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PROCEEDINGS OF THE FIRST INTERNATIONAL
WORKSHOP ON BIOLOGICAL CONTROL OF
CHROMOLAENA ODORATA



February 29 - March 4, 1988
Bangkok, Thailand

Proceedings of the First International Workshop
on Biological Control of *Chromolaena odorata*

February 29 through March 4, 1988

Bangkok, Thailand

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Above: Manual control of *Chromolaena odorata* in Mangalore, India, December 1984.

Center: *C. odorata* defoliated by *Pareuchaetes pseudoinsulata* in Guam 1987.

Bottom: *P. pseudoinsulata* defoliated and dried *C. odorata* in a pasture at Rota, May 1987.

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WORKSHOP PROGRAM

Monday, February 29, 1988

- 0800: Registration
0900: Opening remarks
Adoption of the agenda
1000: Break
1030: Role of NBCRC in biological control in Thailand - Banpot Napompeth
1115: History and distribution of *C. odorata* - Rachel McFadyen
1200: Lunch
1330: Session I: Ecology of *C. odorata*
Chair: Banpot Napompeth
- Ecology of *C. odorata* in the Neotropics - Rachel McFadyen
- Ecology of *C. odorata* in Asia and the Pacific - R. Muniappan
1500: Break
1515: Prospects for the biological control of *C. odorata* - CIBC (M.J. Chacko)
1645: Adjourn

Tuesday, March 1, 1988

- 0800: Session II: Methods of control
Chair: R. Muniappan
- Mechanical, chemical, and cultural control - S. Nesar
- Survey and screening of biological control agents - Rachel McFadyen
- Review of biological control of *C. odorata*
- Earlier attempts - Rachel McFadyen
- CIBC attempts - M.J. Chacko
- Recent attempts - R. Muniappan
1200: Lunch
1330: Chair: Rachel McFadyen
- Rearing, release and monitoring *P. pseudoinsulata*, prerelease and post-establishment
assessment - R. Muniappan
1430: - Interaction between *C. odorata* and *P. pseudoinsulata* - Mari Marutani
1530: Break
1600: Chair: S. Nesar
- Need for screening other potential biological control agents of *C. odorata* and
problems involved in field collection, introduction and establishment - Banpot
Napompeth/R. Muniappan/Rachel McFadyen
1700: Adjourn
1930: Video tapes on biological control

Wednesday, March 2, 1988

- 0800: Session III: Country reports
Chair: Mari Marutani
- | | |
|----------------------------|-----------------------------------|
| - Philippines | E. Aterrado |
| - Indonesia | R. Desmier de Chenon |
| - Malaysia | Peter Ooi |
| - Thailand | Banpot Napompeth/Dumrong Chaiglom |
| - Vietnam | Nguyen Thi Hai/Banpot Napompeth |
| - India | K.M. Subbaiah/M.J. Chacko |
| - Cameroon and Ivory Coast | R. Desmier de Chenon |
- 1030: Break
- 1100: Database on *C. odorata* - James McConnell
- 1200: Lunch
- 1330: Session IV: Open floor discussion on a network for biological control of *C. odorata*
Chair: R. Muniappan
Rapporteur - Banpot Napompeth
- Purpose and goals
 - Current situation
 - Proposed method
 - Structure
 - Benefits
- 1700: Adjourn

Thursday, March 3, 1988

- 0700: Field trip to Khao Yai National park and releases of some biological control agents for *Mimosa pigra*, *Heteropsylla cubana* and *C. odorata*.

Friday, March 4, 1988

- 0800: Session V: Recommendations
Chair: R. Muniappan
Rapporteur - Banpot Napompeth
- 1000: Break
- 1030: Evaluation
- 1200: Lunch
- 1330: Tour of NBCRC facilities at Kasetsart University
- 1500: Closing

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INTRODUCTION

The First International Workshop on Biological Control of *Chromolaena odorata* was held in Bangkok, Thailand, hosted by Dr. Banpot Napompeth, Executive Director, National Biological Control Research Center. There were participants from Australia, France, India, Philippines, South Africa, Thailand, Vietnam and Guam. The organizations that supported the participants were Australian Centre for International Agricultural Research, Australia, Institut de Recherches pour les Huiles et Oleagineux, France, Commonwealth Institute of Biological Control, United Kingdom, Consolidated Coffee Limited, India, National Research Council and the National Biological Control Research Center, Thailand, the Government of South Africa, Guam Agricultural Experiment Station, Guam and Tropical and Subtropical Agricultural Research Program, CSRS-USDA, United States of America.

This workshop provided a forum for the scientists involved in research on biological control of *C. odorata* to exchange views, update research activities, plan for future research programs and above all for active collaboration in the international arena.

There were six recommendations formulated by this workshop. Of these, the one to produce the '*Chromolaena odorata* Newsletter' has already been implemented. The first issue of this newsletter was published in June 1988 and distributed. Necessary action has already been taken to establish an International Working Group on Biological Control of *C. odorata* in affiliation with the International Organization for Biological Control. Hopefully the other four recommendations will be implemented in due course.

HISTORY AND DISTRIBUTION OF *CHROMOLAENA ODORATA* (L.) R.M. KING AND H. ROBINSON

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TAXONOMIC POSITION

Chromolaena is in the plant family *Asteraceae* or *Compositae*, which is one of the largest plant families (Table 1). It is a well-defined, very successful family, regarded as the highest i.e. most evolved of the plant families. The *Asteraceae* are found throughout the world though rare in tropical rain forests, and are particularly abundant in the Americas. Most species are herbaceous; trees are rare. For such a large family, the economic value is low, with relatively few crop plants though many ornamentals (Toelken, 1983).

The *Asteraceae* are divided into 12 to 17 tribes; the *Eupatorieae* is a well-defined mostly New World tribe, with white, reddish or blueish flowers lacking ray florets (Robinson and King, 1977). Within the *Eupatorieae*, there are no crop plants or important ornamentals, which is a definite advantage for biological control. Important weed species are *Mikania scandens* (= *micrantha*) an important weed in some Old World tropical areas, and *Ageratum conyzoides*, a common crop and garden weed in the tropics and sub-tropics.

The super-genus *Eupatorium*, before it was split up by King and Robinson in the 1970s, contained over 1200 species, most in the Americas with a very few in Europe, Asia and Africa. Several are important weeds; *Ageratina altissima* (*E. rugosum*) in the eastern United States, *Ageratina adenophora* and *Ageratina riparia* in Indomalaya to Southern China, South Africa, Hawaii and eastern Australia, *Fleischmannia microstemon*, a minor weed in the Americas, and *Austroeupatorium inulaefolium* in Indomalaya and Sri Lanka (Anon., 1983).

