall flies (Cecidomyiidae) reported attacking *Panicum* spp. (after Barnes 1954b).

Species	Recorded from	Location
Contarinia (= *Stenodiplosis*) *panici*		Yugoslavia, USSR
Lasioptera (= *Dyodiplosis*) *fluitans*	*Panicum fluitans*	S. India
Lasioptera inustorum		USA
Lasioptera kanni		S. India
Lasioptera panici		USA
Lasioptera paniculi		Philippines
Orseolia cynodontis		France, Italy, Algeria, Eritrea, Senegal
Orseolia (= *Courteia*) *graminis*		Java, Sri Lanka, S. India
Orseolia (= *Dyodiplosis*) *andropoginis*		
Orseolia (= *Dyodiplosis*) *fluvialis*	*Panicum fluitans*	S. India
Orseolia (= *Pachydiplosis*) *oryzae*		S and SE Asia, W. Africa
Parallelodiplosis javanica	*Panicum indicum*	Sri Lanka
Parallelodiplosis spp.		Middle East, Java, Peru



Paspalum conjugatum

(after Holm *et al.* 1977)



Map 4.21 *Paspalum conjugatum*

P. conjugatum is of Tropical American origin, but it is recorded as an important weed in a number of situations in the Caribbean area. Very few natural enemies have been reported. A preliminary survey would be required in its centre of origin before the prospects for its biological control could be evaluated.

4.21 *Paspalum conjugatum* Bergius

Poaceae

sourgrass; paitan, rumput canggah, rumput pait (Indonesian), rumput kerbau, jampang canggah, buffalo grass (Malaysia), hulape (Philippines), ya hep (Thailand)

Rating

	+++	Viet, Msia, Indo
15	++	Sing, Brunei, Phil
	•	Myan, Thai, Laos, Camb

Origin

Tropical America.

Distribution

Paspalum conjugatum occurs as a troublesome weed in Central America, West Africa and the islands and peninsulas of Southeast Asia and the Pacific. These are, for the most part, the humid tropics (Holm et al. 1977).

Characteristics

P. conjugatum is a creeping, stoloniferous, perennial grass. The stolons are up to 2 m in length, often reddish purple in colour and bear roots and a tuft of green to purple leaves at each node.

The flower stalks are erect, range up to 60 cm, and have smooth nodes. At the apex of each stalk there are two racemes (flower spikes) 4 to 15 cm long. The stigmas are white and the anthers bright yellow. The weed can be recognised when in flower by the typical T-shaped inflorescence.

Importance

P. conjugatum is mainly a weed of the warm, wet lowlands, although in Hawaii and Sri Lanka it grows up to 1875 m. It is found in waste areas and along paths and streams, its inflorescences trailing in the water. It is common in cultivated fields and in natural and poorly managed pastures and particularly in perennial or plantation crops where the soil is not ploughed frequently. It spreads rapidly by its stolons, forming dense masses which can suppress or eliminate tree seedlings and other small plants. It tolerates some shade and can grow on poor and acid soils.

In the Philippines it flowers all year round and one plant can produce 1500 seeds. It is also dispersed by broken pieces of stolons rooting after being spread by machines used for cultivation. In the Philippines it is particularly important in bananas, coffee, papaya, rice and pineapple; in Cambodia in rice; in Malaysia in citrus, coconuts, oil palm, rice and rubber; in Indonesia in tea, oil palm and rubber; and elsewhere in cassava, cocoa, lawns, maize, pastures, sugarcane and vegetables.

P. conjugatum is suitable for grazing only when young and the seeds of older plants have been reported to choke animals by sticking in their throats (Holm et al. 1977).

Natural enemies

The natural enemies of *P. conjugatum* that have been recorded in the literature (Table 4.21.1) are almost all polyphagous and many of them are of economic importance. One possible exception is the bagworm moth *Brachycyttarus griseus*, which was originally described from Vietnam and is also recorded from Malaysia and the Philippines, as well as from Guam and Hawaii to which it has spread. It feeds on *P. conjugatum* in Hawaii and on the grass *Zoysia pungens* in Guam: it probably also feeds on other grasses. In Guam it is parasitised by the tachinid fly, *Stomatomyia* sp. (Davis 1990). However, it does little to control *P. conjugatum* in the countries where it already occurs, so it does not appear to be a promising species to introduce elsewhere.

Perhaps more valuable is the cecidomyiid fly *Cleitodiplosis graminis*, a gall forming fly described from Brazil. The gall consists of the terminal leaves becoming clustered into an ovoid 30 x 20mm mass as a result of the upper internodes being greatly reduced. Thirty to forty sulphur-coloured larvae may be found in a single gall, in which they pupate. They appear in August and September (Barnes 1956). Barnes (1954b) commented that no gall midge had, at that time, been recorded from the inflorescence of *Paspalum*, although *Parallelodiplosis paspali* (from Java and India) and *Lasioptera* sp. had been recorded from the stems.

The chrysomelid beetle *Colaspis* (= *Maecolaspis*) *aerea* also damages cocoa in Brazil (Ferronatto 1986) and hence would not be acceptable for introduction elsewhere.

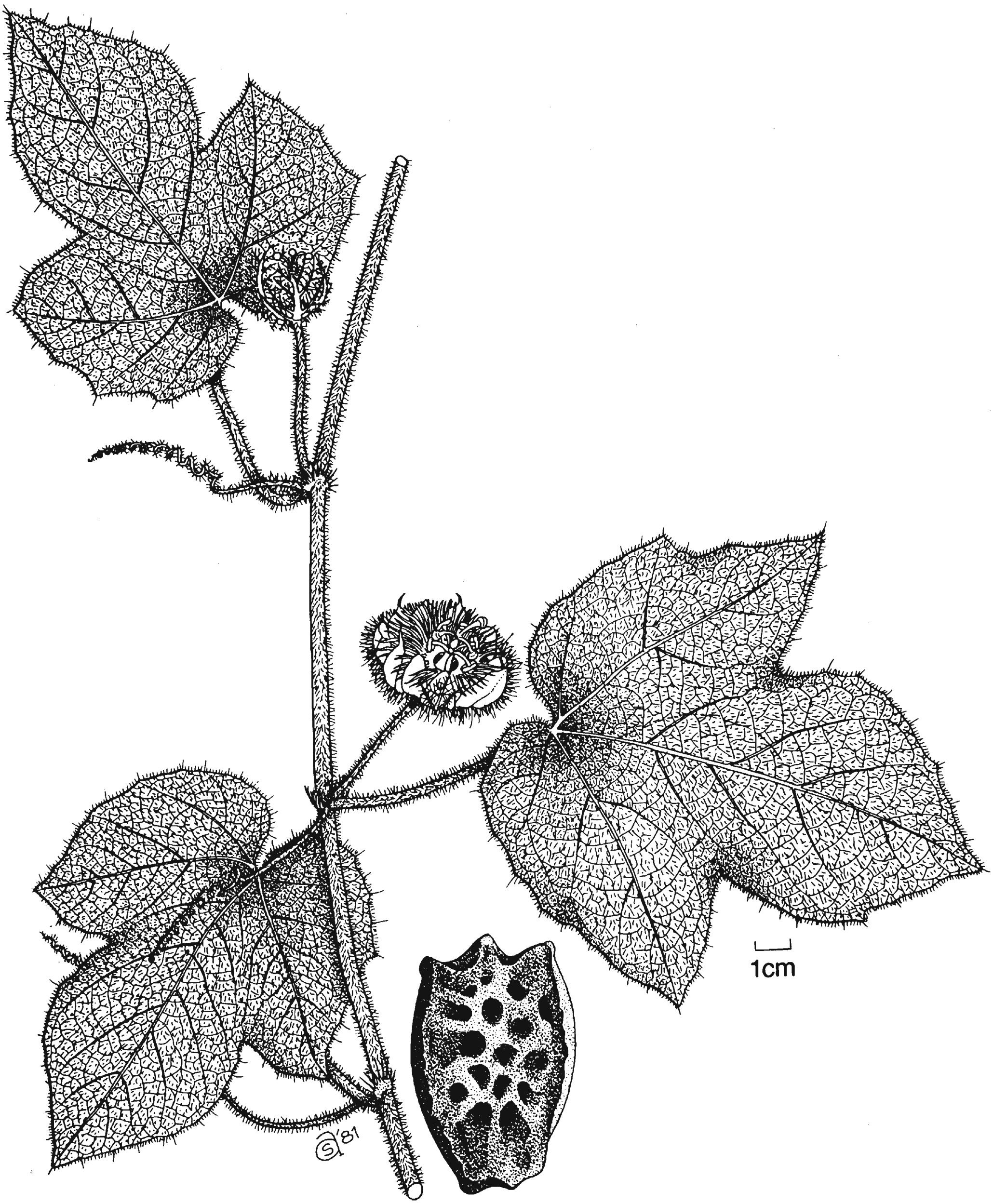
The seeds of *P. conjugatum* are harvested by ants in some areas, but the impact of this on weed density in the field has not been established. Under experimental field conditions in Mexico, the pestiferous fire ant, *Solenopsis geminata*, reduced *P. conjugatum* seed densities by 97% or more but had no effect on the seed densities of *Bidens pilosa* (Carroll and Risch 1984).

Comment

As with *Panicum repens*, so little is known about the natural enemies of *Paspalum conjugatum* that it is not possible to evaluate the prospects for its biological control. Again, there is the limitation that some closely related species in the genus *Paspalum* are of economic value for fodder (e.g. *P. dilatatum* (paspalum), *P. distichum* (saltwater couch), *P. plicatulum*, *P. scrobiculatum* (scrobic), *P. vaginatum* (saltwater couch)). However, a fungus attacks the seeds of the first two species, producing the toxin, ergot, and most of the species are considered weedy in at least some situations, so there may be occasions where a conflict of interests would have to be resolved, should effective agents be discovered. The prospects for finding these are not perhaps very promising, since Holm et al. (1977) record *P. conjugatum* as a weed in a number of countries in and around the Caribbean.

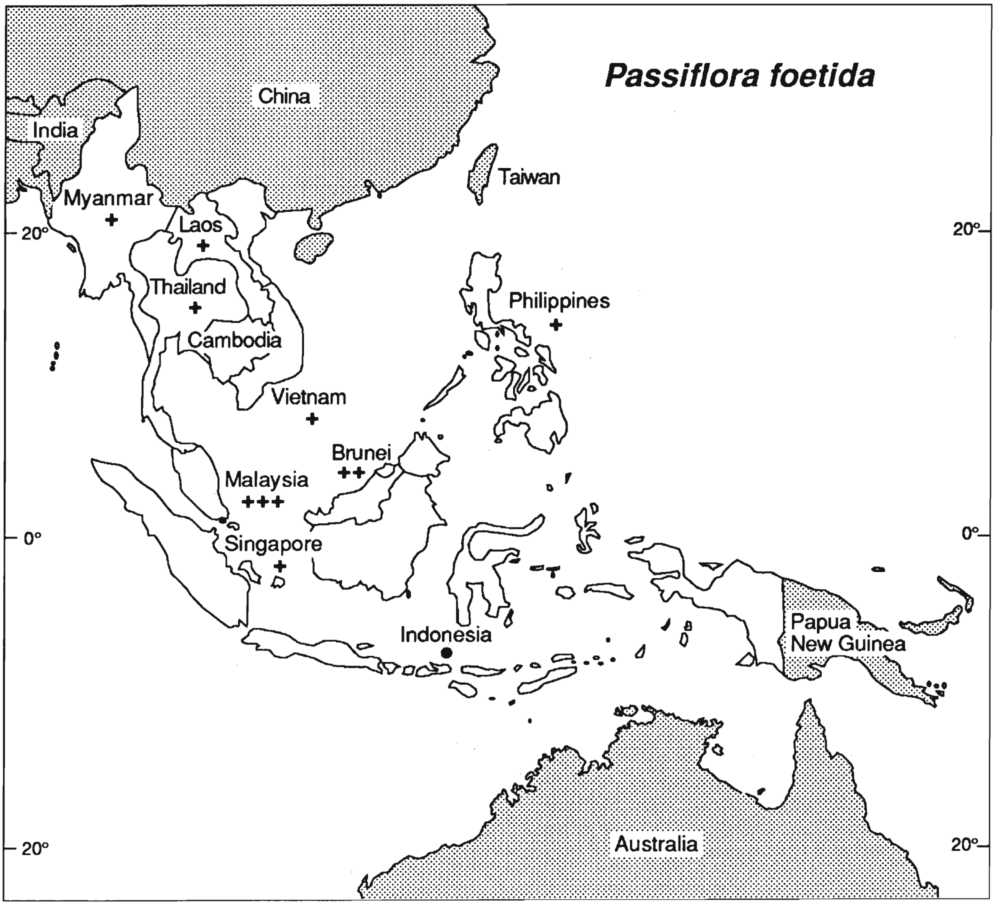
Table 4.21.1 Natural enemies of *Paspalum conjugatum*.

Species	Country	References
INSECTS		
Thysanoptera		
Haplothrips gowdeyi	Hawaii	Sakimura 1937
Haplothrips paumalui	Hawaii	Sakimura 1937
Coleoptera		
CHRYSOMELIDAE		
Colaspis (= *Maecolaspis*) *aerea*	Brazil	Ferronatto 1986
Diptera		
CECIDOMYIIDAE		
Cleitodiplosis graminis	Brazil	Barnes 1956
Lepidoptera		
ARCTIIDAE		
Creatonotos (= *Amsacta*) *gangis*	Philippines	Catindig et al. 1993
HESPERIIDAE		
Taractrocera ina	Australia	Common & Waterhouse 1981
PSYCHIDAE		
Brachycyttarus griseus	Guam, Hawaii, Malaysia, Vietnam, Philippines	Davis 1990
PYRALIDAE		
Cnaphalocrocis medinalis	Philippines	Abenes & Khan 1990
Cnaphalocrocis (= *Marasmia*) *patnalis*	Philippines	Abenes & Khan 1990
Parapoynx stagnalis (= *Nymphula depunctalis*)	Philippines	Bandong & Litsinger 1984
FUNGI		
Exserohilum paspali	Brazil	Muchovej & Nesio 1987
Leptosphaeria proteispora	Hawaii	Stevens 1925
Myriogenospora atramentosa	Brazil, USA, Venezuela	Hanlin & Tortolero 1990
Physarum cinereum	Brazil	Muchovej & Muchovej 1987
Sorosporium paspali	Hawaii	Stevens 1925
BACTERIA		
Xanthomonas albilineans	Australia	Persley 1973
NEMATODES		
Rotylenchulus reniformis	Trinidad	Singh 1974
VIRUSES		
sugarcane mosaic	Hawaii, Japan, Taiwan	Chen et al. 1989b, Holm et al. 1937, Ohtsu & Gomi 1985



Passiflora foetida

(after Soerjani *et al.* 1987)



Map 4.22 *Passiflora foetida*

No searches have been made for natural enemies of *P. foetida* in its area of origin in South America, where it is not a weed. It is known to be attacked there by the larvae of some nymphalid (heliconiine) butterflies.

However studies of the related *P. tripartita*, a serious forest weed in Hawaii, recorded upwards of 200 species of insects. It may thus be inferred that a similar study would reveal many insects attacking *P. foetida.* However, until a relevant study is carried out, it is not possible to evaluate the prospects for its successful biological control.

4.22 *Passiflora foetida* L.

Passifloraceae

stinking passionflower, wild passionfruit; love-in-a-mist; ka thok rok (Thailand), timun padang (Malaysia), buah tikus (Indonesia)

Rating

	+++	Msia
11	++	Brun
	+	Myan, Thai, Laos, Viet, Sing, Phil
	•	Indo

Origin

South America. Natural populations have been observed in the coastal mountain ranges in the State of Parana, Brazil (G.P. Markin pers. comm. 1993).

Distribution

Widespread throughout the tropics and serious in Southeast Asia; also a weed in the Pacific Region, West Africa and Central America. Introduced to Java a long time ago.

Characteristics

A foetid, woody, annual or perennial vine, 1.5 to 6 m long; stem, cylindrical, densely hairy; tendrils arise next to leaves on the shaded side of the stem; leaves heart-shaped to three lobed, alternate, arranged helically, with long-stalked glands and long fine hairs on margins, producing a disagreeable smell when crushed; flowers white to lilac, bisexual. It flowers all year round, opening in the morning and closing before noon. The green to orange or red fruits are enclosed in lacy bracts. A large number of varieties occur (Wagner et al. 1990).

Importance

P. foetida is a weed of upland rice and other field crops. It occurs in wet areas or those where there is a pronounced wet season. It is common in plantations, rough pastures, roadsides and wasteland.

In the Philippines it is sometimes used as a soil cover in coconut plantations to control *Imperata cylindrica* grass or erosion. In Papua New Guinea it is planted between sweet potatoes to suppress *Imperata.* Young leaves are used in Surinam and Java as a vegetable. Seeds are flat, black, woody and enclosed in a sweet aromatic pulp (Swarbrick 1981). Young fruit are cyanogenic. Stems and leaves are suspected of poisoning livestock.

P. foetida contains alkaloids and at least 10 flavonoids. One of the latter, ermanin, is a feeding deterrent to larvae of the nymphalid butterfly *Dione juno* which, in Colombia, do not attack *P. foetida* leaves, but eat large amounts of other *Passiflora* species.

The Passifloraceae contain about 12 genera and 600 species, most of which are tendril climbing vines native to warm regions of the world. The genus *Passiflora* contains some 500 tropical and subtropical species, mostly from Central and South America. Several have edible fruits and attractive flowers, about 40 species have been cultivated, but fewer than 6 are fruit crops in the neotropics and only one, *P. edulis* (and its varieties, such as the yellow *flavicarpa*), is economically important (Waage et al. 1981). *P. ligularis* is also cultivated in Malaysia (Ong and Ting 1973). A few species, such as *P. foetida* and *P. lonchocarpa*, are extremely foul smelling (Benson et al. 1976). Eleven species, including *P. foetida* and *P. tripartita* (= *P. mollissima*) (in Hawaii) are recorded as weeds in different parts of the world (Swarbrick 1981). Both *P. foetida* and *P. tripartita* are closely related taxonomically, whereas, *P. edulis* belongs to a different subgenus (Waage et al. 1981) and is the only economic crop at risk from oligophagous insects attacking *P. foetida*.

Natural enemies

Upwards of 200 insects are recorded attacking Passifloraceae in Central and South America. The most notable are heliconiine butterflies of the family Nymphalidae. Their larvae develop only on plants of the family Passifloraceae, with the single exception of *Eueides procula*, which will develop on the Turneraceae (Pemberton 1983, Waage et al. 1981). Only 5 of the 65 or so species of heliconiines are recorded as pests of *Passiflora edulis*, namely *Agraulis vanillae*, *Dione juno*, *Dryas julia*, *Eueides aliphera* and *E. isabella*, although larvae of a few other species are occasionally found on it (Waage et al. 1981). It is apparent that heliconiine butterflies are well worth investigating for species of adequate host specificity to *P. foetida*.

Little is known about the natural enemies of *P. foetida* (Table 4.22.1) and no attempts have been made at biological control. The passion vine butterfly *Agraulis vanillae*, an accidental introduction to Hawaii before 1977, is now widespread there. In addition to attacking *Passiflora edulis*, its larvae feed on the leaves of *P. foetida*, *P. manicata* and *P. suberosa*, but they seldom attack banana poka, *P. tripartita*, which is a serious forest weed in Hawaii. *P. foetida* is widely distributed on Hawaii from sea level up to about 500 m and a rainfall from 750 to 3000 mm. It occurs generally in highly disturbed areas, where it is a very minor component among other introduced species. On the west side, the taxon has red fruit and, on the east, green. It has very few natural enemies, with the exception of *Agraulis vanillae*. *A. vanillae* larvae are common but usually in small numbers, although occasionally there are outbreaks that completely defoliate the plants (G.P. Markin pers. comm. 1993). *A. vanillae* is native to the Americas and ranges from Argentina up through Mexico to Florida, the Gulf States and California (Beardsley 1980, Bianchi 1982, 1983, Klots (1951)). In Hawaii it is attacked by a nuclear polyhedral virus which limits its numbers (G.P. Markin pers. comm. 1993), in California by *Phorocera claripennis* (Tachinidae) and in eastern USA by *Brachymeria ovata* (Nakahara 1977). The other species of heliconiine recorded as attacking *P. foetida* is *Heliconius hecale*, which is widespread in Central and South America and attacks a large number of

Passifloraceae (Benson et al. 1976, Waage et al. 1981). On the other hand, larvae of *H. charithonia*, *H. cydno* and *H. erato* did not develop on *P. foetida* (Waage et al. 1981).

In the Ivory Coast larvae of the pterophorid moth *Sphenarches anisodactylus* eat the leaves of *P. foetida*, *Lagenaria siceraria* and *Brillantaisia lamium*. Although the moth also occurs in India and Japan it is not known from *P. foetida* there, but attacks two economic plants, the legumes lablab bean, *Lablab purpureus* and pigeon pea, *Cajanus cajan* (Bigot and Vuattoux 1979). Thus there is some uncertainty whether the host specificity of the African taxon is the same as that in Asia.

The National Parks and Forest Service authorities in Hawaii have been carrying out searches for some years in South America for natural enemies of banana poka, *P. tripartita*. Two insects from Colombia have been introduced to Hawaii (Gardner et al. 1992). One of these was the moth *Cyanotricha necyria* (Dioptidae), which was released in 1988, but did not become established (Casañas-Arango et al. 1990, Julien 1992, Markin and Nagata 1989, Markin et al. 1989). In host specificity tests *C. necyria* did not oviposit on *P. foetida*, but the larvae could develop on its foliage (Markin and Nagata 1989). The fungus *Colletotrichium gloeosporioides* f. sp. *clidemiae* has been mass produced for liberation (E.E. Trujillo memorandum 1989).

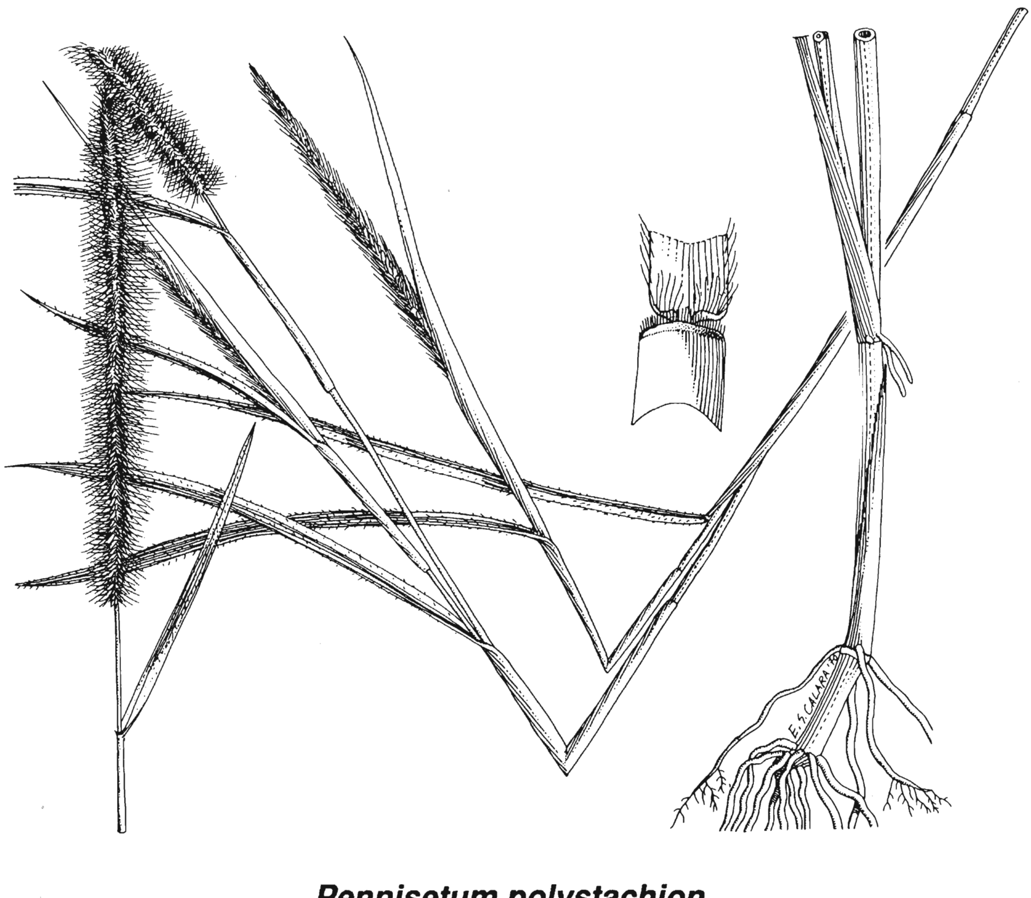
In Hawaii the fungus *Fusarium oxysporum* f. sp. *passiflorae* attacks *P. foetida*, *P. tripartita* and *P. ligularis*, but not *P. suberosa* or the cultivated *P. edulis* f. *flavicarpa* (Gardner 1989).

Table 4.22.1 Natural enemies of *Passiflora foetida*.

Species	Location	Other hosts	References
INSECTS			
Hemiptera			
APHIDIDAE			
Aphis fabae	Kenya	polyphagous	Bakker 1974
Aphis gossypii	Ivory Coast	polyphagous	De Wijs 1974
Aphis spiraecola	Ivory Coast		De Wijs 1974
Myzus persicae	Japan	polyphagous	Yonaha et al. 1979
Uroleucon compositae	Kenya		Bakker 1974
Diptera			
AGROMYZIDAE			
Melanagromyza polyphyta	Australia	polyphagous, including *Passiflora* spp.	Kleinschmidt 1960, 1970
Tropicomyia theae	Papua New Guinea	polyphagous	Spencer 1990
Lepidoptera			
NOCTUIDAE			
Helicoverpa zea (= *H. obsoleta*)	Sumatra	polyphagous	Den Doop 1918
Heliothis virescens	Venezuela	polyphagous	Venturi 1960
NYMPHALIDAE			
Agraulis vanillae	Central America, Hawaii	restricted to some *Passiflora* spp.	Anon 1977, Beardsley 1980, Bianchi 1982, 1983, Waage et al. 1981

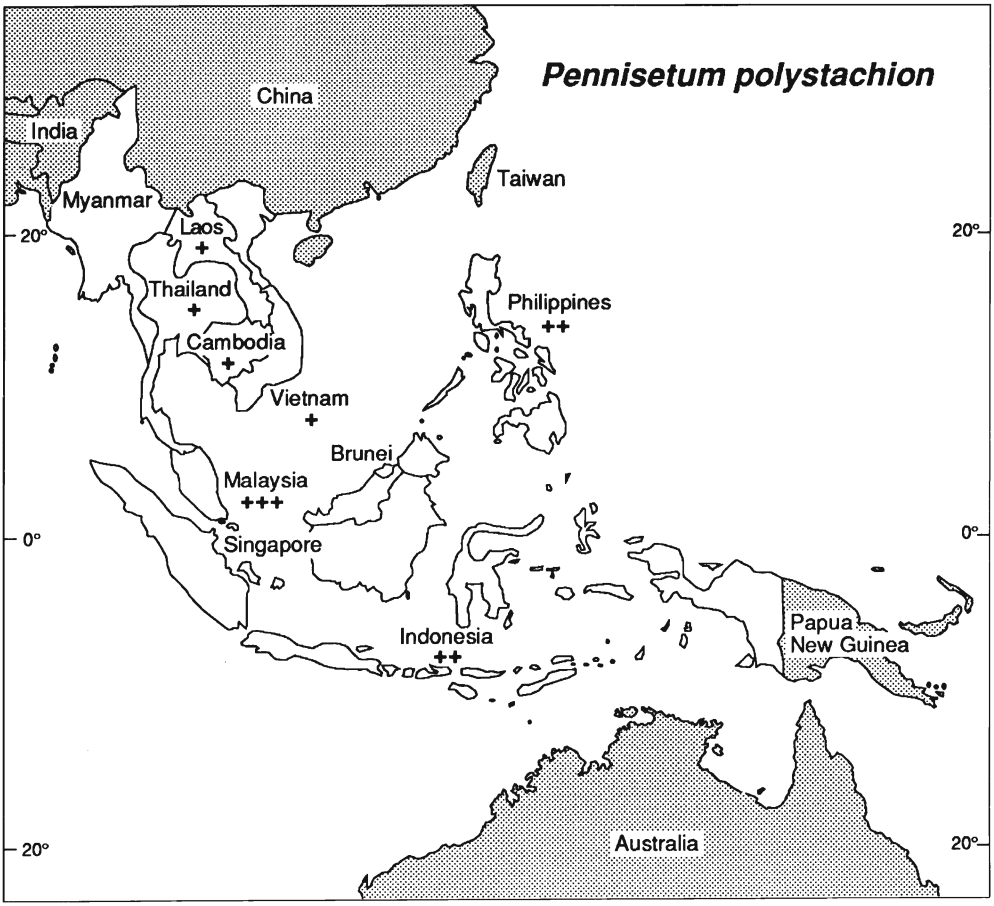
(continued on next page)

Species	Location	Other hosts	References
Heliconius hecale	widespread in Central & South America	restricted to some *Passiflora* spp.	Waage et al. 1981
PTEROPHORIDAE			
Sphenarches anisodactylus	Ivory Coast	see discussion	Bigot & Vuattoux 1979
FUNGI			
Alternaria passiflorae	Hawaii		Raabe 1965
Alternaria tenuis	Hawaii		Raabe 1965
Colletotrichium gloeosporioides	India		Mallikarjunaiah & Rao 1972
Fusarium oxysporum f.sp. *passiflorae*	Hawaii		Gardner 1989
Haplosporella passifloridia	India		Pande 1980
Hemphyllium sp.	Hawaii		Raabe 1965
NEMATODE			
Meloidogyne incognita	Australia		Sauer & Alexander 1979
VIRUS			
cucumber mosaic	Japan		Yonaha et al. 1979
passionfruit chlorotic spot	Papua New Guinea		Van Velsen 1961
passionfruit mosaic	Hawaii, Malaysia		Ong & Ting 1973, Raabe 1965
passionfruit ringspot potyvirus	Ivory Coast		Brunt et al. 1990, De Wijs 1974
passionfruit woodiness potyvirus	Australia, Kenya		Anon 1976, Bakker 1974, Brunt et al. 1990, Leggat & Teakle 1975



Pennisetum polystachion

(after Holm *et al.* 1977)



Map 4.23 *Pennisetum polystachion*

This erect, tufted, non-stoloniferous grass, originated in Tropical Africa from where it has spread throughout Asia and Southeast Asia to the Pacific.

Almost nothing is known of the natural enemies of *P. polystachion* or closely related species. It is not possible to evaluate the prospects for its biological control without a search for natural enemies in its region of origin.

4.23 *Pennisetum polystachion* (L.) Schultes
(= *Pennisetum setosum*)

Poaceae

mission grass; feather *Pennisetum;* yaa khaehyon chop (Thailand), rumput gajah, rumput berus, rumput kuning, ekor kucing (Malaysia) rumput jurig (Indonesia)

There are differences in opinion over the spelling of the specific name, *polystachion* or *polystachyon*, with the former being used here. In Africa, there are three subspecies *P. polystachion polystachion*, *P. p. setosum* (sometimes regarded as a true species) and *P. p. atrichum.* There is some evidence of crossing between the varieties of *P. polystachion* and the related *Pennisetum hordeoides* and the production of populations with different chromosome numbers (Brunken 1979).