The genus *Chromolaena* contains 129 species all from South and Central America and the West Indies (King and Robinson, 1970). Of these, *C. ivaefolia* and *C. laevigata* are widespread and occasionally weedy in the Americas, but only *C. odorata* has spread beyond the New World.

It is worth noting here that considerable confusion exists even in published papers regarding the different weed species of *Eupatorium*. Holm et. al. (1977) included Australia (New South Wales) in the distribution of *C. odorata*; this is based on a paper by Auld (1977) which lists a specimen of *Eupatorium odoratum* in the Melbourne herbarium. This specimen, collected by A. Cunningham, has no locality or date and may well have been collected by Cunningham on his 1814-16 voyage to Brazil. This is the sole record of *C. odorata* from Australia; it has never been found wild there. Holm et. al. (1977, p 214) also cite references for the biological control of "other *Chromolaena* species in Hawaii and Australia". These were the species *Ageratina riparia* and *A. adenophora*; no other *Chromolaena* species occur outside the Americas or have ever been the subject of biological control programs. This kind of confusion is the understandable result of the adoption of new generic names, compounded by simple misidentifications of plant specimens, but it is important that weed scientists working with the group keep errors to a minimum and avoid repeating old errors. It is particularly important for

successful biological control, as the insects of *C. odorata* do not attack the *Ageratina* species, and vice versa.

Table 1. Families of plants

Family - *Asteraceae* (*Compositae*)- Cosmopolitan, highly successful: few of economic importance except ornamentals.

Tribe - *Eupatorieae*- Well-defined, largely American tribe. Flowers white, reddish, or bluish, without ray florets.

Mikania - mostly Brazil.

M. scandens (= *micrantha*) - widespread tropical weed.

Ageratum

A. conyzoides - widespread tropical and sub-tropical weed.

Super-Genus - *Eupatorium* - Over 1200 species, mostly American, a few species in Europe, Asia and Africa.

Ageratina adenophora- weed in Indomalaya to Southern China, South Africa, Hawaii and Eastern Australia, poisonous to horses.

Ageratina altissima (*E. rugosum*)- weed in Eastern U.S.A., poisonous to livestock and in milk.

Ageratina riparia- weed in North India, Hawaii and Eastern Australia.

Fleischmannia microstemon - weed in Americas.

Austroeupatorium inulaefolium- weed in Indomalaya and Sri Lanka.

Chromolaena odorata

SPREAD OF *C. ODORATA*: NATURAL DISTRIBUTION

C. odorata occurs naturally over a wide area of the tropical and subtropical Americas, from southern Florida to the northern border of Argentina. There is no evidence of recent spread in these countries nor is the plant a significant or important weed in the New World. It is however one of the more widespread species in the super-genus *Eupatorium*, most of the other species having quite restricted distributions, and even in the Americas, *C. odorata* shows some weedy characteristics such as the rapid invasion of cleared forest or abandoned pasture.

C. odorata is a herbaceous perennial, which reproduces almost entirely by seed. Where branches lie along wet ground, they will root and very occasionally develop into new plants, but this is of very minor importance. The crown of each plant is single and does not divide even when many-stemmed; suckering from the root does not occur. However, considerable reserves of starch are stored in the root and crown, and plants re-shoot freely after being cut or burnt to ground level.

Flowering is photoperiod controlled, even near the equator, and thus occurs synchronously in a region. Flowers develop at the tips of all stems and branches and seed production is prolific. The achenes float on a small stiff pappus and may be blown considerable distances; they also bear short hooks and cling to clothes, hair, etc. once settled. There is no seed dormancy, and germination occurs as soon as there is adequate moisture.

SPREAD INTO ASIA AND AFRICA

The accepted view has been that *C. odorata* was first spread to the Old World via ballast in ships from the West Indies, turning up in Singapore and Malaya in the 1920s (Bennett and Rao, 1968). However, Hooker in 1882 said "*E. odoratum* ... (is) ... cultivated but very rarely in India" and Prain in 1903 and 1906 stated that it was cultivated 'sparingly' or 'occasionally' in gardens in Central and East Bengal and around Calcutta. It therefore seems more likely that seed from these cultivated plants escaped and gradually spread south into lower Burma and Malaysia and north into Assam (Anon., 1967). However, Konigsberger, Director of the Java Botanical Gardens, in 1912 reported a very vigorous weed in the genus *Eupatoria* choking out other weeds at Deli in Sumatra (Johnstone and Tryon, 1914) which may have been *C. odorata*. Deli is a small island at the extreme south of Sumatra, off the eastern tip of Java, and if the weed was present there and not in Jakarta, it must either have been widespread on the east coast of Sumatra by then, or reached Deli via small boats trading along the coast. It was certainly recorded as a major weed in these areas, including Sumatra, by 1940 (Biswas, 1934 and Laan, 1940). It was reported as a dangerous weed in Ceylon in 1944 (Grierson, 1980).

Once established in the Bengal, lower Burma and Malaya area, *C. odorata* spread rapidly throughout Southeast Asia. Much of this spread must have been natural progressive spread as the light wind-borne seeds were blown into new areas. However, with the extensive movements of people, machinery and materials as a result of the Second World War, there must also have been at least some human transport of seeds into new areas. By the late 1960s when the first investigations into biological control began in Trinidad, *C. odorata* was a major weed in much of Southeast Asia from Mauritius, the south and west coast of India, Borneo and Java to Nepal, Bhutan and Indo-China, and has since spread to the Philippines (Pancho and Plucknett, 1971), southern China, southern Sulawesi (Desmier de Chenon, pers. comm. 1988) and the Marianas (Figure 1).