Rating

	+++	Msia
11	++	Indo, Phil
	+	Thai, Laos, Camb, Viet

Origin

Tropical Africa.

Distribution

P. polystachion is widespread in the tropics of Africa and Asia, but also occurs in northern Australia and the Pacific. It rarely extends beyond 23°N or 23°S. In Africa it occurs mainly in the savanna and open areas in the forest zone of West Africa from Senegal to Cameroun and then south and east to Mozambique and Kenya (Brunken 1979, Kativu and Mithen 1988).

Characteristics

P. polystachion is an erect, tufted annual or perennial grass, with fibrous roots, but no stolons. Its leaves are narrow and 5 to 45 cm long. Its flowering stems are sometimes branched, 50 to 300 cm tall, ending in a cylindrical yellow-brown flowering spike, 5 to 25 cm long, bearing densely hairy, unequal bristles of two lengths, the longer 2 to 5 cm and the shorter 1cm.

Importance

P. polystachion grows on dry lateritic soils and is often present along roadsides, in wastelands and in upland crops. Propagation is by seeds, but regrowth can occur from dormant buds located at the base of the stems and from aerial nodes.

It becomes dominant in upland tropical hillsides and croplands after forests have been cleared, or when shifting cultivation or subsistence agriculture have been practised (Holm et al. 1977). Because of the rapid germination of its wind-dispersed seeds and its aggressive and highly competitive growth, it rapidly takes over wastelands. Since a single cultivation rarely kills enough of the weed to provide control, it often impedes further use of areas for crops.

In Indonesia it was first observed in 1972 (Titrosoedirdjo 1990). It is now an important weed of rubber and occasionally a problem in upland rice.

P. polystachion is thought to have reached Malaysia via Thailand as recently as the early 1980s, infesting at least 10 km^2 of roadsides and is now widely distributed, occurring up to an altitude of 900 m (Baki et al. 1990). It is now a major weed in rubber, oil palm, sugarcane, orchards, vegetables and upland rice (Titrosoedirdjo 1990).

In the Philippines *P. polystachion* is able to compete effectively even with blady grass *Imperata cylindrica* in grassy fields in Central Luzon and in rubber plantations in west Java (Titrosoedirdjo 1990).

P. polystachion is a good fodder grass when young and makes excellent hay.

Natural enemies

Very few natural enemies of *P. polystachion* appear to have been recorded in the literature (Table 4.23.1). The only species of possible relevance are several gall midges from Africa, but very little is recorded of their biology. Three species of gall midge have been reared from *P. polystachion* in the Gold Coast. One is similar to the pestiferous sorghum midge *Contarinia sorghicola* (but may be different), the second belongs to the Trifila group and the third belongs to the Lasiopterariae (Barnes 1954a,b, Geering 1953). Three species of gall midge have been described from ears of *Pennisetum* in southern India, *Cecidomyia penniseti* (from *P. glaucum* = *P. typhoideum*), *Geromyia* (= *Itonida*) *penniseti* (from *P. cenchroides*) and *Geromyia* (= *Itonida*) *seminis* and an unidentified species from the stems. Of these, *G. penniseti* may be predaceous (Barnes 1954b, Felt 1920, 1921).

In Madagascar there is a gall midge (?*Cecidomyia* sp.) whose larvae live in the inflorescence of *Pennisetum* (no species given) and in Sudan a gall midge, possibly *Geromyia seminis*, has been reared from the ears of *Pennisetum* (no species given) (Barnes 1954b).

The larvae of the Brazilian satyrid butterfly *Eryphanis polyxena* were bred in the laboratory on *P. polystachion* (= *P. setosum*) (Dias 1979), but damage is not reported from the field.

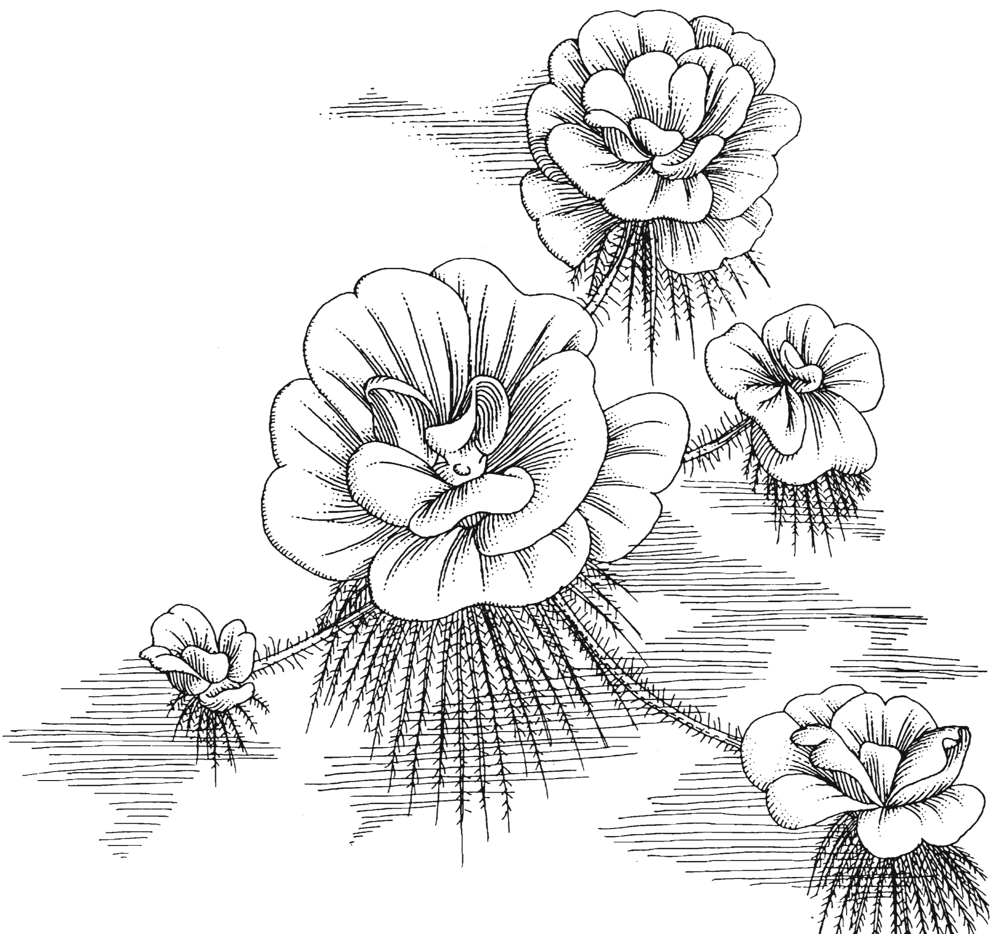
Comment

There is little doubt that a range of natural enemies attacking *P. polystachion* would be found if a search were made in Tropical Africa.

Several other weedy species of *Pennisetum* also originated in Africa, in addition to three or more species that have at least some desirable attributes. Perhaps the best known is kikuyu grass, *P. clandestinum,* which is a valuable fodder during the warmer months, although it is a weed in some situations and its nitrate levels can be toxic to grazing animals. *P. glaucum* (= *P. americanum*), pearl millet, is used as food in some areas. *P. purpureum,* elephant or napier grass, can grow to 3 m, is valuable for fodder when young and can be used as fuel when old. However, it can also be a weed, as in rubber in Malaysia. Little has been recorded of the natural enemies attacking these species of *Pennisetum*. The most interesting are three cecidomyiid gall midges in India, *Geromyia penniseti*, *G. seminis* and *Mycodiplosis indica* from *Pennisetum glaucum* (= *P. typhoideum*) and *Geromyia seminis* from *Pennisetum cenchroides* (Barnes 1931, Felt 1920).

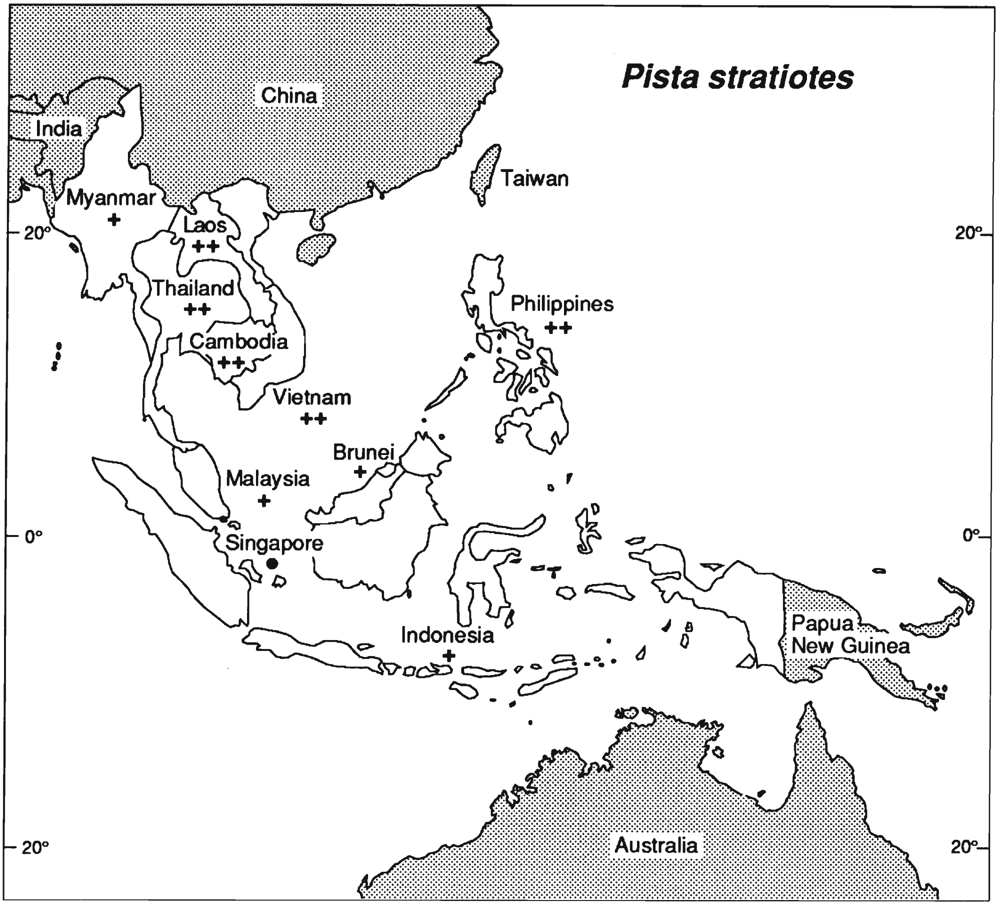
Table 4.23.1 Natural enemies of *Pennisetum polystachion*.

Species	Country	References
INSECTS		
Diptera		
CECIDOMYIIDAE		
Cecidomyia penniseti	India	Barnes 1954b
Contarinia ?sorghicola	Gold Coast	Barnes 1954b
Contarinia sp. 1	Gold Coast	Barnes 1954b
Contarinia sp. 2	Gold Coast	Barnes 1954b
Contarinia sp. 3	Madagascar	Barnes 1954b
Contarinia sp. 4	India	Barnes 1954b
Geromyia (= Itonida) penniseti	India	Barnes 1954b
Geromyia (= Itonida) seminis	India, Sudan	Barnes 1954b
Lepidoptera		
HESPERIIDAE		
Parnara bada bada	Malaysia	C.L. Tan pers. comm. 1993
NYMPHALIDAE		
Eryphanis polyxena	Brazil	Dias 1979
PYRALIDAE		
Cnaphalocrosis medinalis	Malaysia	C.L. Tan pers. comm. 1993
FUNGI		
Bipolaris papendorfii		H.C. Evans pers. comm. 1992
Gloeocercospora sp.		H.C. Evans pers. comm. 1992
Helminthosporium rostratum		Thite & Chavan 1977
Phakospora apoda		H.C. Evans pers. comm. 1992
Puccinia chaetochloae		H.C. Evans pers. comm. 1992
Puccinia substrata		H.C. Evans pers. comm. 1992
Pyricularia oryzae	Brazil	Prabhu et al. 1992
Spacelotheca penniseti		H.C. Evans pers. comm. 1992



Pistia stratiotes

(after Holm *et al.* 1977)



Map 4.24 *Pistia stratiotes*

Water lettuce is a widespread, floating water weed, which probably originated in South America.

The host specific South American weevil, *Neohydronomus affinis*, has been established readily in six countries and, in all, has produced substantial to excellent control. The moth, *Samea multiplicalis*, which attacks *P. stratiotes* and *Salvinia* spp., has been established in Australia but its impact has not been evaluated.

In Thailand, classical biological control has not been attempted, but mass rearing and release of the native noctuid moth *Spodoptera pectinicornis* has replaced the use of herbicides.

The prospects are excellent for classical biological control of *P. stratiotes* in countries where it is still regarded as an important weed.

4.24 *Pistia stratiotes* L.

Araceae

water lettuce; chak thom (Cambodia), apoe apoe, apon apon (Indonesia), kiambang besar (Malaysia), chok, jawg (Thailand), bèo cái (Vietnam)

Rating

	++	Thai, Laos, Camb, Viet, Phil
14	+	Myan, Msia, Brun, Indo
	•	Sing

Origin

The origin of *Pistia stratiotes* is unknown, although the number of host specific insects present there (Table 4.24.1) suggests South America. However, there is also a host specific noctuid moth that ranges from India to Papua New Guinea. Dray and Center (1992) examine the various theories concerning the area of origin of water lettuce.

Distribution

Water lettuce occurs very widely as a troublesome water weed between the tropics of Capricorn and Cancer, particularly in Africa, Asia, Southeast Asia and the Caribbean. Pliny refers to its use in Egypt in AD77 (DeLoach et al. 1979, Holm et al. 1977). It is absent from a number of Pacific countries although recorded as a weed in Papua New Guinea, Solomon Is, Guam, New Caledonia and Hawaii.

Characteristics

Pistia stratiotes is a free-floating, perennial monocotyledon, with a tuft of fibrous feathery roots up to 1 m long. Numerous secondary roots may be up to 4 cm in length. Stolons up to 60 cm are produced from the base of the plant and develop into new plants. Leaves are pale green, upright, 2.5 to 15 cm long, broad at the top and tapered at the base. They are prominently veined beneath and form a rosette. They are spongy in texture and bear numerous fine, water-repelling hairs on both sides. The flowers are bisexual, inconspicuous, green, surrounded by tubular bracts and arise from the centre of the rosette. It is said that water lettuce does not flower in Thailand but a small number of flowers have been observed (B. Napompeth pers. comm. 1993). It flowers in the Philippines, Australia, Africa and USA. The fruit is berry-like and green and contains 4 to 12 small brown seeds which can float on the water for up to 2 days. There are as many as 9 varieties of water lettuce (Neal 1965).

Importance

The free-floating plants are found in reservoirs, ponds, in marshes along the edges of large tropical lakes and in slow-moving or stagnant waters. They multiply rapidly and can block streams, interfere with fisheries and hydroelectric generating plant and bank up at dams, bridges and culverts, leading to increased flooding problems. Despite earlier claims (Holm et al. 1977), unlike water hyacinth, water lettuce does not increase water loss through evapotranspiration (Lallana et al. 1987). Together with water hyacinth it is a common and important component of the dense aggregations of free-floating vegetation, known as sudds. It grows best at pH 4, whereas water hyacinth produces greatest dry weight at pH 7 (Holm et al. 1977).

Water lettuce plants act as a substrate for sandfly larvae (Ceratopogonidae) and larvae and pupae of the disease-transmitting mosquito genus *Mansonia* obtain their oxygen by attaching to *Pistia* roots. *P. stratiotes* is an important weed of irrigated rice, floating into paddy crops, taking root in the soil and competing much like other weeds.

On the other hand, it has been used as human food in India during famines and is still fed to pigs and ducks. It is said to have some medicinal value as a cure for skin diseases and dysentery, as a laxative, to treat asthma and, its ash rubbed into the scalp, as a treatment for ringworm.

Natural enemies

AUSTRALIA

Although water lettuce was first recorded in the Northern Territory only in 1946 it was already an important weed in some locations in Queensland before the introduction of *Neohydronomus affinis*, although plants in the Northern Territory were rarely thrifty. Heavy damage was observed there by larvae of the moth *Parapoynx* (= *Nymphula*) *tenebralis,* which lays it eggs on the leaves. Newly emerged larvae excise a portion of leaf to make a protective case in which they shelter while feeding and moving around the plant. These larvae also attack *Salvinia molesta,* as do larvae of the related *Parapoynx* (= *Nymphula*) *turbata* (Gillett et al. 1988). In Thailand this species attacks water lettuce (Napompeth 1982), so it presumably has the same habit in the Northern Territory. A bug, *Nisia nervosa* (= *N. atrovenosa*) feeds on water lettuce as it does in India (Gillett et al. 1988, Joy 1978).

CENTRAL AND SOUTH AMERICA

Bennett (1975) listed 12 species of phytophagous insects that had been reared from *Pistia stratiotes* and Cordo et al. (1981) added one more. Particularly notable (Table 4.24.1) is the group of South American weevils which are generally confined to water lettuce, although adults of several may produce minor attack on some of the nearby aquatic plants whose stems and leaves nevertheless would be too small to support larval development. Preliminary host range studies suggest that several may be specific enough to be employed for biological control, although adequate information is available only for *Neohydronomus affinis*. This has been successfully established in several countries (see later). Larvae of the small pyralid moth *Samea multiplicalis*, which occurs from Argentina to the southeastern United States, feed on the growing buds of water lettuce and sporadically cause very heavy damage and dieback of the plants (Cordo et al. 1978, 1981, DeLoach et al. 1976, 1979).

Table 4.24.1 Natural enemies of *Pistia stratiotes.*

Species	Location	References
INSECTS		
Hemiptera		
APHIDIDAE		
unnamed	Thailand	Napompeth 1990a
Rhopalosiphum nymphaeae	Florida	Ballou et al. 1986, Bennett 1975, Joy 1978
COCCIDAE		
Planococcus citri	Nigeria, Trinidad	Bennett 1975
LYGAEIDAE		
Valtissius sp.	Argentina	Bennett 1975
MEENOPLIIDAE		
Nisia nervosa (= *N. atrovenosa*)	Australia, India	Gillett et al. 1988, Joy 1978
Orthoptera		
ACRIDIDAE		
Paulinia acuminata	South America	Bennett 1966, 1975
TETRIGIDAE		
Criotettrix sp.	Thailand	Napompeth 1990a
Coleoptera		
CURCULIONIDAE		
Argentinorhynchus bennetti	Mexico, Venezuela	O'Brien & Wibmer 1989a,b
Argentinorhynchus breyeri	Argentina, Paraguay	O'Brien & Wibmer 1989a,b
Argentinorhynchus bruchi	Argentina, Paraguay	Cordo et al. 1978
Argentinorhynchus minimus	Venezuela	O'Brien & Wibmer 1989a,b
Argentinorhynchus squamosus	Argentina, Paraguay	Cordo et al. 1978
Neohydronomus affinis	South America	DeLoach et al. 1976
Neohydronomus elegans	Honduras, Cuba	O'Brien & Wibmer 1989c
Neohydronomus pulchellus	Trinidad to Argentina, Cuba	Bennett et al. 1975, O'Brien & Wibmer 1989c
Ochetina bruchi	Argentina	Cordo et al. 1981
Pistiacola cretatus	Argentina, Brazil	Cordo et al. 1981
Pistiacola fasciatus	Central and South America	Wibmer & O'Brien 1989
Pistiacola sp. nr *nigrirostris*	Argentina	Cordo et al. 1981
Lepidoptera		
ARCTIIDAE		
Spilosoma virginica	Florida	Thompson and Habeck 1988
NOCTUIDAE		
Erastroides curvifascia	India	Chaudhuri & Janaki Ram 1975
Proxenus hennia	Indonesia	Mangoendihardjo & Nasroh 1976
Spodoptera pectinicornis	India, Bangladesh, Thailand	Alam et al. 1980, George 1963, Napompeth 1990a, Sankaran 1974, Sankaran & Rao 1972, Sankaran et al. 1964

(continued on next page)

Species	Location	References
PYRALIDAE		
Argyractis subornata	Brazil	Forno 1983
Elophila responsalis	India, Indonesia	Handayani & Syed 1976, Mangoendihardjo et al. 1977, Sankaran & Rao 1972, Subagyo 1975
Parapoynx (= *Nymphula*) *diminutalis*	Thailand	Napompeth 1990a, Suasa-Ard 1976
Parapoynx (= *Nymphula*) *tenebralis*	Australia	Gillett et al. 1988
Parapoynx (= *Nymphula*) *turbata*	Australia, Thailand	Gillett et al. 1988, Napompeth 1990a, Suasa-Ard 1976
Petrophila drumalis	Florida	Dray et al. 1988
Samea multiplicalis	southern USA, Trinidad, northern South America	Bennett 1966, 1975, Bennett et al. 1975, Dray et al. 1988
Synclita obliteralis	Florida	Dray et al. 1988
MITES		
Hydrozetes subornata	Australia	Gillett et al. 1988
FUNGI		
Cercospora canescens	Australia	Gillett et al. 1988
Cercospora sp.	India	Bennett 1975, Nag Raj and Ponappa 1966
Phyllosticta stratiotes	India	Bennett 1975
Sclerotium rolfsii	India	Bennett 1975

UNITED STATES

Dray et al. (1988) recorded larvae of three species of moth, a mealy bug, a leafhopper and an aphid on water lettuce which has been present in Florida for at least 200 years (Thompson and Habeck 1988). Only one of these insects, a root feeding moth, was considered to be possibly host specific. This was later identified as the pyralid moth *Petrophila drumalis*: the two other moths were *Samea multiplicalis* and *Synclita obliteralis* (Dray et al. 1989). The aphid was probably *Rhopalosiphum nymphaeae*, a well known transmitter of a number of economically important viruses. It has been recorded to cause dieback of water lettuce in Nigeria (Pettett and Pettett 1970). This aphid was reported to be widespread on water lettuce in Florida (Ballou et al. 1986). An aphid, possibly the same species, transmitted a virus that caused widespread dieback of *P. stratiotes* on Lake Volta in Ghana (Okali and Hall 1974), although serious dieback has not been reported in Florida. The non-specific larvae of the arctiid moth *Spilosoma virginica* was also common on water lettuce in Florida (Thompson and Habeck 1988).

INDIA

Larvae of the moth *Spodoptera pectinicornis* cause extensive damage to *Pistia*. On average, a single larva can consume the leaves of two *Pistia* plants during its developmental period of 15 to 20 days. Some 100 larvae developing from an average egg mass destroy all *Pistia* leaves within an area of 1 m^2 and, during peak abundance in the field, the number of larvae per m^2 of *Pistia* surface was always higher than this (George 1963, Sankaran and Ramaseshiah 1974). The bug *Nisia nervosa* successfully completes its life cycle on *Pistia*, but is reported as a minor pest of rice (Joy 1978).

INDONESIA

In Java and Sulawesi, water lettuce is attacked by larvae of the noctuid moth *Proxenus hennia* which appears to be specific (Mangoendihardjo and Nasroh 1976). Other species found attacking it were *Elophila* (= *Nymphula*) *responsalis*, *Spodoptera mauritia*, an aphid and a cicadellid (*Zygina* sp.) (Mangoendihardjo and Syed 1974, Mangoendihardjo et al. 1976, 1977, Syed et al. 1977).

THAILAND

Water lettuce is attacked by several insects (Table 4.24.1), of which only the pygmy grasshopper *Criotettrix* sp. and the native water lettuce moth *Spodoptera pectinicornis* are capable of inflicting serious damage. In certain areas where the density of *Criotettrix* was as high as 100 per m^2 considerable suppression of the weed occurred. Both adults and nymphs were able to walk on the surface of the water and were observed to attack also the water fern, *Salvinia cucullata* (Napompeth 1982). The extensive damage that can be caused by *Spodoptera pectinicornis* is discussed later.

Attempts at biological control

AUSTRALIA

The first attempt to bring about classical biological control of *Pistia stratiotes* was the liberation of adults and larvae of *Neohydronomus affinis* in 1982 near Brisbane. Within two months of release, plants were rotting and sinking and, by eight months, about one third of the plants in a dam were chlorotic and some had been destroyed. Severely damaged plants produced short stolons terminating in small plantlets before sinking and dying, but these plantlets failed to grow to the size of their parents before, in turn, becoming severely damaged, producing plantlets and then sinking. Continued weevil attack led initially to an increase in the number of plants, but a decrease in their size and dry weight. Before long, few water lettuce plants remained (Harley et al. 1984). The moth *Samea multiplicalis* was liberated in Australia in 1981, primarily against *Salvinia molesta*, on which it became established. However, within four years, its effectiveness was restricted by protozoan disease and three hymenopterous parasitoids (Thomas and Room 1986). It presumably attacks *Pistia stratiotes* also, although there seems to be only one observation of it doing so. This was at Townsville (D.P.A. Sands pers. comm. 1993).

PAPUA NEW GUINEA

The moth *Spodoptera pectinicornis* attacks water lettuce, but is unable to prevent its increase when the plant is freed from competition by the biological control of *Salvinia* or

Table 4.24.2 Liberations for the biological control of *Pistia stratiotes*.

Species	Where	From	When	Result	References
Coleoptera					
CURCULIONIDAE					
Neohydronomus affinis	Australia	Brazil	1982	+	Harley et al. 1984, 1990
	Botswana	Brazil via Australia	1988	+	Chikwenhere & Forno 1991 I.W. Forno pers. comm. 1993
	Papua New Guinea	Brazil via Australia	1985	+	Chikwenhere & Forno 1991, Harley et al. 1990, Laup 1987b
	South Africa	Brazil via Australia	1985	+	Cilliers 1987, 1989b
	United States of America	Brazil via Australia	1987	+	Center et al. 1989, Thompson & Habeck 1988, Dray et al. 1990
	Zambia	Zimbabwe	about 1990	+	P. Room pers. comm. 1993
	Zimbabwe	Brazil via Australia	1988	+	Chikwenhere & Forno 1991
Lepidoptera					
NOCTUIDAE					
Spodoptera pectinicornis	Florida	Thailand	1990	?	Center et al. 1989, Julien 1992
Napompeth 1990a					
PYRALIDAE					
Samea multiplicalis	Australia	Brazil	1981	+	Forno 1987, Room et al. 1984

Eichhornia. *Neohydronomus affinis* was successfully established in the Sepik River system in 1985, but its impact is yet to be recorded (Laup 1987b).

THAILAND

Although no introductions of biological control agents for *Pistia stratiotes* have been made in Thailand, the mass rearing and release of the native noctuid moth *Spodoptera pectinicornis* has replaced the use of herbicides for this weed. Under laboratory conditions mixed instar larvae at the rate of 300 or more per m^2 gave as fast and effective control as any herbicide. In the field a substantial initial release of larvae, followed by one or two additional releases at two-week intervals has led to complete control within 6 to 10 weeks. Thus, a 4.5 km^2 infestation of water lettuce was controlled in 6 weeks at Sri Nakarint Dam in 1978 and a 10 km^2 infestation in 1982 (Napompeth 1982). *S. pectinicornis* occurred throughout the year and in all infestations of *Pistia* (Suasa-Ard and Napompeth 1982).

UNITED STATES

Neohydronomus affinis was released in Florida in 1987, became established readily, multiplied rapidly and soon spread from the release sites to cause considerable damage to water lettuce (Dray et al. 1990). In one release site the *Pistia* population was reduced from 50 to less than 5 acres in 2 years and, in another, a 10 acre site was virtually cleared in 3 years. However, in a third site, little effect was noted. It was postulated that this might be due to the presence of a different genetic strain of *P. stratiotes*, which had a far greater seed production than that at the other two sites (Dray and Center 1992). *Spodoptera pectinicornis* has also been established in Florida (Center et al. 1989; Napompeth 1990a).

BOTSWANA

N. affinis was released on the Linyanti R at the Selinda spillway in 1988. Excellent control was achieved within 12 months (I.W. Forno pers. comm. 1993).

SOUTH AFRICA

Neohydronomus affinis was released in Kruger National Park and a water lettuce infestation in a motionless water body was completely controlled within 10 months (Cilliers 1987, 1989a,b). The weevil has been less successful on fast-flowing rivers where plants infested with weevil larvae are continually washed down stream and replaced by uninfested plants from higher up. However, even under these circumstances, up to 90% of plants showed signs of feeding damage (Cilliers 1991b).

ZAMBIA

N. affinis was already established by natural spread at Kafubu Lake when *N. affinis* from Zimbabwe was liberated about 1990 and by 1992 there were only scattered plants of *Pistia* but no mats (P.M. Room pers. comm. 1993).

ZIMBABWE

Neohydronomus affinis was released in 1988, was well established in 4 months and, within a year, water lettuce was no longer a problem in the Manyame River (Chikwenhere and Forno 1991).

Major natural enemies

Argentinorhynchus bruchi Coleoptera: Curculionidae

This yellow spotted weevil (4.7 mm long) is known from Argentina, Bolivia, Paraguay and Uruguay (O'Brien and Wibmer 1989a,b). Although it is rare, it has the potential to cause heavy damage to water lettuce. Under laboratory conditions adults ate 1 cm^2 of leaf surface per day, producing some 10 oval holes all the way through the leaf. Adults feed mostly by night and generally on medium-aged leaves. Field collected females laid on average 1575 eggs among the dense hairs on the leaf surface. Eggs hatch in 7.6 days. First instar larvae enter the leaf and feed on the spongy leaf tissue and second and third instars in the crown. Fourth instar larvae could not be reared: in the laboratory they left the plant and drowned. Adults fed and oviposited only on water lettuce and, except for slight feeding on *Spirodela*, of the 26 plant species tested, larvae only developed on water lettuce. In the laboratory 6 larvae per plant killed water lettuce within a month. It was suggested that egg predation may account for the rarity of *A. bruchi*; also that the difficulty experienced in rearing the fourth instar larvae may indicate that special conditions are required, lack of which may reduce survival (Cordo et al. 1978).

Neohydronomus affinis Coleoptera: Curculionidae

This mottled, brown-grey weevil was earlier confused in the literature with the closely related *N. pulchellus*. It occurs naturally in Argentina, Brazil, Colombia, Paraguay, Peru, Uruguay and Venezuela (O'Brien and Wibmer 1989c). Adults (males 1.8 mm, females 2.1 mm long) feed on the leaves of *Pistia stratiotes* and mine the tissues: they do not appear to attack the crown or roots. Females lay about 1 egg per day beneath the leaf epidermis, usually on the upper surface near the margin. Eggs hatch after 3 to 4 days and larvae tunnel through the leaf tissues to complete development in 11 to 14 days. Pupation occurs in small pockets in the leaf tissues and adults emerge after about 4 days. The period from egg to adult varies from 4 to 6 weeks, but there are only 3 generations a year in Argentina (December, February to March and June). Overwintering probably occurs in the adult stage (DeLoach et al. 1976).

N. affinis is very destructive under laboratory conditions. Maximum damage occurred in midsummer in Argentina, when peak populations of 200 to 600 per m^2 produced 1.6 feeding spots per cm^2 of leaf surface. Adult *N. affinis* are occasionally parasitised by nematodes in Argentina (DeLoach et al. 1976).