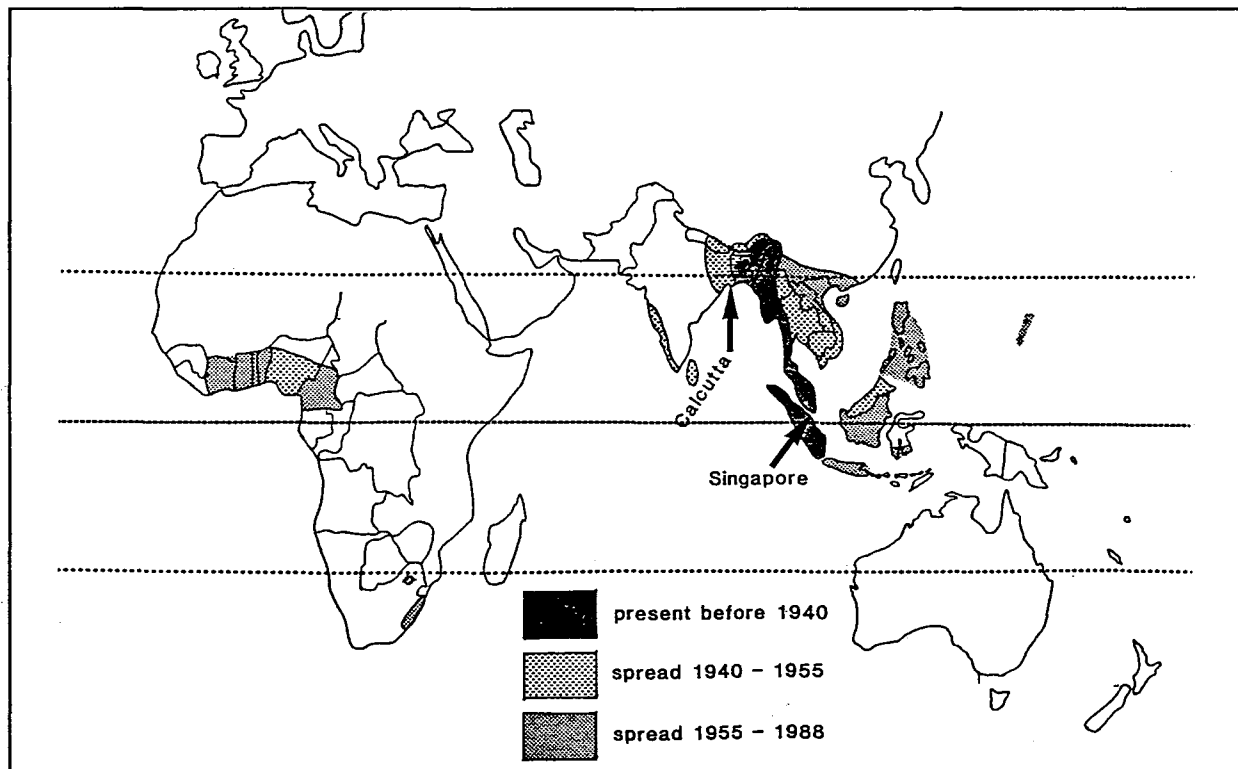


Figure 1. Spread of *Chromolaena odorata* in Asia and Africa.

The first African country to be affected was Nigeria, where the weed appeared in the 1940s. The original introduction was probably via contaminated seeds of *Gmelina arborea*, a fast-growing forestry tree from Ceylon. By the late 1960s, *C. odorata* was a major weed in Nigeria and since then, has spread to Ghana, Ivory Coast and Cameroon. *C. odorata* also appeared near Durban, in South Africa in the late 1940s, from where it spread till it is now a problem throughout the coastal region of Natal, and recently has been found inland in the Transvaal.

BIOLOGICAL CONTROL INVESTIGATIONS

C. odorata was already noticed as a serious weed from Assam to Malaya prior to 1940. By the mid 1960s, its rapid spread in West Africa was also causing alarm, and action towards biological control was urged by Drs. Simmonds, Bennett, Rao and others. In 1966, the Nigerian Institute for Oil Palm Research provided funds for the C.I.B.C. to undertake investigations of the insects attacking *C. odorata* in the Neotropics and to ship suitable insects to Nigeria for field release. I was employed by the West Indian Station initially as a student in 1966 and then as Assistant Entomologist, and these investigations continued until I left Trinidad at the end of 1972. Unfortunately, political and financial problems in Nigeria at the time hindered attempts to rear and release the insects recommended, and only a few and unsuccessful releases of *Apion brunneonigrum* and *Pareuchaetes pseudoinsulata* were made in Nigeria in 1970. Later, more successful attempts were made by India, Sri Lanka and Malaysia and these will be presented in the succeeding chapters.

FUTURE DISTRIBUTION

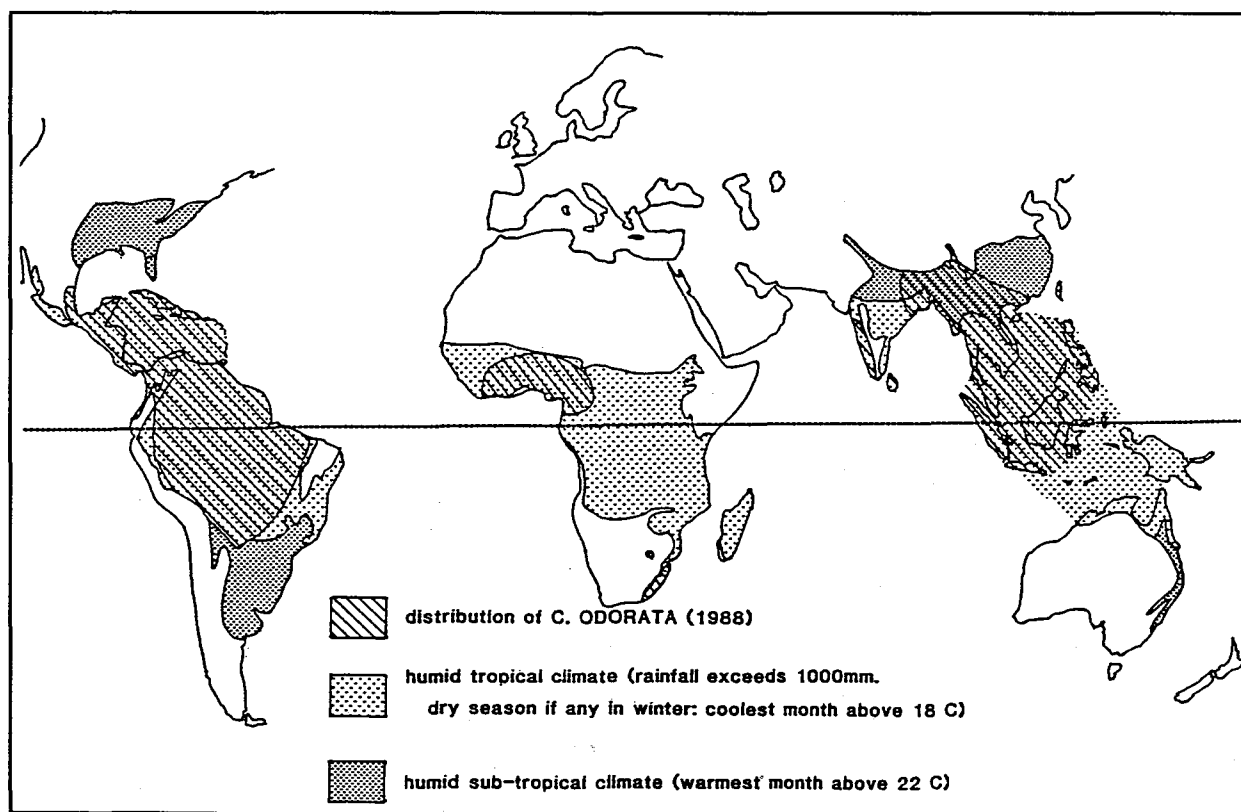


Figure 2. Humid tropical and sub-tropical areas of the world compared with the distribution of *Chromolaena odorata*.