N. affinis is highly specific to water lettuce, as shown by tests in Zimbabwe (Chikwenhere and Forno 1991), South Africa (Cilliers 1989b), Florida (DeLoach et al. 1976, Dray et al. 1990, Thompson and Habeck 1988, 1989) and Australia (Harley et al. 1990); and also by absence of reported damage to economic plants in any of the countries to which it has been introduced.

Pistiacola cretatus Coleoptera: Curculionidae

This brown 2.3mm long weevil, earlier known as *Onychylis cretatus*, occurs in Argentina and Brazil (Wibmer and O'Brien 1989). Adults feed mainly on the upper surface of the leaves of *P. stratiotes* and oviposit into the leaf tissue. The slender larvae tunnel into the denser tissues of the basal third of the leaf and also into the crown. Pupation occurs within the spongy part of the leaf. In the field, adult *P. cretatus* were found only on water lettuce (Cordo et al. 1981).

Samea multiplicalis Lepidoptera: Pyralidae

This brown moth with dark markings and a wingspan of about 17 mm occurs from Florida to Argentina.

Up to 290 eggs are laid per female, mainly on the upper surface of the leaves. These hatch after 4 days and the larvae construct a silken canopy under which they feed, or they may tunnel into the leaves to feed on the spongy tissues: they also eat the buds. After 5 or 6 instars in the course of 16 days, they pupate in silken cocoons, to emerge as adults 5 days later. Adults live up to 7 days (DeLoach et al. 1979, Knopf and Habeck 1976, Sands and Kassulke 1984). *S. multiplicalis* has three main hosts in Florida, *Pistia stratiotes*, *Azolla caroliniana* and *Salvinia rotundifolia* and it may occasionally attack *Eichhornia crassipes*. Oviposition is highest on *P. stratiotes*. Although medium to large larvae fed on a number of plants under laboratory conditions, *S. multiplicalis* has never been reported as a pest of cultivated plants in Argentina or Brazil (DeLoach et al. 1979). It passed strict host specificity tests in Australia, larvae completing development on *P. stratiotes*, *Azolla pinnata* and *Salvinia molesta*. Larvae that had fed first on *S. molesta* were unable to complete their development on water lettuce, although they produced minor leaf scars. *S. multiplicalis* was released in Australia, but primarily against *Salvinia molesta* (Sands and Kassulke 1984).

Samea multiplicalis has 3 generations a year in the field in Argentina, with population peaks in December, February and May, when populations reach a maximum of 5 larvae per plant. In laboratory tests females laid 99.3% of their eggs on *P. stratiotes*. Larvae caused heavy, but sporadic, damage to water lettuce in the field. However, in most years, populations were held at low levels, apparently by parasitoids (*Apanteles* sp. and *Podogaster* sp.) (DeLoach et al. 1979). In Florida 52% parasitisation was recorded, 42.7% by three species of Hymenoptera (*Agathis* sp., *Apsilops* sp. and *Temelucha ferruginae*) and 9.3% by a tachinid fly (*Lixophaga* sp.) (Knopf and Habeck 1976). *Nosema* sp. was detected in Australia in some larvae from Brazil and the culture was freed of these before release (Sands and Kassulke 1984).

***Spodoptera pectinicornis* Lepidoptera: Noctuidae**

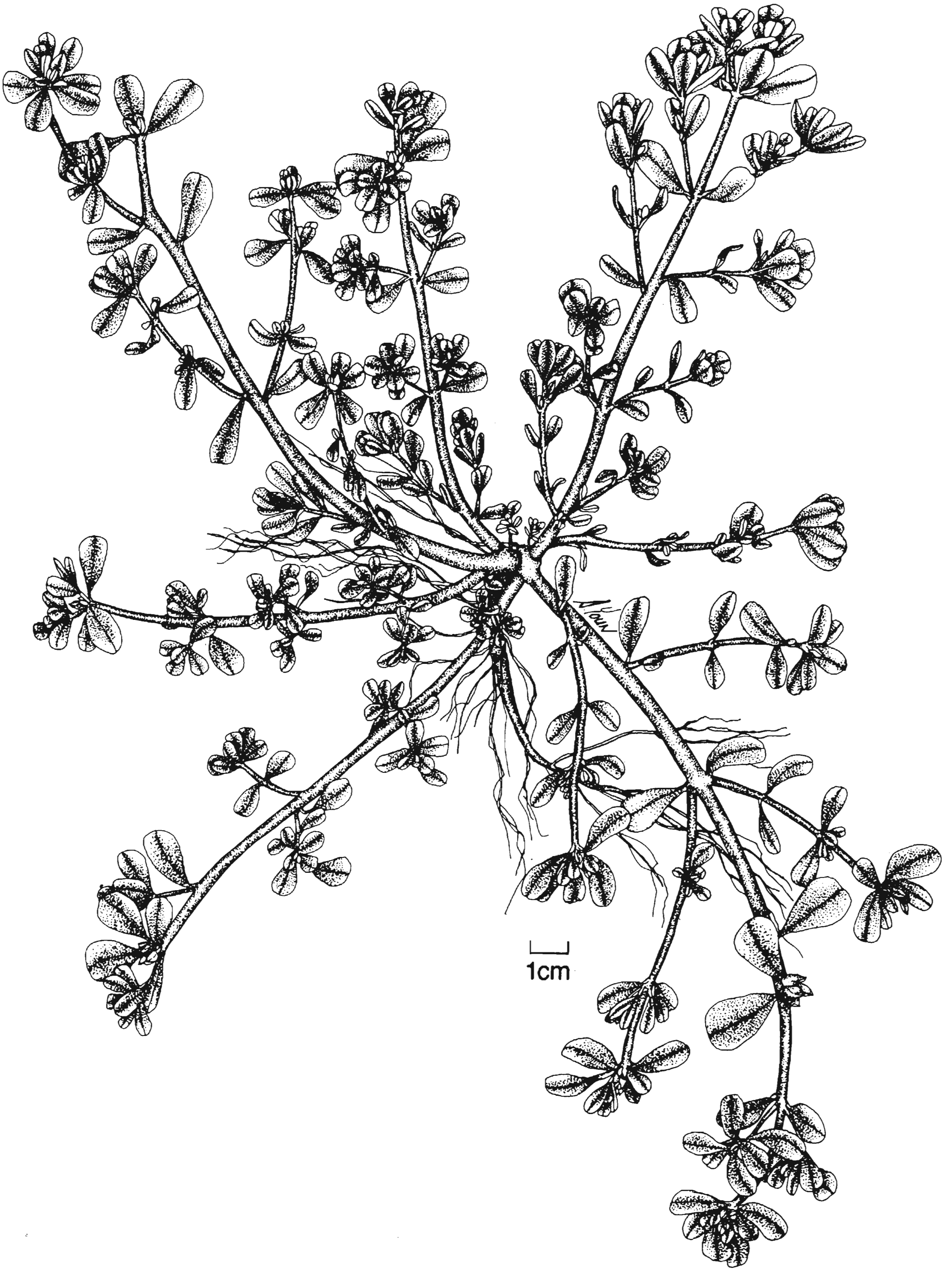
This moth ranges over an extensive area from India through Sri Lanka, Thailand and Indonesia to Papua New Guinea. Eggs are laid in masses of 70 to 120 on the undersurface of the *Pistia* leaf near its edge. They hatch in 40 to 60 hours to produce pale green larvae that burrow in the leaf parallel to the longitudinal veins. After some 20 days the 1.5 to 2 cm long larvae pupate, to emerge two to three days later as small silvery brown moths about 1cm long (George 1963). In Thailand the period from egg to adult averaged 30 days and females laid an average of 666 eggs. Host specificity tests showed that it would develop only on *Pistia stratiotes* (Suasa-Ard 1976). Napompeth (1990a) reports that it is relatively simple to mass rear in the laboratory and to distribute in the field. Details are available of its rearing and ecology in Thailand (Suasa-Ard 1976, Suasa-Ard and Napompeth 1978). It was mass reared and released in Florida after tests showed that it was sufficiently host specific (Center et al. 1989, Napompeth 1990a).

Comment

Pistia stratiotes is seldom more than a minor component of the floating weed mass when either *Eichhornia crassipes* or *Salvinia molesta* or both are present. However, when it occurs alone or when the strong competition from these two weeds is greatly reduced by their effective biological control, water lettuce can increase rapidly to occupy the vacated water surface. Since damaging biological control agents are available for all three weeds, it is sensible to embark on a biological control program for them all, either at the same time or in sequence.

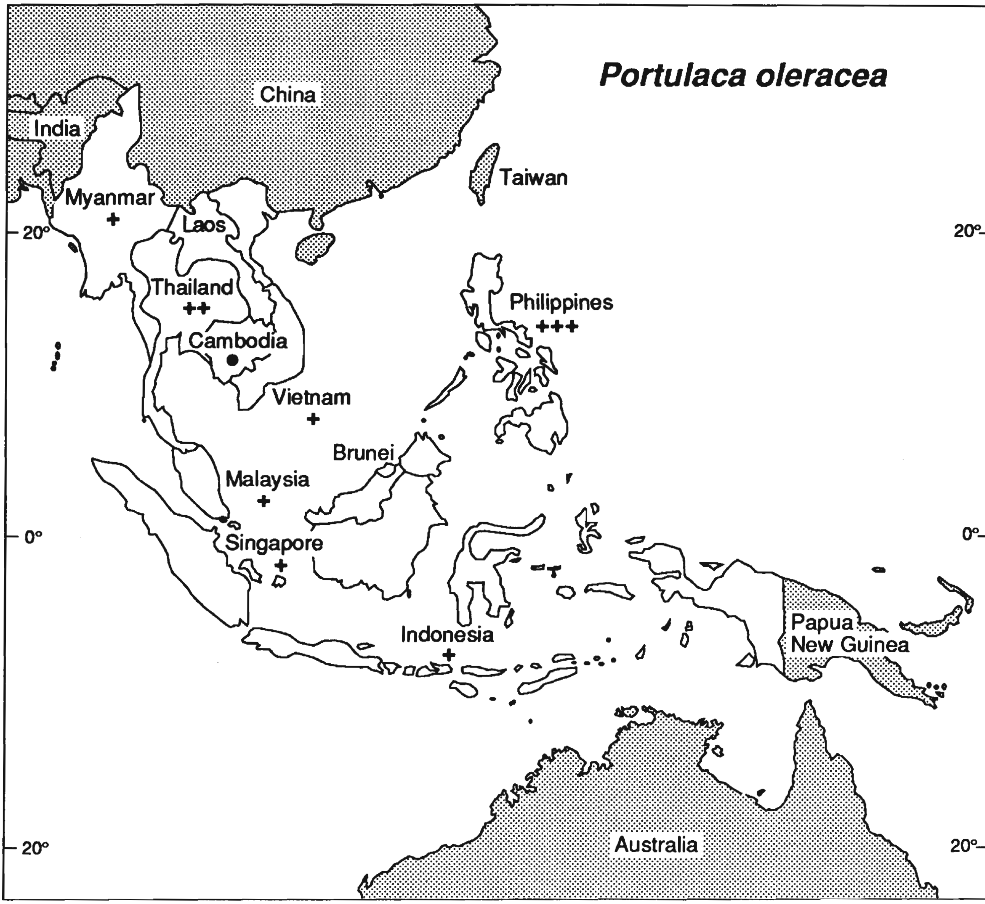
Adequate biological control of water lettuce has been achieved by the introduction of the weevil *Neohydronomus* alone. However, if an even greater degree of control is desired, there are, in South America, additional species of weevil and also several moths that appear to be well worthwhile investigating further. This is particularly so, as some are known to be heavily attacked by natural enemies and, if introduced without these, would be expected to be even more effective.

It can be concluded with some confidence that water lettuce is a promising candidate for biological control.



Portulaca oleracea

(after Holm *et al.* 1977)



Map 4.25 *Portulaca oleracea*

Portulaca oleracea is a serious weed throughout tropical, subtropical and temperate areas, attaining high overall pest status more because of its very widespread importance than by being amongst the top few weeds in any one country.

About 14 of the 140 or so species of insects that are known to attack it appear to be restricted to the genus *Portulaca* and probably several to *P. oleracea* or its very close relatives. In their native ranges 4 leaf-mining or gall-forming flies, 1 leaf-mining moth, 1 leaf-mining sawfly and 2 weevils all cause considerable damage and show high specificity to *P. oleracea*.

If this group of phytophagous insects is not already present, the establishment of several without their own natural enemies should lead to a significant lowering in the weed status of *P. oleracea*.

Portulaca oleracea is an attractive target for an attempt at biological control.

4.25 *Portulaca oleracea* L.

Portulacaceae

pigweed, purslane; gelang, krokot (Indonesia); gelang pasir, segan (Malaysia); phak bia yai (Thailand), mya byit, mye byet (Myanmar); kbet choun (Cambodia); golasiman, ulasiman (Philippines), rau sam (Vietnam)

Rating

	+++	Phil
10	++	Thai
	+	Myan, Viet, Msia, Sing, Indo

Much of the material in this dossier is summarised from the account in Waterhouse (1993b).

Origin

Uncertain; possibly Central America, but see comment.

Distribution

Very widespread in tropical, subtropical and temperate regions of the world, including Southeast Asia, Australia and the Pacific.

Characteristics

Pigweed is a fleshy annual herb, reproducing by seed, or by stem-fragments rooting when lying on moist soil. The stems are succulent, often reddish and 0.2 to 0.5 m in length. The stems and leaves are smooth and fleshy and form mats. In sunlight the plants are prostrate, but in partly shaded situations they may attain a height of 0.5 m. The leaves are alternate, flowers are yellow, sessile, self-pollinated and either occur singly, or several may occur together, in the leaf clusters at the ends of branches. They open on sunny mornings and later produce numerous tiny (0.5 mm diameter) black seeds.

Importance

P. oleracea was ranked 9th of the world's worst weeds, being recorded in 45 crops in 81 countries (Holm et al. 1977). With a rating of 10 in Southeast Asia, it ranked equal 32nd in the region; also 6th in the Pacific and 49th in Australia (Waterhouse 1993a,b). In Southeast Asia, it is particularly important in many upland crops, including vegetables, rice, maize, sorghum, groundnuts and sugarcane. It is drought hardy, colonising waste places and bare areas but thrives in moist fertile soils. There are many ecological types, some of which are occasionally used as a vegetable. In the Philippines up to 10 000 and in North America up to 243 000 seeds are produced per plant. The tiny seeds are spread by wind, water, as a contaminant of the seeds of crops and by birds, surviving passage through the digestive tract. They also survive burial for long periods and germinate best above 30°C, but poorly below 24°C.

Pigweed does not compete well with other weeds. It is successful because it establishes rapidly after soil disturbance and may flower and seed before being outcompeted by taller plants. The succulent leaves and stems are rich in oxalates and nitrates and have been implicated in livestock deaths. The succulent leaves of some strains have been used as human food (Miyanishi and Cavers 1980).

Natural enemies

The 138 insect species that have been recorded attacking *P. oleracea* were listed by Waterhouse (1993b), most of them from Central and South America (Bennett and Cruttwell 1972) and USA (Romm 1937). A few additional records are now listed in table 4.25.1. Most of these species are known to be (or suspected of being) polyphagous and many are pests. Nevertheless, table 4.25.2 lists 14 insects that, so far as known, are restricted to *P. oleracea*, or at least to the genus *Portulaca*. Eight of these appear to have originated in the Americas, 2 each in Africa and India, and 1 each in France and Southeast Asia. With the exception of the weevil *Ceutorhynchus portulacae*, described from *P. oleracea* in Java, there do not appear to be any reports of native insects which might possibly be restricted to pigweed in Southeast Asia, the Pacific or Australia.

Table 4.25.1 Natural enemies of *Portulaca oleracea*: additional insect records to those of Waterhouse (1993b).

Species	Country	Other hosts	References
Hemiptera			
APHIDIDAE			
Myzus persicae	Australia	polyphagous	author's record
CICADELLIDAE			
Circulifer haematoceps	Israel	polyphagous	Klein & Raccah 1991
Orosius orientalis (= *O. albicinctus*)	India	polyphagous	Kooner & Deol 1982
LYGAEIDAE			
Nysius cymoides	Italy	jojoba	Parenzan 1985
Nysius vinitor	Australia	polyphagous	Elshafie 1976, Ramesh & Laughlin 1984
Coleoptera			
CURCULIONIDAE			
Hypurus bertrandi	Australia, India, Guam, Northern Marianas	specific	R.E. McFadyen pers. comm. 1993, Zaka-ur-rab 1991, Zimmerman 1957
Diptera			
AGROMYZIDAE			
Liriomyza caulophaga	Australia	*Beta vulgaris* var. *cicla*	R.E. McFadyen pers. comm. 1993
Liriomyza trifolii	USA	polyphagous	Chandler & Chandler 1988

(continued on next page)

Table 4.25.1 (continued)

Species	Country	Other hosts	References
Lepidoptera			
NOCTUIDAE			
Agrotis ipsilon	India	polyphagous	Das & Ram 1988
Neogalea (= *Spodoptera*) *sunia*	Nicaragua	polyphagous	Savoie 1988
Spodoptera eridania	Nicaragua	polyphagous	Savoie 1988
Spodoptera exigua	Nicaragua	polyphagous	Savoie 1988
PYRALIDAE			
Loxostege bifidalis	N. America	cotton	Allyson 1976

The host specificity has been investigated of 5 of the 6 species of Diptera, Lepidoptera and Hymenoptera listed in table 4.25.2, but, except for *Baris arctithorax* and *Hypurus bertrandi*, both of which appear to be adequately specific (see later), little is known about that of the 8 weevils.

Several of the fungi listed in table 4.25.3 are reported to damage *P. oleracea*, sometimes severely (Waterhouse 1993b), but too little is known about host specificity or host specific strains to evaluate their possible role as classical biological control agents. Nevertheless their specificity certainly merits investigation should the need arise.

Attempts at biological control

There have been no attempts to establish natural enemies as biological control agents for *P. oleracea*. However three insect species have appeared in countries well out of their native range, in particular the European weevil *Hypurus bertrandi*, but also the American sawfly *Schizocerella pilicornis* and the American leaf-mining fly *Haplopeodes palliatus*. These successful, unassisted establishments suggest that there should be little difficulty in securing assisted establishments elsewhere. Unfortunately there is no information available on what effects, if any, these three insects have had on *P. oleracea* in their new countries, but it is suspected that a group of species may be required to secure substantial effects in Australia.

The sawfly *Schizocerella pilicornis* appeared in eastern Australia (Queensland and New South Wales) in the early 1960s; (Benson 1962, Krombein and Burks 1967) but there are no records of it building up in sufficient numbers to cause serious damage. In 1993 *Hypurus bertrandi* and *Liriomyza caulophaga* were bred from *P. oleracea* leaves in Brisbane (R.E. McFadyen pers. comm.), but numbers were too low to cause serious damage. It is not known whether these species have only become established recently. *L. caulophaga* was previously known only from *Beta vulgaris* var. *cicla* (silverbeet) in Australia. Larvae tunnel in the soft white spongy tissue between the vascular strands in the leaf petioles and midribs and pupate there (Kleinschmidt 1960, 1970, Spencer 1990).

EGYPT

Tawfik et al. (1976) recorded *Hypurus bertrandi* attacking *P. oleracea.*

GUAM AND THE NORTHERN MARIANA IS.

Zimmerman (1957) records *Hypurus bertrandi* from Guam, Tinian, Saipan and Agrihan, some of the specimens from Saipan being taken from the crops of swifts.

Table 4.25.2 Insects restricted to *P. oleracea* or at least to the genus *Portulaca* (after Waterhouse 1993b).

Species	Distribution	References
Coleoptera		
CURCULIONIDAE		
Apion sp.	Brazil	d'Araujo e Silva et al. 1968a,b
Baris arctithorax	Egypt	Tawfik et al. 1976
Baris lorata	Sudan	Marshall 1911
Baris portulacae	India	Marshall 1916
Ceutorhynchus oleracae	Java	Marshall 1935
Ceutorhynchus portulacae	India	Marshall 1916
Hypurus bertrandi	Puerto Rico, France, Egypt, USA, Hawaii, Marianas, Australia	Wolcott 1948 Tempère 1943 Tawfik et al. 1976 Clement and Norris 1982 RE McFadyen pers. comm. 1993, Zimmerman 1957
Linogeraeus (= *Centrinaspis*) *perscitus*	Colombia, Trinidad, USA	Bennett and Cruttwell 1972, Romm 1937
Diptera		
AGROMYZIDAE		
Haplopeodes palliatus	Australia, USA	R.E. McFadyen pers. comm. 1993, Romm 1937
ANTHOMYIIDAE		
Pegomya dolosa	Trinidad	Bennett and Cruttwell 1972 Cruttwell and Bennett 1972a
CECIDOMYIIDAE		
Asphondylia portulacae	El Salvador, Argentina, Colombia, Bolivia, Leeward Is, St Kitts Nevis, Montserrat, Jamaica	Gagné 1968, Bennett and Cruttwell 1972
Lasioptera portulacae	USA	Felt 1911
Neolasioptera portulacae	Cuba, Florida, St Vincent Trinidad, St Kitts Nevis,	Gagné 1968 Bennett and Cruttwell 1972
Lepidoptera		
HELIODINIDAE		
Heliodines quinqueguttata	Trinidad,Montserrat Puerto Rico	Bennett and Cruttwell 1972, Cruttwell and Bennett 1972b Wolcott 1948
Hymenoptera		
TENTHREDINIDAE		
Schizocerella pilicornis	California, Mexico USA, Australia Argentina to USA	Bennett and Cruttwell 1972 Krombein and Burks 1967 Muesebeck et al. 1951

Table 4.25.3 Natural enemies of *Portulaca oleracea*: fungi, viruses and nematodes.

Species	Country	Other hosts	References
FUNGI			
Albugo portulacae	Europe, Africa, Asia, Americas		IMI 1992, Miyanishi & Cavers 1980
Albugo portulacearum	Poland		IMI 1992
Ascochyta portulacae	USSR		IMI 1992
Bipolaris (= *Drechslera*) *indica*	USA	many, including *Amaranthus spinosus*	Evans 1987, Kenfield et al. 1989
Cercospora portulacae	India		IMI 1992
Cercosporella dominicana	Dominica		IMI 1992
Dendrographium lucknowense	India		IMI 1992
Dichotomophthora indica (= *D. lutea*)	USA, West Indies, Europe, India	*Helianthus*, *Pennisetum*	Baudoin 1986, IMI 1992, Rao 1966
Dichotomophthora portulacae	Europe, Sudan, Hawaii, California, Jamaica Venezuela	tarragon, cactus, capsicum, *Glycine max*	Vegh & Le Berre 1984 Klisiewicz 1985, Klisiewicz et al. 1983, Mehrlich & Fitzpatrick 1935 Mitchell 1986
Helminthosporium (Bipolaris) portulacae	USA	*Portulaca grandiflora*	IMI 1992, Rader 1948, Strider & Chi 1984
Phoma sp.	France	tarragon	Vegh & Le Berre 1984
Phytophthora palmivora	Sarawak	pepper and several weeds	Anon 1979
Polymyxa betae f. sp. *portulacae*	Bulgaria, Japan	sugar beet, wheat, many weeds	Abe & Ui 1986, Vrbanov & Krumov 1989
VIRUSES			
anemone brown ring	Hawaii	anemone	Holm et al. 1977
aster yellows	Hawaii	aster	Holm et al. 1977
beet curly top	Hawaii	sugar beet	Holm et al. 1977
chili vein banding	Hawaii	chili	Holm et al. 1977
clover big vein	Hawaii	clover	Holm et al. 1977
cucumber mosaic	Bulgaria Hungary USA	many economic plants cucumber, tobacco	Dikova 1989, Nasser & Basky 1988, Dodds & Taylor 1980
groundnut rosette	Malawi	groundnut	Adams 1967
tobacco broad ring spot	Hawaii	tobacco	Holm et al. 1977
tobacco etch	Hawaii	tobacco	Holm et al. 1977
tobacco mosaic	Philippines	many	Eugenio & del Rosario 1962
tobacco streak	Hawaii	tobacco	Holm et al. 1977
NEMATODES			
Criconemella xenoplax	USA	many legumes and other plants	Zehr et al. 1990
Ditylenchus dipsaci	USSR	polyphagous	Kholod 1983
Helicotylenchus indicus	India	polyphagous	Rahman & Khan 1986
Helicotylenchus multicinctus	Brazil, Ivory Coast	banana	Luc et al. 1990, Zem & Lordello 1983
Heterodera glycines	Colombia	soybean	Quintero et al. 1988

(continued on next page)

Species	Country	Other hosts	References
Heterodera marioni	Hawaii		Linford & Yap 1940
Hoplolaimus indicus	USA	eggplant, tomato	Rahman & Khan 1986
Meloidogyne sp.	Cuba	coffee	Izquierdo et al. 1987
Meloidogyne arenaria	USA	tobacco	Tedford & Fortnum 1988
Meloidogyne hapla	Hungary		Dabaj & Jenser 1990
Meloidogyne incognita	India, USA, Philippines	several weeds	Maqbool et al. 1986, Tedford & Fortnum 1988, Valdez 1968
Meloidogyne javanica	India	polyphagous	Maqbool et al. 1986
Pratylenchus minutus	Hawaii		Linford et al. 1949
Pratylenchus sp.	Ivory Coast	polyphagous	Luc et al. 1990
Radopholus similis	Ivory Coast	*Musa* sp., several weeds	Luc et al. 1990
Rotylenchulus reniformis	India, USA, Hawaii	ornamentals and many weeds	Heald et al. 1974, Inserra et al. 1989 Khan & Khan 1985 Linford & Yap 1940
Tylenchorhynchus brassicae	India	polyphagous	Rahman & Khan 1986

HAWAII

Pigweed was established in Hawaii prior to 1871 (Hillebrand 1888). *Hypurus bertrandi*, originally misidentified as *Ceutorhynchus* sp., was reported in 1950 to be numerous enough in many cases to defoliate *P. oleracea* and to cause it to collapse as if sprayed with a herbicide (Bianchi 1955). Nevertheless, in 1992, Hawaiian weed scientists considered it as one of their worst weeds (W.C. Mitchell pers. comm. 1992), so the control exerted by *H. bertrandi* and various non-specific insects is clearly insufficient. Zimmerman (1957) postulates that *H. bertrandi* was introduced from the Marianas to Hawaii, possibly with war material being returned from the battlefields. However it is more likely to have moved in the reverse direction.

INDIA

Zaka-ur-rab (1991) records *Hypurus bertrandi* as one of the leaf-mining weevils of the Indian subcontinent.

PUERTO RICO

Wolcott (1948) recorded *H. bertrandi* from Puerto Rico, but no other information is available.

Major Natural Enemies

Summarised below is what is known of the biology of nine of the natural enemies listed in table 4.25.2.

Apion sp. Coleoptera: Curculionidae

Apion sp. produces galls in the flower buds of *P. oleracea* in Brazil (d'Araujo e Silva et al. 1968a,b) and *Apion* larvae also cause significant damage by gall formation in flowers in northern Argentina (Bennett and Cruttwell 1972, Bennett pers. comm. 1992).

Asphondylia portulacae **Diptera: Cecidomyiidae**

Oviposition by this flower gall midge into the very small pigweed buds causes them to develop abnormally. Usually only one larva develops per bud and occupies a chamber in the swollen receptacle. Galled flowers do not produce seed. *A. portulacae* is heavily attacked by parasitoids (Bennett and Cruttwell 1972) and might be an important natural enemy if freed from them. The genus *Asphondylia* is considered to be highly host specific and 52 of its 54 species are known from only a single host. Each of the two exceptions only attacks two plants of the same genus and Bennett and Cruttwell (1972) suggested, on the basis of this information, that host specificity testing was unnecessary.

Baris arctithorax **Coleoptera: Curculionidae**

In Egypt this weevil forms stem galls on pigweed, but is not known from any economic plant. Eggs are laid singly in cavities gnawed in the stem by the female, leading to the production of single closed galls in which the larvae feed. Pupation occurs in the soil. Young infested plants produce weak vegetative growth, few seeds and may even be killed. Adult weevils feed on the surface of leaves causing white blotches or holes. At temperatures from 25 to 30°C the development time from egg to adult is about 40 days. Infestations of up to 74% of plants are recorded in summer and a peak of 95% in autumn (Awadallah et al. 1976, Tawfik et al. 1976).

Haplopeodes palliatus **Diptera: Agromyzidae**

The genus *Haplopeodes* contains 13 species, all from the Americas and known on only four plant families—Portulacaceae (1 species) Amaranthaceae (3 species), Chenopodiaceae (2 species) and Solanaceae (8 species) (Spencer 1990). Each appears to be specific to a single genus and *H. palliatus* is known only from *P. oleracea*. It is a typical leaf miner.

Heliodines quinqueguttata **Lepidoptera: Heliodinidae**

Eggs, which are laid singly or in groups of up to 6, hatch in 5 to 6 days and larvae wander some distance over the plant before mining into a leaf, stem or seed capsule. After 7 to 8 days the fifth instar larva leaves the mine and pupates within a flimsy silk cocoon attached to the stems or leaves of the plant. Larvae are attacked by a braconid endoparasitoid, *Pholetesor* (= *Apanteles*) sp. (*circumscriptus* group).

Host specificity tests were carried out on a wide variety of economic and non-economic plants, but development was completed only on *Portulaca oleracea*, *P. pilosa* (also weedy) and the ornamental *P. grandiflora*. However, in the field in Trinidad, neither *P. pilosa* nor *P. quadrifida* (also weedy) were attacked and *P. grandiflora* was not grown. There appear to be no records of *Heliodines* species attacking crops and each species appears to be restricted to a single plant family. Cruttwell and Bennett (1972b) suggested, therefore, that it should be considered as a biological control agent.

Hypurus bertrandi **Coleoptera: Curculionidae**

This tiny (2mm long) weevil has spread unaided from its native France to Egypt (prior to 1926) (Hoffman and Tempère 1944, Tawfik et al. 1976), Puerto Rico (Wolcott 1948), Hawaii (1950) (Davis 1955, Maehler 1954), Guam and the Northern Marianas

(Zimmerman 1957), California (1980) and Queensland (1993) (R.E. McFadyen pers. comm.).

Eggs are deposited singly and larvae mine the leaves. Infested leaves wilt and fall; and the larvae then migrate to fresh leaves, each destroying four or five in its lifetime. If no undamaged leaves are available the outer tissues of stems are attacked. Pupation occurs in a cell formed by soil particles cemented by fecal secretion and, in France, adults overwinter under the bark of trees. Adults feed on leaf margins, stems and developing seed capsules. Development is rapid, from egg to adult in 10 days at 32.2°C and under 16 hours light. *P. oleracea* is its only reported host plant. In France it is parasitised by a number of wasps (Tawfik et al. 1976, Clement and Norris 1982, Hoffmann and Tempère 1944, Norris 1985, Tempère 1943, 1944, 1950).

***Neolasioptera portulacae* Diptera: Cecidomyiidae**

Oviposition in the stem by this midge leads to globular galls up to 1.5 cm in diameter, each containing up to 10 larvae. Galls retard or prevent growth and also flower and seed production. In open, infertile sites every pigweed stem may be infested but, in vigorous growth or in shaded sites, the level of attack is usually very low. The larvae are heavily attacked by parasitoids.