Figure 2 shows the areas of the world with a tropical (coolest month above 18°C) or subtropical (warmest month above 22°C) humid climate, where the dry season if present occurs in the winter i.e. the summers are hot and wet (Anon., 1980). If this is compared with the present distribution of *C. odorata*, two facts are obvious. First, in the Americas *C. odorata* has not spread into the subtropical humid areas while in Asia it has, notably in northern India and Nepal across to southern China. This difference is presumably due partly to competition with the numerous other *Eupatorium* species occurring in the Americas, and partly to attack by insects and diseases found in the Americas and not in Asia and Africa.

The second obvious fact is that all of humid equatorial Africa is under threat from this weed, particularly where the annual rainfall exceeds 1200 mm. In the Pacific area, the islands of New Guinea (Irian Jaya and Papua New Guinea), New Britain, Sulawesi, the Solomon Islands and the islands further west, New Caledonia, Vanuatu, Fiji etc., as well as the north and north-east coasts of Australia, are all climatically suitable for *C. odorata*. They have escaped so far, but agriculture and weed officials and scientists in these countries need to be aware of the weed and vigilant to destroy any plants that might establish. The Australian Quarantine office is currently producing a warning leaflet about the danger of *C. odorata* reaching northern Australia; the leaflet will appear in time for the many visitors expected for Expo, and also in time for Thai Airways new Bangkok-Cairns-Brisbane flights, for each new international airport in the humid tropics increases the risk.

On the same theme, this talk started with a discussion of the tribe Eupatoriae and supergenus *Eupatorium*. *C. odorata* and *M. micrantha* are the only species to have become widespread weeds of major economic importance, but there are many other species in tropical South and Central America that have equal weedy potential. Agricultural authorities need to be wary of deliberate introductions of new plants, and quarantine authorities need to be aware of possible weed contamination of packing and other material from the Americas. Finally, scientists and officials involved in weed control must react quickly to any reports of a new weed, as initial infestations can be eradicated when still small, but not after several years of seed spread.

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ECOLOGY OF *CHROMOLAENA ODORATA* IN THE NEOTROPICS

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INTRODUCTION

As discussed in the previous chapter, *C. odorata* is native to the Neotropics, where it is part of a very rich flora of Asteraceae. The tribe Eupatorieae is largely New World, the more than 1200 species previously in *Eupatorium* are nearly all New World, and the 129 species of the genus *Chromolaena* are all from the Neotropics. Thus *C. odorata* in the Neotropics is always in competition or association with closely related species not found in the Old World.

In Central America, *C. odorata* is common throughout the area up to about 1,000 meters altitude (L.O. Williams pers. comm., 1968). In South America, it is found as far south as Paraguay (Cheeseman, 1940) and the extreme north of Argentina, but is not present in southern Brazil (G.M. Barroso, pers. comm., 1968). In Guyana and Amazonian Brazil, it is present but scarce (J.M. Risco, pers. comm., 1968). In Venezuela, it is common in shady sites and at higher altitudes (Schree, 1960). It is also present in most West Indian islands, but not in Bermuda (Britton, 1965) (Figure 1).

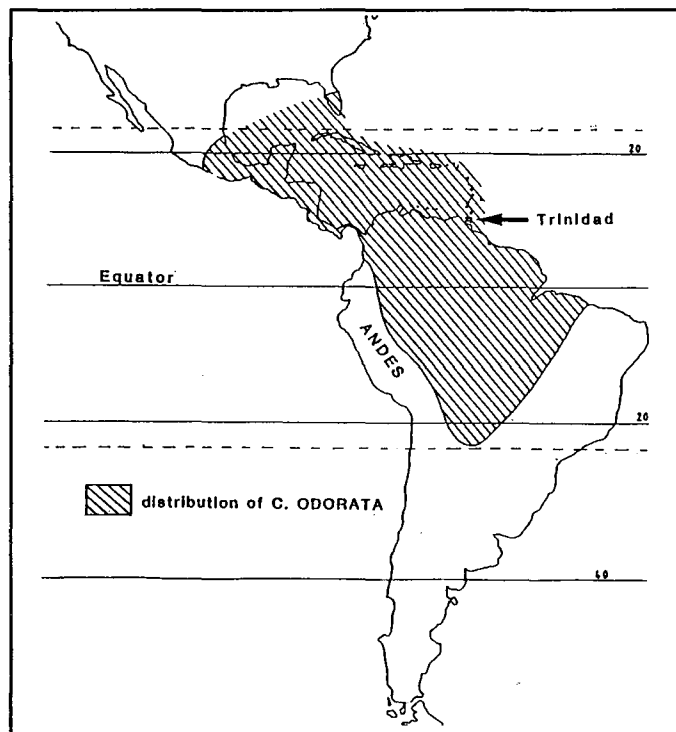


Figure 1. Distribution of *Chromolaena odorata* in the Americas.

Detailed studies of the ecology of *C. odorata* have only been made in Trinidad (Cruttwell, 1972), though some observations have been made in Central and South America. Ecologically, Trinidad is an off-shore island in the delta of the river Orinoco in north-east South America, and its flora and fauna are reduced versions of those of the mainland. Human population density is much higher than on the adjacent mainland, and more of the original forest has been cleared.

C. ODORATA IN TRINIDAD: DISTRIBUTION AND GROWTH

In Trinidad, *C. odorata* is found wherever there is open well-drained ground, including dry and exposed slopes, though plants in such situations are stunted. It grows in young citrus plantations, but not in rainforest, nor in close-planted established citrus, coffee or cocoa plantations. *C. odorata* is thus most common in abandoned fields and pastures, on building sites and along roads; railways and streams, and is found in these situations throughout Trinidad (Figure 2). It is scarce in the areas bordering the Caroni Swamp in the west, and is absent from the Aripo and Erin savannahs, except along raised dykes, possibly because of the poor drainage. All soil types found in Trinidad appear to be suitable for growth although *C. odorata* is less common in the sandy soils of the east coast. In Trinidad, *C. odorata* forms dense tangled bushes two to three meters in height, very occasionally reaching a maximum of six meters as a climber on other plants. The stems branch freely, with laterals developing in pairs from the axillary buds. A large plant may have twenty or more stems of varying size, often bent over under the weight of their branches, and shading a ground area of approximately 3.5 m². The older stems are brown and woody near the base; tips and young shoots are green and succulent. The root system is fibrous and does not penetrate beyond 20-30 cm in most soils. The plants do not reproduce vegetatively, though old stems may die and be replaced by new shoots from ground level.

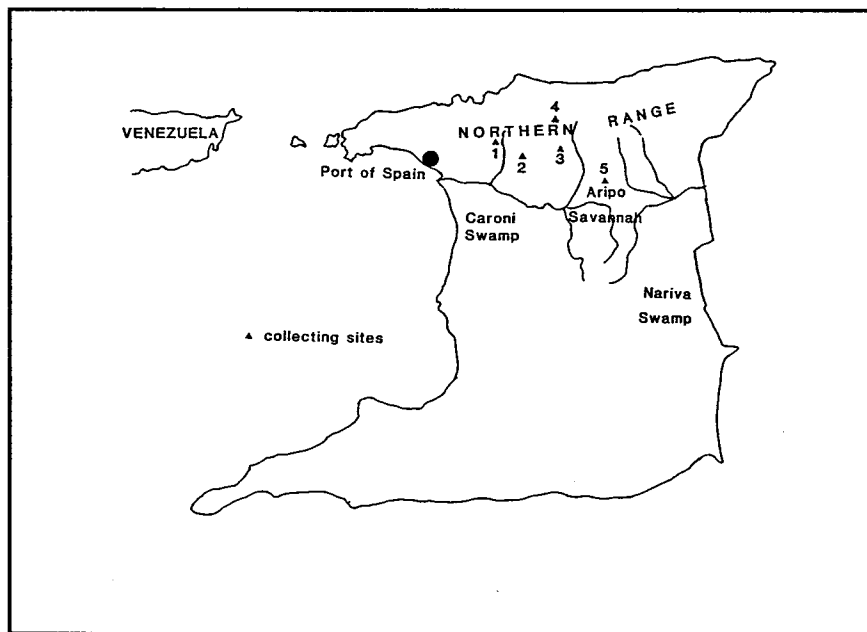


Figure 2. Map of Trinidad showing collecting sites.

LIFE HISTORY

There are two seasons in Trinidad, a dry season extending from January to June, and a wet season starting with heavy rains in June and July, and lasting until November or December. The severity and duration of the seasons vary greatly from year to year (Anon., 1968).

Flowering of *C. odorata*, induced by shortening days, starts in late December and continues till the middle of February, although occasional plants, especially regrowth, may flower until the end of March. The capitula are borne in heads of 20-60 at the tips of all stems, branches, and axillary shoots, and the onset of flowering prevents further growth. Each capitulum contains seventeen, 30-36, or 63-70 florets; although exhibiting this wide range between plants the number is nearly constant for a given plant. The flowers are white or pale blueish-lilac, and form masses covering the whole surface of the bush. *C. odorata* is conspicuous when in bloom in late December and January, hence its name in Trinidad "Christmas Bush".

When flowering is over, most of the leaves wither and fall. New leaves and shoots grow from the old leaf axils, and the dead terminal parts of the stems drop off. The extent of leaf-fall, and the rate of regrowth, depend on the moisture available. On the cleared slopes in the foothills of the Northern Range, bush fires are common at this season, and frequently destroy all above-ground growth. The ripe seeds are wind-dispersed, or adhere to the fur of animals or to clothes.

With the start of the rainy season in June or July, new growth is rapid and extensive. New shoots appear from the roots, and from all undamaged axillary buds. Seeds germinate rapidly, and in suitable soil large numbers of seedlings develop. If unchecked, *C. odorata* plants form dense masses of lush green growth by the time the rains slacken in September.

When flowering is over, individual stems may die back for varying lengths, or in unfavourable situations may die altogether. Axillary buds may have been destroyed by insect attack, so that growth can occur at only one or two sites along a stem. Old stems are gradually shaded by new growth above them, and suffer dieback. Old bushes thus form a tangled mass of old and new stems, with green shoots and branches in all directions.

LIFE SPAN AND MORTALITY FACTORS

Well-established and mature plants first recorded in December 1966 were still healthy in December 1969, and the maximum length of life is not known. Many plants die each year, at all seasons, from a variety of causes. In poor soil, cutlassing to ground level or burning may kill the plant; in good soil, regrowth occurs at once, and very few plants die.

Plants often die when they become shaded by the growth of bushes such as black sage (*Cordia curassavica*) or wild guava (*Psidium guajava*), or they may be shaded by the growth of other *C. odorata* plants. Dieback of stems becomes increasingly severe, and new shoots are etiolated and feeble. Etiolated stems are very liable to insect attack, and regrowth from axillary buds is slow, until finally the last stem dies. This is the normal plant succession as open ground gradually gives way to low bush, and then to the rainforest which is the climax vegetation over most of Trinidad. *C. odorata* does not survive once trees have grown to six meters or higher, except in clearings or along pathways. Plants also die if the soil becomes water-logged; the leaves yellow, the stems blacken and wither, and fungal attack occurs.

In order to investigate the factors preventing the growth of *C. odorata* in shade, healthy plants in pots were placed in areas where *C. odorata* does not normally grow and their growth compared with controls kept in the laboratory grounds. The areas chosen were Site 5, Aripo savannah, with a thin sandy soil on clay, the ground being alternately dry and waterlogged with a sparse flora of dodder (*Cuscuta americana*), sundew (*Drosera capillaris*), orchids, sedges and *Paspalum* species, but no *C. odorata*; Site 3, Simla, in a valley of the Northern Range, where plants were placed under dense stands of guava and other trees six to nine meters tall; *C. odorata* grows naturally at the edge of these stands but not in the centre; and Site 4 in the rainforest of the Northern Range, where *C. odorata* grows on roadsides at the same altitude (c. 800 meters) but not in the forest.

The results in Table 1 demonstrate the inability of *C. odorata* to persist in shade in Trinidad. The plants in the rainforest survived for less than four months; those at Simla in less dense shade survived eight months. At Aripo, however, the potted plants maintained themselves adequately, showing that the barrier to colonization is the poor soil and frequent waterlogging. Control plants at the laboratory slowly increased in size throughout the eight months.

Table 1. Growth of potted plants of *C. odorata* at four different sites

Site	Measurement	1986					
		April	May	July	Sept.	Oct.	Dec.
Simla (3)	stem length	15.8m	-	23.4m	11.3m	8.8m	1.2m**
	leaf no.	572	738	801	535	416	6
	total buds	78	95	130	79	73	2
	undamaged	82%	48%	21%	13%	15%	-
Rain forest (4)	stem length	7.5m	-	6.3m ***	14.9m	13.3m	11.5m*
	leaf no.	288	313	199	608	59	239
	total buds	23	45	44	61	88	63
	undamaged	78%	64%	18%	54%	27%	40%
Aripo Savannah (5)	stem length	7.6m	-	15m	13.4m	12.5m	12.1m
	leaf no.	360	576	827	585	555	398
	total buds	52	87	94	49	43	46
	undamaged	75%	89%	44%	63%	64%	50%
Controls	stem length	11m	-	17.3m	17.3m	17.3m	-
	leaf no.	514	708	864	932	899	-
	total buds	85	110	133	142	225	-
	undamaged	68%	63%	53%	59%	67%	-

Total of three plants at each site
* One plant dead

** Two plants dead

*** All plants dead: replaced with three new plants

Table 1 also shows the effect of insect attack; the number of damaged buds (growing points) is much greater in shade than in sun. Plants in the forest site were also attacked by the stem-boring weevil *Rhodoabaenus* sp. nr. *cariniventris*; seven larvae were collected from these plants in the first three months. The leaves of these plants and those at Simla were heavily damaged by Orthoptera and by Lepidopterous larvae.