All except one of the 51 species of *Neolasioptera* are restricted to one plant genus and the remaining species only attacks two plant genera. This was taken by Bennett and Cruttwell (1972) to indicate that *N. portulacae* is sufficiently host specific to be employed for biological control.

***Pegomya dolosa* Diptera: Anthomyiidae**

Eggs are laid singly on the underside of the pigweed leaf and hatch after about 3 days. The larvae are leaf miners, devouring the contents of the leaf and then leaving to enter another. Two or more leaves are commonly destroyed by each larva. After feeding for about 7 days larvae leave to pupate in the soil, later emerging as 3 to 4 mm long adults. Eggs are parasitised and larvae are attacked by a pteromalid wasp.

***Schizocerella pilicornis* Hymenoptera: Tenthredinidae**

This leaf-mining sawfly occurs naturally over a very wide range from Argentina and Brazil to USA (Muesebeck et al. 1951). It appeared unaided in eastern Australia (Benson 1962, Krombein and Burks 1967). There are two biotypes. The larvae of one which is widespread in USA mines the leaves, whereas those of the other (from Mississippi northwards) feeds externally on the leaves.

Females mate soon after emergence and lay up to 40 eggs singly in the edges of the leaves. The larvae mine the leaves, damaging each to the point of collapse before moving to another. At least two leaves are destroyed by each larva. The mature larvae enter the soil and spin cocoons. The life cycle can be completed in 13 days and there are a number of generations each year (Clement and Norris 1982, Gorske et al. 1976). In California prepupae in diapause overwinter in the soil. Adults live for a day and do not feed. In California up to 84% of *P. oleracea* leaves were severely damaged, leading to defoliation and sometimes death of the plant. When *P. oleracea* was protected by insecticide from both *S. pilicornis* and *Hypurus bertrandi* it produced about four times as much seed as unprotected plants, although the latter still produced enough (4000 to 5000/m^2/day) to maintain a high seed bank in the soil (Force 1965, Garlick 1922, Gomes de Lima 1968, Gorske et al. 1977, Norris 1985, Webster and Mally 1900).

S. pilicornis has not been recorded from any economic plant and, in starvation tests, was only able to feed on *P. oleracea* and the related *Montia perfoliata* (Gorske et al. 1976). A microsporidan, *Nosema pilicornis* causes high mortality in infected *S. pilicornis* larvae in USA and should be eliminated during any transfer of the sawfly to new areas (Gorske and Maddox 1978).

Comment

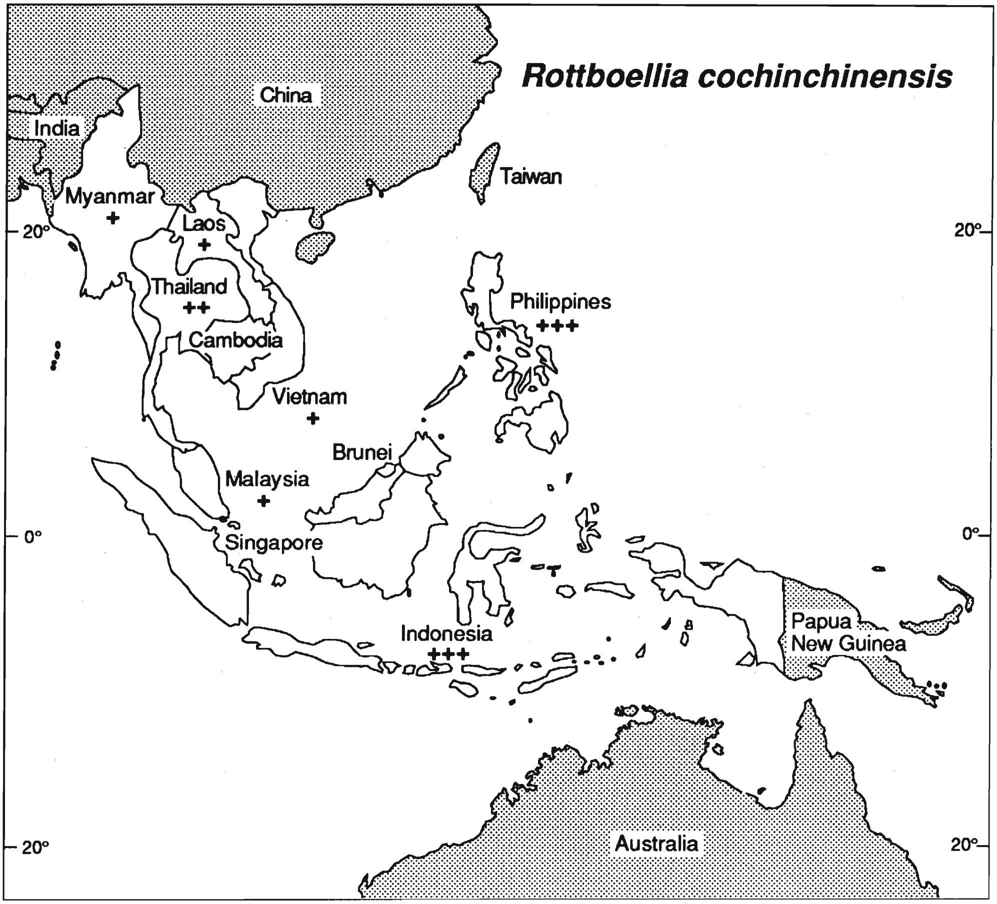
It is generally believed that, through coevolution, there are likely to be a number of specific (or nearly specific) natural enemies of an organism in its area of origin. Furthermore, that not all such organisms will have accompanied their host when it has moved outside its area of origin. If this generalisation is applied to *P. oleracea* it can be seen that 8 of its 14 specific (or nearly specific) natural enemies are of American origin but no more than 2 from any other region of the world (Table 4.25.2). The inference from this is that *P. oleracea* is probably of American origin, an inference supported by the finding of seeds in Louisiana, Illinois and Kentucky dating between 1000BC and 750AD and pollen and seeds in Ontario sediments dating back to 1350AD (Miyanishi and Cavers 1980). This suggests that, if it is desired to evaluate insects additional to those listed in table 4.25.2, they should first be sought from the Americas and possibly from amongst those listed by Waterhouse (1993b).

The family Portulacaceae is relatively small with 20 genera and about 250 species worldwide, of which the genus *Portulaca* contains about half (West 1990). Very few Portulacaceae are cultivated: *Portulaca grandiflora* as a brightly flowering garden plant, *Talinum paniculatum* and *T. triangulare* as pot herbs (but they are sometimes regarded as weeds), *Montia fontana* for salads, *Lewisia* spp. as rockery plants and *Anacampseros* as a succulent; but these are not considered to be of great economic importance (Cruttwell and Bennett 1972a).

From what is known about the biology of the insects in table 4.25.2 it appears that, if a group of them is established in a new country without their own natural enemies, they should cause serious damage to *P. oleracea* and significantly reduce its competitiveness and seed production.

Rottboellia cochinchinensis

(after Holm *et al.* 1977)



Map 4.26 *Rottboellia cochinchinensis*

Rottboellia cochinchinensis is probably of Southeast Asian or Indian origin, although one biotype may have evolved in East Africa. Very little is known of its insect enemies in these regions and they certainly merit investigation. Current research on fungal pathogens indicates that *Sporisorium ophiuri* is a potential agent for the Americas and other regions where it does not yet occur.

If preliminary surveys for specific insect enemies in Asia and Africa support a Southeast Asian origin it is unlikely to be an attractive early target for classical biological control in this region.

4.26 *Rottboellia cochinchinensis* (Lour.) W.D. Clayton
(= *Rottboellia exaltata*)

Poaceae

itch grass; myet ya, myet ya nge (Myanmar), brânjângân (Indonesia), aguiñgay (Philippines), yaa prong khaai (Thailand)

Rating

	+++	Indo, Phil
12	++	Thai
	+	Myan, Laos, Viet, Msia

Origin

Uncertain but probably India to Southeast Asia; one biotype in East Africa.

Distribution

Worldwide, and weedy between 23° north and south latitudes (Holm et al. 1977). Formerly known as *Rottboellia exaltata*. Two biotypes have been recognised in USA and at least five in the Philippines (Fisher et al. 1987). The origin of *R. cochinchinensis* has not been completely resolved. It is said to be native to India (Holm et al. 1977), but in his survey of fungal pathogens and their specificity (or lack of it) Evans (pers. comm. 1992) was led to the conclusion that it may be Southeast Asia; and furthermore, that there is a distinct East African biotype, with possibly specific natural enemies of its own. It is interesting that, of the 14 Kenyan tribes visited by Ellison and Evans (1990), 13 had a separate and specific vernacular name for itch grass. Although it was a common weed and dense stands occurred at the edge of fields and along roadsides, control was achieved by early season hoeing and none of the farmers suggested it was a major problem. This evidence was taken as reinforcing the theory that East Africa is the centre of origin at least of the local biotype of the weed.

Characteristics

R. cochinchinensis is a tall, erect, strongly tufted, annual grass growing to 3 m. It has stilt roots. Its leaves and stems have long, sharp, fragile, siliceous, irritating hairs that break off in the flesh on contact. The inflorescence is a single cylindrical spike.

Importance

It is an aggressive C4, annual grass of 18 tropical and subtropical crops in 28 countries, including maize, rice, sorghum, soybeans and sugarcane. The heaviest infestations occur in the Caribbean, Central America, and parts of South America, to which it is a relatively recent introduction; also a widespread weed in southern Africa. It is an important weed in sugarcane, maize and upland rice in the Philippines. It is often a primary coloniser of disturbed land. It flowers all year round. Reproduction is by seed and up to 8000 may be produced per plant. The seed is about the size of a rice grain and is not easily separated from intermingled rice grains. Some seeds germinate immediately, whereas others lie dormant for varying periods, sometimes years. Buried seeds may germinate and emergence take place from a depth of 15 cm. It is common in open, well-drained places, but also grows in wet places and even in shallow water. It commonly occurs on contour banks and roadsides. It prefers sunny or no more than moderately shaded situations, but can grow in deep shade. Its many needle-like hairs deter hand removal of older plants, since the hairs penetrate hands and clothing and result in painful infections.

R. cochinchinensis is sometimes grazed and used for green fodder, although avoided at times by some animals because of its sharp hairs.

Natural enemies

Fungi are the only natural enemies (Tables 4.26.1 to 4.26.3) for which there is any reasonably comprehensive information. Fungi have been surveyed and their specificity is being examined in a joint International Institute of Biological Control and Long Ashton Research Station project covering East Africa, South America, India, Nepal, Sri Lanka and Thailand (Ellison 1992, Ellison and Evans 1990, 1993, Evans 1991, Natural Resources Institute 1992).

As indicated earlier, *R. cochinchinensis* shows high biotype variation between countries and this is correlated with varying levels of susceptibility to different fungal isolates. Also, a clear positive correlation was found between high pathogen virulence and inadequate specificity to itch grass (Ellison 1992). Maize (*Zea mays*) proved to be the crop species most at risk from itch grass pathogens, which is not surprising in view of the close evolutionary relationship of the two genera involved. This suggests that the use of fungi for classical biological control of itch grass may not show great promise, but that their use as mycoherbicides might prove effective. All except one of the fungi from tropical America that have been tested are non-specific to itch grass and most are local pathogens that have transferred from local grasses (Evans 1987). In Kenya, in addition to at least 10 non-specific fungi attacking itch grass, a head smut, *Sporisorium* (= *Sphacelotheca*) *ophiuri* was found, which appears to be restricted to *Rottboellia* and the closely related genus *Chasmopodium* (Ellison and Evans 1990, Zundel 1953).

S. ophiuri is recorded as occurring in East Africa, Sri Lanka, Philippines and Thailand, but apparently not in the Americas. It is often locally damaging, significantly reducing vigour and virtually eliminating seeding. Its host specificity is under detailed investigation (Ellison and Evans 1993, Evans 1991) as a potential candidate for classical biological control for areas where it does not already occur. In an annual weed where seeds are the only means of propagation, a destructive seed head disease, such as *S. ophiuri*, is a highly promising biological control agent (Evans 1991).

A *Curvularia* isolate from Trinidad proved highly damaging to itch grass, while not damaging rice, maize, sugarcane or pearl millet (Evans 1991). A *Curvularia* from Somalia was able to kill *R. cochinchinensis* in a few days, but was also able to infest maize. However the crop readily recovered (Ellison 1992). If further tests confirm its specificity, it may be a potential biological control agent. The same applies to *Puccinia* *rottboelliae* about which less is recorded (Evans 1987). Special attention is now being paid to the possibility of developing preparations of one or more of these fungi as a mycoherbicide. An isolate from Thailand of *Colletotrichium* sp. which appears to be specific to itch grass has been selected from 900 fungal samples and field trials have already demonstrated that an appropriate formulation has potential against this weed, particularly when combined with low doses of herbicide (Ellison 1992, Ellison and Evans 1993, Natural Resources Institute 1992).

Surprisingly few insects (Table 4.26.1) have been recorded attacking itch grass and only one unidentified gall midge recorded in India from *Rottboellia compressa* (Barnes 1946) might, if it attacks *R. cochinchinensis* also, be specific enough to be a candidate agent. It is regrettable that parallel observations were not made on insects during the extensive fungal surveys. In East Africa a stem borer, a lepidopteran leaf feeder and a fly larva all proved to be non-specific graminaceous feeders (H.C. Evans pers. comm. 1992, 1993).

R. cochinchinensis is an alternative host for a number of viruses, almost all of them serious diseases of maize (Table 4.26.3). It is surprising that the only record encountered dealing with nematodes related to a study of 16 plant parasitic species attacking sugarcane in the Philippines. This found that itch grass was not infected by *Meloidogyne* sp. (Reyes and Beguico 1978).

Comment

Rottboellia belongs to the same grass tribe (Andropogoneae), but not to the same subtribes, as *Saccharum*, *Sorghum* and *Zea* (Table 4.26.4). This suggests that candidates for classical biological control of this weed will have to pass extensive host specificity testing against all of the crop and pasture grasses belonging to these and related genera before being considered for release.

Table 4.26.1 Natural enemies of *Rottboellia cochinchinensis*: insects.

Species	Location	Other hosts	References
Orthoptera			
GRYLLIDAE			
Euscyrtus concinnus	Philippines	*Eleusine indica*, *Dactyloctenium aegyptium*, *Cyperus rotundus*, *Digitaria sanguinalis*	Barrion & Litsinger 1980
Pteronemobius sp.	Sierra Leone		Alghali & Domingo 1982
Hemiptera			
APHIDIDAE			
Myzus persicae	Peru	a very wide range	Ortiz 1981
Uroleucon (= *Dactynotus*) *ambrosiae*	USA	sorghum, maize	Koike 1977

(continued on next page)

Species	Location	Other hosts	References
CICADELLIDAE			
Nephotettix nigromaculatus	Sierra Leone	rice, *Ischaemum rugosum*, *Paspalum vaginatum*	Alghali & Domingo 1982
DELPHACIDAE			
Peregrinus maidis	Venezuela	a virus transmitter on many hosts	Ferreira et al. 1989, Migliori & Lastra 1980, 1981, Trujillo et al. 1974
Coleoptera			
COCCINELLIDAE			
Chnootriba (= *Epilachna*) *similis*	Sierra Leone		Alghali & Domingo 1982
Diptera			
AGROMYZIDAE			
Pseudonapomyza philippinensis	Philippines	known only from *R. cochinchinensis*	Spencer 1961
CECIDOMYIIDAE			
a gall midge	India	recorded only from *Rottboellia compressa*	Barnes 1946
MUSCIDAE			
Atherigona soccata	Kenya	rice	Ogwaro 1978
Lepidoptera			
LYMANTRIIDAE			
Psalis pennatula	Kenya	generalist Poaceae leaf eater	H.C. Evans pers. comm. 1993
NOCTUIDAE			
Sesamia sp.	Ghana		Sampson & Kumar 1986
Spodoptera frugiperda	USA	many graminaceous crops	Rajapakse et al. 1988
PYRALIDAE			
Chilo sp.	Ghana		Sampson & Kumar 1986
sp.?	Kenya	generalist Poaceae leaf eater	H.C. Evans pers. comm. 1993

Table 4.26.2 Natural enemies of *Rottboellia cochinchinensis:* fungi.

Fungi	Location	Other hosts	References
Ascochyta sp.	Kenya	no tests on other plants	Ellison & Evans 1990, 1993
Bipolaris perotidis	Australia	many other grasses	QDPI, unpublished
Cercospora spp.	Kenya, Ethiopia, Zanzibar, Madagascar, Americas, SE Asia	maize mildly	Ellison & Evans 1990, 1993

(continued on next page)

Table 4.26.2 (continued)

Fungi	Location	Other hosts	References
Cercospora fusimaculans	Sudan, Zambia, Ghana, Guinea, Togo, Uganda, Jamaica	many grasses	Evans 1987
Cercospora rottboelliae	Guinea		Evans 1987
Cochliobolus (*Helminthosporium*) *bicolor*	Zimbabwe, Somalia	sugarcane, maize, pearl millet	Ellison & Evans 1990, 1993
Cochliobolus (*Curvularia*) *cymbopogonis*	Bolivia, Kenya, Trinidad, Zanzibar, USA, SE Asia	sugarcane, maize, pearl millet, sorghum	Ellison & Evans 1990, 1993, Evans 1987, Walker & White 1979
Cochliobolus heterostrophus (*Drechslera maydis*)	Kenya, Papua New Guinea, SE Asia	sugarcane, maize	Ellison & Evans 1990, 1993, Evans 1987
Colletotrichium sp.	Thailand	(this species is close to *C. graminicola*)	Ellison 1992, Ellison & Evans 1993
Coniothyrium sp.	Africa, SE Asia		Ellison & Evans 1993
Curvularia spp. (many)	Trinidad, Papua New Guinea, Madagascar, Somalia, Zanzibar	most (not all) attack economic crops	Ellison 1992, Evans 1991
Diaporthe (*Phomopsis*) sp.	Kenya, SE Asia	maize mildly	Ellison & Evans 1990, 1993
Diplodia sp.	Kenya	no tests on other plants	Ellison & Evans 1990, 1993
Fusarium moniliforme (*Gibberella fujikuroi*)	Guatemala	the particular strain tested had limited host range with no symptoms in maize, sorghum or sugar cane, but other strains attack these and rice	Jimenez et al. 1990
Glomerella (Colletotrichium) graminicola	India, Nepal, Sri Lanka, Thailand	No *Colletotrichium* infection observed in East Africa	Evans 1987, 1991
Leptosphaeria sp.	Kenya, SE Asia	no tests on other plants	Ellison & Evans 1990, 1993
Magnaporthe (*Pyricularia*) *grisea*	Kenya, Zimbabwe	maize mildly, also *Eleusine* spp.	Ellison & Evans 1990, 1993, Evans 1987
Phaeoseptoria sp.	Kenya, SE Asia	no tests on other plants	Ellison & Evans 1990, 1993
Phyllachora sacchari	Asia, Nigeria, Sicily, Argentina		Anahosur and Sivanesan 1978
Puccinia rottboelliae	Kenya, Madagascar, Ghana, Uganda, Zambia, Ethiopia, Guinea, Nigeria, Sierra Leone, Sudan, Zimbabwe, India	limited host range	Ellison & Evans 1990, 1993, Evans 1987

(continued on next page)

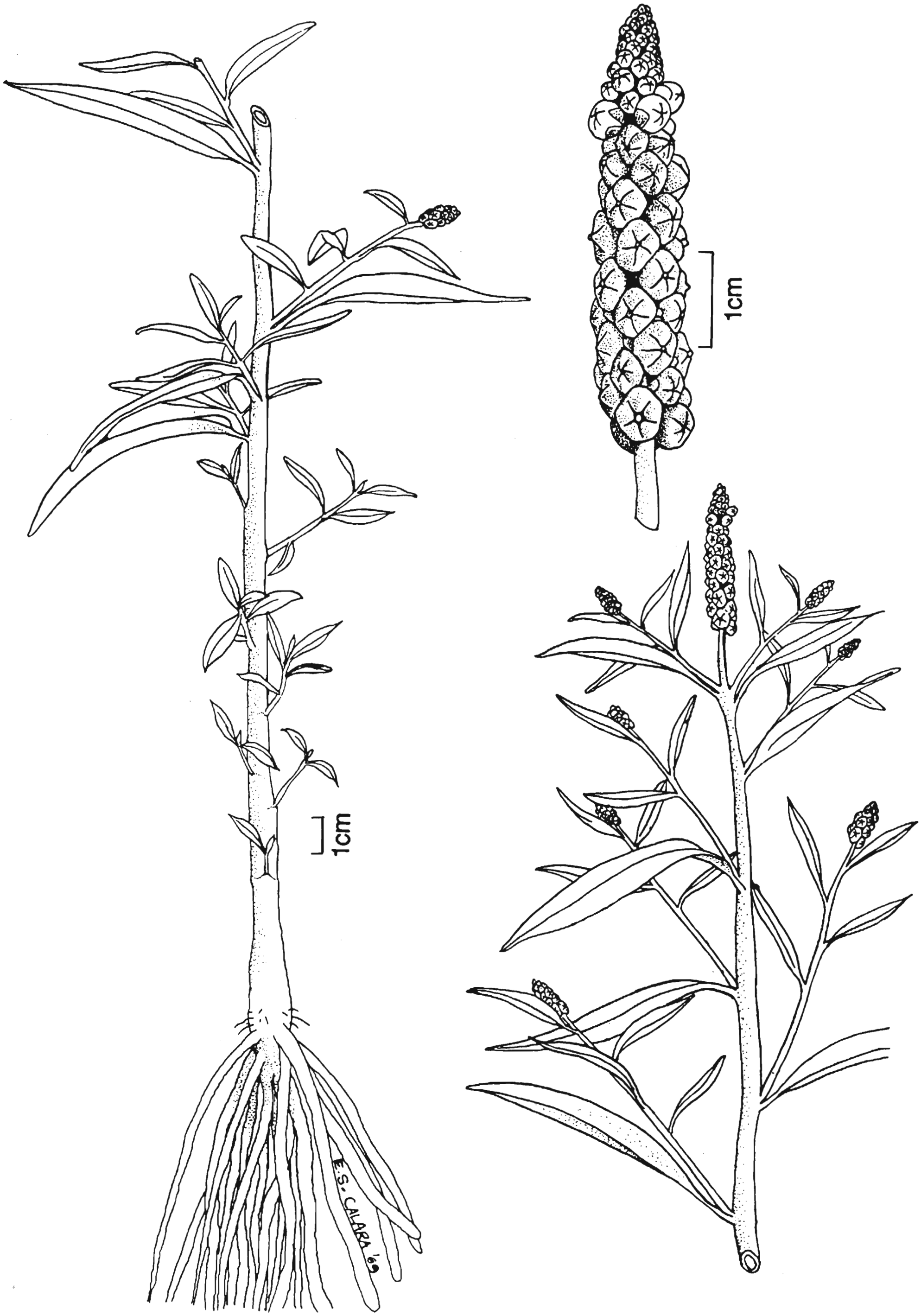
Fungi	Location	Other hosts	References
Pyrenochaeta sp.	SE Asia		Ellison & Evans 1993
Sphacelotheca rottboelliae	Malawi, India	also on *Saccharum spontaneum*	Evans 1987
Sporisorium (= *Sphacelotheca*) *ophiuri*	Kenya, Somalia, Sudan, Uganda, Zimbabwe, Sierra Leone, Sri Lanka, Philippines	limited host range, and not present in the Americas	Ellison & Evans 1990, 1993, Evans 1987, 1991
Ustilago scitaminea	Philippines		Latiza 1980

Table 4.26.3 Natural enemies of *Rottboellia cochinchinensis:* viruses.

Virus	Location	Other hosts	References
corn leaf gall virus	Philippines		Agati & Calica 1950
maize stripe tenuivirus	USA	sorghum	Bradfute & Tsai 1990
maize stripe virus	USA	sorghum	Gingery et al. 1981
maize hoja blanca	Venezuela	sorghum	Ferreira et al. 1989
maize white leaf	Venezuela		Trujillo et al. 1974
maize rayado fine	Texas	several grasses	Nault et al. 1980
maize mosaic	Guadeloupe, French Guinea	sorghum	Migliori & Lastra 1981
maize dwarf mosaic	USA	sorghum, sugarcane	Gillespie & Koike 1973
maize yellow mottle	Nigeria		Thottapilly et al. 1992
virus like disease of maize	Guadaloupe	sorghum	Migliori & Lastra 1980
rice leaf gall	Philippines		Agati & Calica 1950

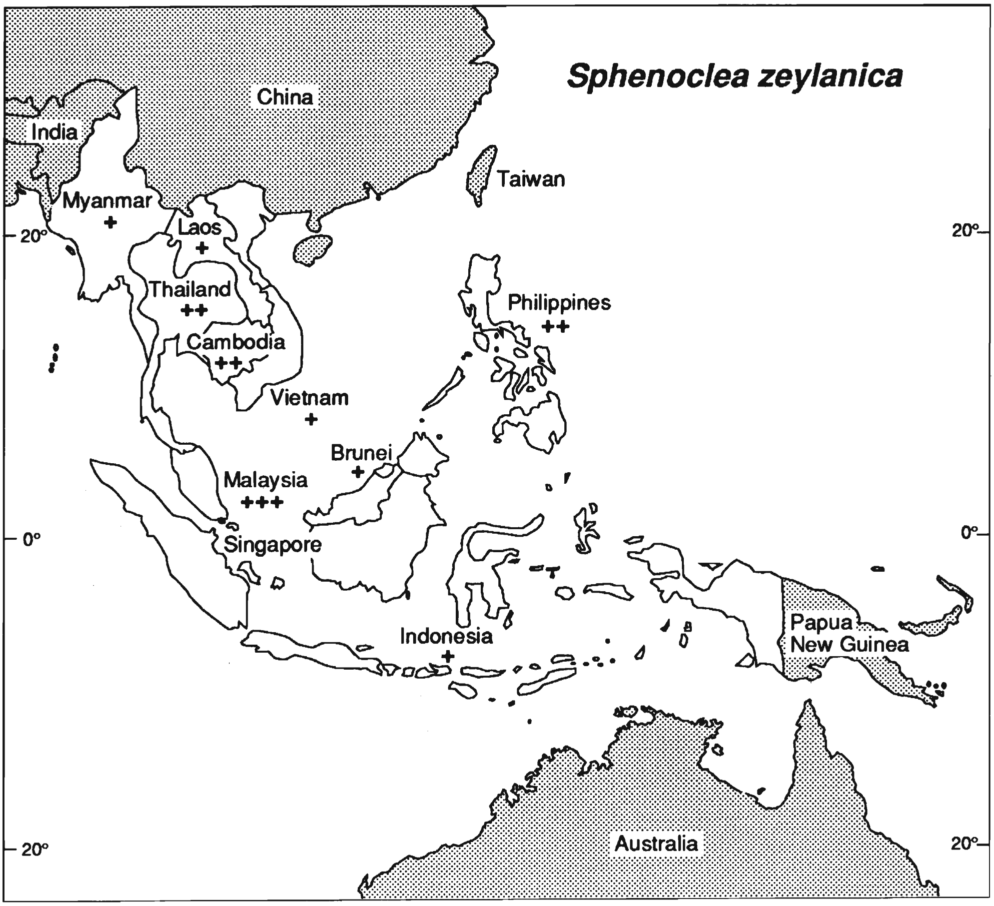
Table 4.26.4 Taxonomic position of the major exotic grass weeds (bold text) in relation to the major genera of crops in the family Poaceae (= Gramineae).

Subfamily	Tribe	Sub-tribe	Genera
Bambusoideae	Bambuseae		*Bambusa*
	Oryzeae		*Oryza*
Pooideae	Triticeae		*Hordeum, Secale, Triticum*
	Aveneae		*Avena*
Chloridoideae	Eragrostideae		***Eleusine***, *Eragrostis*
	Cynodonteae		***Cynodon***
Panicoideae	Paniceae	Setariinae	***Echinochloa, Panicum, Paspalum***, *Setaria*
		Digitariinae	*Digitaria*
		Cenchrinae	***Pennisetum***
	Andropogoneae	Saccharinae	*Saccharum*
		Sorghinae	*Sorghum*
		Rottboelliinae	***Rottboellia***
	Maydeae	Tripsacinae	*Zea*



Sphenoclea zeylanica

(after Holm *et al.* 1977)



Map 4.27 *Sphenoclea zeylanica*

Goose weed, *Sphenoclea zeylanica*, is native to Tropical Africa where it is not regarded as a weed, although there are no natural enemies recorded from it there. In Southeast Asia, where it is an important weed of rice, and in India, it is sometimes severely affected by a fungus which may have some promise as a bioherbicide.

A survey for natural enemies in its area of origin would be required to evaluate the prospects for its biological control.

4.27 *Sphenoclea zeylanica* Gaertn.

Sphenocleaceae

gooseweed; goenda (Indonesia), silisilihan (Philippines), pakpawd, phak pot (Thailand) xà bông (Vietnam)

Rating

	+++	Msia
14	++	Thai, Camb, Phil
	+	Myan, Laos, Viet, Brun, Indo

Origin

Tropical Africa

Distribution

In tropical and subtropical regions across the world. From Iran extending eastwards to Indonesia and the Philippines, also China, Japan, USA, the Caribbean, Guyana, Surinam and Madagascar. Not reported from Papua New Guinea, Australia or the oceanic Pacific.

Characteristics

S. zeylanica is an erect, fleshy, herbaceous annual, often with much branched, hollow stems, growing to 1.5 m; leaves alternate, oblong to lanceolate, tapering to both ends; flowers sessile in dense spikes, terminal, whitish; seed yellowish brown, 0.5 mm long; roots cord-like.

Importance

S. zeylanica is unusual in that it is not reported as a weed in any crop except rice (Holm et al. 1977). It thrives in damp ground at altitudes up to 350 m. In Africa it grows in the mud of tidal creeks, but does not have this habit in Malaysia. It occurs on the sides of ponds and along ditches and rivers, on dry river beds and in seasonal swamps. It prefers stagnant water sites. It reproduces continuously by seed in the Philippines. In spite of its competition with the rice plant, *S. zeylanica* can give valuable practical control (up to 99%) of populations of rice nematodes (*Hirschmaniella* spp.), with the additional benefit of increased soil nitrogen. It acts through the production of toxic plant exudates (Mohandes et al. 1981).

In Java, young plants and tips of older plants are steamed and eaten with rice.

Natural enemies

The only natural enemy encountered in the literature search is a fungus (Table 4.27.1). This was a severe infestation of the fungus *Cercosporidium helleri* on the lower surface of *S. zeylanica* leaves in India (Ponnappa 1967). The affected leaves became deformed and fell off. Similar fungi capable of causing death of the weed were observed at Los

Banos, Philippines and at Prey Phadu, Cambodia (Moody et al. 1987). If this fungus proves to be adequately specific it may have some value as a bioherbicide.

Table 4.27.1 Natural enemies of *Sphenoclea zeylanica*

Species	Location	References
NEMATODE		
Meloidogyne graminicola		Luc et al. 1990
FUNGUS		
Cercosporidium helleri	Cambodia, India, Philippines	Moody et al. 1987, Ponnappa 1967

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6 Index of scientific names of insects

7 General index

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