These results were confirmed by data obtained from regular collections made over two years at three different sites (Figure 2): 1) an area of thin rocky soil, fully exposed to the sun; 2) a pasture field with rich soil open to the sun; 3) an area with rich soil partially shaded by citrus and guava trees. The number of phytophagous insects collected on the plants increased with the degree of shade.

STATUS IN PLANT COMMUNITIES

Originally *C. odorata* was presumably a plant of forest clearings and of the edges of rivers and savannahs. During a visit to Jari, at the mouth of the Amazon in Brazil, it was noted that *C. odorata* was entirely absent where virgin rainforest had been cleared, but was present around an old established village, and was beginning to invade cultivation land which had been cleared three years previously (Cruttwell, 1971). Slash-and-burn shifting agriculture traditionally practiced in these areas would have provided a succession of short-lived habitats for the plant, which would probably always have been scarce.

Because of the nature of the habitats colonized, *C. odorata* is typically found growing in small patches, discontinuous in time and space. Open land is usually cultivated or used for building, but if abandoned, black sage, guava or some similar shrub competes with *Chromolaena* and ultimately reaches a height at which *C. odorata* is shaded out. Conversely, a newly broken piece of ground will be fairly quickly colonized by *C. odorata* together with razor grass (*Paspalum virgatum*) and sensitive plant (*Mimosa pudica*) in exposed sites, and *Bidens pilosa* and other composites, and a variety of herbs, in more sheltered areas.

In Trinidad, three other species, previously *Eupatorium*, occupy similar habitats and often grow in association with *C. odorata*. *Austroeupatorium inulaefolium* is usually found in the wetter and shadier sites; it does not occur in the more exposed and dry areas but is found under shade denser than that tolerated by *C. odorata*. *Eupatorium iresinoides* is also a plant of shady places and is often found along roadsides and forest edges. *C. ivaefolia* grows in similar sites to *C. odorata* though again not in the more exposed places. These two species are very similar in form and growth; they flower at the same time, and will form fertile hybrids readily when they grow in close proximity. Nevertheless, the two species are not difficult to separate; hybrids have leaves intermediate in shape, or resembling those of *C. odorata*, and flowers with bracts similar to those of *C. ivaefolia* (Cheeseman, 1940).

C. odorata is thus a plant of open land, where it supercedes the pioneer ephemeral herbs, is in turn displaced by small trees and bushes, and disappears completely when the forest canopy begins to close.

STATUS AS A WEED

In its native habitat in the Americas, *C. odorata* is not considered a serious weed. On intensively cultivated land, the seedlings seldom become established. In pasture and along roadsides, growth is usually cutlashed at three to four monthly intervals, and this is sufficient to control *C. odorata*. In well grazed pastures, trampling and competition from the pasture prevents the establishment of seedlings. Under citrus or cocoa the plants are etiolated or present only at the edges where they are easily controlled by annual or biannual cutting. In plantations of young trees, *C. odorata* establishes initially, but after four or five years, with increasing shade from the

trees the *C. odorata* plants become weaker and disappear completely as the canopy closes. There are no reports of *C. odorata* competing successfully with young trees in forestry plantations in Trinidad or elsewhere.

EFFECTS OF INSECT ATTACK ON *C. ODORATA* IN TRINIDAD

Damage to stem tips and axillary buds

During 1967 and 1968, at Sites 1, 2 and 3, regular weekly samples of stem tips and axillary buds were counted and the number destroyed by insect attack recorded. The insect species causing the damage was also recorded when ascertainable.

At Site 3 the percentage destroyed was 40 to 50% in October, November and December of both years, and fell to 15 to 40% in July and August. *Mescinia parvula* and *Melanagromyza eupatoriellae* were always scarce and caused little damage, most of which was due to the feeding of adult weevils. *Rhodoabaenus* adults destroyed stem tips, both by feeding and oviposition; *Apion brunneonigrum*, the small black weevils *Centrinaspis* sp., *Baris* spp. and others, destroyed terminal and axillary buds by feeding on them (Cruttwell, 1974).

At Site 2 the percent destroyed varied between 20 and 40% at all seasons. Most damage was by adult *Centrinaspis* and other weevils, some by the bud gall *Clinodiplosis* sp. and some by *Melanagromyza*. From September to June many were eaten by caterpillars including larvae of *Pareuchaetes*.

At Site 3 the percentage destroyed was 40 to 60% from August to February, and during the rest of the year fell to three to 15%. Damage was caused by *Centrinaspis* spp., an undetermined flea beetle, and *Clinodiplosis* sp. which was common and destroyed many buds. The larger weevils and *Mescinia* were not found.

These data give the total growing points present and the percent damaged, but do not show the percentage damage to new buds developing each month. In June, July and August most old stems were dead and stem tips recorded had thus grown during the previous month. Twenty to twenty-five percent of the tips were attacked in those months in Sites 2 and 3. At Site 1 which was burnt in April and May of both years, 10 to 20% of the growing points recorded were damaged in May, June and July in 1967 and 1968. In addition, two small samples were taken of new growth near Site 2. Eighty-seven stem tips were examined in January 1968, of which three were destroyed by *Mescinia* larvae, two by *Melanagromyza*, and 19 by *Clinodiplosis*. In January 1968, 56 stem tips were examined of which three were destroyed by *Melanagromyza* and 20 by *Clinodiplosis*. The overall destruction was 35 to 50% which agrees with the data obtained for this time of year from the monthly counts.

There was thus a considerable though variable destruction of growing tips. *Rhodoabaenus* adults may destroy all stem tips on some plants in the northern valleys, and during June and July *Aerenica* adults may have the same effect in other areas. *Mescinia* and *Melanagromyza* larvae are sometimes locally common, destroying up to 50% of all growing points including axillary buds, especially in plants growing in partial shade. In contrast, plants growing in the open after the start of the rains may be practically unattacked: in September and October long stems can be found on roadsides and in fields, with every axillary bud developed into a side shoot, and all growing points undamaged.

There is also a great variation in the species of insects responsible for the damage. Generally *Mescinia* and *Melanagromyza* cause most damage in new growth after cutlassing or after the start of the rains. On old growth in shade, adults of *Rhodobaenus* and the other weevil species are more harmful. In open ground, *Clinodiplosis* sp., *Centrinaspis* and other small weevil adults, together with lepidopterous larvae, are commonest.

However, under all conditions, the overall effect is about the same, with 25 to 50% destruction throughout most of the year. This must greatly affect the competitiveness of the plant, particularly during periods of rapid growth. The destruction of the stem tips slows the rate of growth, and may result in the plants being crowded out by other undamaged species. During the dry season when all growth is reduced, the effect is probably less, but a lack of viable axillary buds for regrowth may retard recovery. Destruction of the growing tips must also be a serious check on the ability of plants to recover from cutlassing or brush cutting.

Damage to stems

Stem destruction is the damage or destruction of stems other than the top 12 to 15 cm, which are considered stem tips. Three species damage stems, the larvae of the two beetles *Aerenica hirticornis* and *Rhodobaenus cariniventris*, and the stem gall *Neolasioptera cruttwellae*. The last is widespread and abundant but does little damage. It is most abundant at Site 1 particularly after the rains, when it may affect nearly all the young growing stems.

A. hirticornis is only abundant in small and restricted areas; 25 to 50% of stems may be attacked, but not killed, and growth appears unaffected.

R. cariniventris is much the most damaging species, with extensive damage caused by adult feeding and oviposition, and each larva completely destroying between 20 and 40 cm of stem during development. However the species is confined to the northern valleys, and egg-parasitism is high, thus the overall effect on *C. odorata* in Trinidad is trivial.

Damage to leaves

Many species including lepidopterous larvae, adult weevils, orthopteran adults and nymphs, leaf-mining agromyzid and hispid larvae, feed on the leaves, and together may cause extensive damage. Complete defoliation only occurs as a result of feeding by the larvae of *Pareuchaetes* and even this is unusual; partial defoliation by this species occurs in restricted areas during the wet season. All other species together destroy up to 25% but usually less than 10% of the total leaf surface, most damage being done by the larger lepidoptera such as noctuids, by adult weevils and various Orthoptera.

Damage to the seeds

The seeds are attacked by several different insect species, and flowerheads forming in late February and March contain few viable seeds. The most destructive species are the lepidoptera *Adaina bipunctata*, and *Recurvaria* sp., the diptera *Melanagromyza minima* and *Cecidochares fluminensis*, and, in the shade, the weevil *A. brunneonigrum*. If these species were abundant at the beginning of the flowering season in late December and January, seed production would be greatly reduced. As their populations remain very low until late February, in the first five weeks of the flowering season only 10% of the heads are damaged, and the total effect of seed destruction is insignificant. Germination percentages are however generally low, less than 50%, and this may be due to feeding by thrips, hemiptera, etc.

CONCLUSION

C. odorata in the Neotropics is a widespread common plant of temporary or disturbed areas, but is never regarded as a serious weed. When land is cleared, *C. odorata* establishes after the ephemeral herbs and disappears when tree height exceeds six meters. The chief factor limiting the occurrence and reducing the aggressiveness of this weed appears to be attack by a large complex of insects, some of which are host-specific and some not. Diseases probably also play a part but have not been studied. Competition by related Asteraceae is not a factor but these species do provide alternative hosts for some of the insects.

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ECOLOGY AND DISTRIBUTION OF *CHROMOLAENA ODORATA* IN ASIA AND THE PACIFIC

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Chromolaena odorata is a neotropical weed that was introduced to Asia in mid or late 1800s. Biswas (1934) reported that *C. odorata* was accidentally introduced from the West Indies in the ballast of cargo boats into Singapore whence it spread to humid tropical regions of Southeast and South Asia. Ramachandra Rao (1920) reported rapid spread of this weed in Burma and Assam and Bengal in India. Possibly, it has spread to Burma and India through Malaysia and parts of Thailand. Since then, it has spread to Indonesia, Philippines, Laos, Cambodia, Vietnam, China, Sri Lanka, Nepal, Bhutan and Bangladesh. It was introduced to Southwestern part of India from Eastern India during the Second World War, supposedly through the contaminated clothings from the returning soldiers (Bennett and Rao, 1968).

In 1980 *C. odorata* has become a problem in the island of Rota in the Marianas archipelago. In 1984-85, the weed has been identified as a menace in other islands of the Marianas namely, Saipan, Tinian, Aguijan and Guam. Now, it has spread to Yap, Palau, and Pohnpei in the Caroline Islands.

The distribution of *C. odorata* is limited to warm and humid tropical regions. The existence of strong and universal correlations between the distribution of vegetation and two major features of climate: namely temperature and precipitation has been emphasized by Woodward and Williams (1987). Climatograph shown in Figure 1 clearly distinguishes four major climates based on temperature and precipitation (Brower and Zar, 1977). The hydrological budget, i.e., the overall sum of precipitation minus evaporation (from leaf and soil surfaces) and run-off, a measure of water that is available to the plants and the thermal climate collectively influence the plant distribution. Annual minimum temperature may effectively limit plant distribution and perhaps vegetation type, by exceeding the lethal threshold for survival (Woodward, 1986).

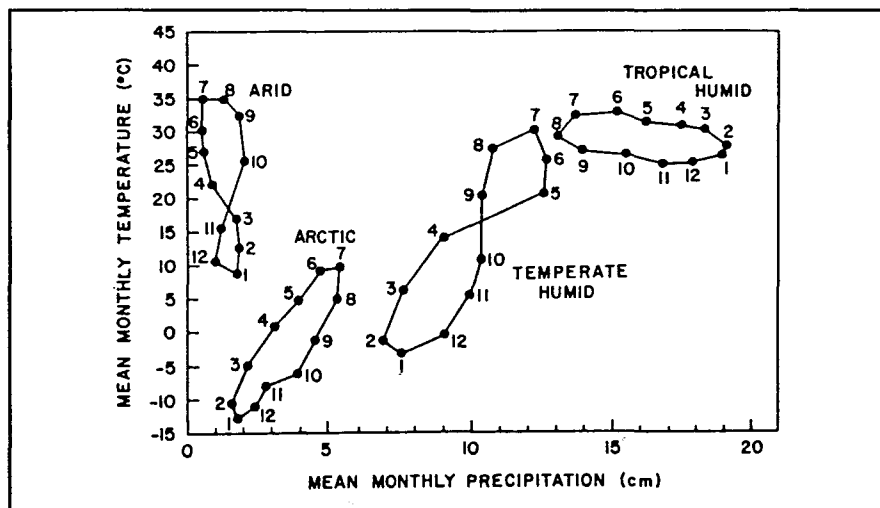


Figure 1. Climatographs, describing climate in terms of mean monthly temperature and precipitation (from Brower and Zar, 1977).

The geographical distribution of *C. odorata* has been limited to about 30° N and S latitudes and about 1000 m in altitude near the equator. Further, its distribution is limited to areas wherein the rainfall is 200 cm and above per annum and the temperature range 20 to 37° C.

C. odorata has been reported as a weed from Bhutan, Nepal and Yunnan Province of China in the north latitude to Indonesia and Sri Lanka in the south latitude in Asia. Its distribution extends from western Ghats in India to the Philippines in Asia and the Marianas and Caroline islands in the Western Pacific.

In addition to precipitation and temperature, light intensity influences the distribution of *C. odorata* within a bioclimatic region. *C. odorata* is not a shade tolerant species; as a result it is not capable of penetrating thick undisturbed native forest vegetation. In the disturbed forest areas and in plantations of rubber, cashew, oil palm, coconut, citrus, coffee, tea, mango, rambutan, and other perennial crops, pastures and vacant lands, it becomes a serious weed.

Because of its capability of spreading rapidly and becoming the dominant vegetation in newly introduced areas, many local names were given in different countries. To site a few examples are:

Country	Names
Burma	Bi-zat, Tawbizat, Curse of Caylan, Kal-bun Kombat-nong-rim, Rel-Hlow, Camphur grass
India	Gandhi Gulabi, Communist pacha, Sam-Solokh, Tongal-lati, Sam-Rhabi
Indonesia	Siam Weed
Cambodia	Tontrem khet
Malaysia	Siam Weed, Pokok Tjerman
Mariana Islands	Masiksik
Nepal	Banmara
Philippines	Hagonoy, Hulohagonoy and others
Thailand	Saab Sua, Yah Sua Mop
Vietnam	Co Hoi, Communist weed

GROWTH

In the northern hemisphere *C. odorata* flowers in November-December and the seed dispersal takes place in February. January through June is the dry season in most areas in Asia and the Western Pacific. *C. odorata* stands dry up during dry season and become a serious fire hazard. When a fire goes through a *C. odorata* bush, mostly the stems burn and the basal clump remains alive and shoot up soon after the commencement of the rainy season. Since most other vegetation might have been killed by the fire, *C. odorata* will become the dominant species in the next season.

C. odorata is known to possess allelopathic properties (Ambika and Jayachandra, 1980). Allelopathic chemicals released by this plant suppress the growth of other plants underneath and adjacent to it and prevent the germination of seeds of other vegetation.

ECONOMIC IMPORTANCE

C. odorata is considered as one of the top three weeds in coconut plantations in Sri Lanka. In Asia it is a problem in rubber, oil palm, coconut, tea, coffee, cashew, mango, rambutan, teak and other plantations of perennial crops, pastures, forests and vacant lands. In the Pacific, it is a weed of pastures, road sides and vacant lands.

In the Philippines some villages have been deserted because of the nonproductivity of the land infested with this weed (Pancho and Plucknett, 1971). It is poisonous to livestock.

C. odorata is known to harbor a number of insects and mites injurious to other crops in Asia and have been reported by Naezer and MeerMohr (1953), Bennett and Rao (1968), Joy et. al. (1979), Ramani and Haq (1983) and Muniappan and Viraktamath (1986). In Thailand, it has been reported as an alternate host of the leaf spot, *Cercospora* sp. (Puckdeedindan, 1966).

In Cambodia, *C. odorata* is used as a green manure crop for black pepper (Garry, 1963) rice and cassava in addition to black pepper production (Litzenberger and Lip, 1961). *C. odorata* used as green manure was reported to kill fish.

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PROSPECTS FOR THE BIOLOGICAL CONTROL OF *CHROMOLAENA ODORATA* (L.) R.M. KING AND H. ROBINSON

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ABSTRACT

Chromolaena odorata is an exotic plant in most areas where it is a serious weed. It is therefore a good candidate for biological control by the introduction of natural enemies from its center of origin in Central and South America. An extensive study of the arthropod natural enemies has been made in Trinidad and one, *Pareuchaetes pseudoinsulata*, has been established successfully in Sri Lanka and subsequently in India, Sabah and Guam. There is evidence that adaptation of the Trinidad strain occurred in Sri Lanka which enabled it to establish more readily when subsequently transferred to other areas. A period of pre-adaptation in a part of the outbreak area closely matched climatically to the area of origin is therefore suggested for introductions to West Africa and other outbreak areas. Several other promising agents also exist and they should be introduced to complement control by *P. pseudoinsulata*.

No serious study of pathogens of *C. odorata* has been made but the rust *Cionothrix praelonga* and some *Cercospora* spp. are promising candidates for classical introduction. Evidence from a related weed species suggests that *Cercospora eupatorii* in particular is a potentially valuable control agent. A search for more pathogens is strongly recommended.

No significant conflict of interest is foreseen in the introduction of natural enemies for control of *C. odorata*.

INTRODUCTION

The *Asteraceae* (*Compositae*) are the largest family of dicotyledons and contains many species which have become invasive weeds in areas outside their centers of origin. For example, Auld and Medd (1987) list species in 67 genera which are weeds in Australia; only nine belong to native Australian genera and 28 originate in the New World. The genus *Chromolaena* as revised by King and Robinson (1970) contains only New world species but one of these, *C. odorata*, has been distributed to West Africa and Southeast Asia where it has become a serious weed. Other weed species in closely related genera included *Ageratina riparia* (Regel) King and Robinson (formerly *Eupatorium riparium*) and *A. adenophora* (Sprengel) King and Robinson (formerly *E. adenophorum*). Some members of the genus *Eupatorium* not transferred to *Chromolaena* by King and Robinson occur in the Old World.

C. odorata is native to the Caribbean, Central and South America. It is still spreading in Africa and Southeast Asia and has recently become a serious weed in the Philippines and Guam. It is not yet recorded as a problem in East Africa or in many Pacific Islands or Australia. It is

principally a weed of perennial plantation crops but may also invade smallholder crops and pastures (Table 1). Problems include impeded access, fire risk from old stalks, competition with crops and reduced yield (Cock, 1984).

Table 1. Crops where *C. odorata* is a problem¹

Country	Crop
Burma	Unspecified.
Cameroon	Oil palm, rubber, cocoa.
Cote d'Ivoire	Oil palm, rubber, cocoa.
Ghana	Oil palm, rubber, cocoa.
Guam	Unspecified.
India	Rubber, tea, teak, citrus, vegetables.
Indonesia	Rubber, upland rice.
Malaysia	Rubber, abaca, oil palm, tobacco.
Nigeria	Oil palm, rubber, cocoa, pastures, rice, smallholder farms.
Philippines	Coconuts, pastures.
Sri Lanka	Coconuts, rubber, pineapple.
Thailand	Rubber, cotton, maize.
Trinidad	Coconuts, sugar cane.

¹Principally from Holm et al. (1977).

Biological Control of Asteraceous Weeds

C. odorata is a species which has become a weed because of its aggressive and invasive growth habit. This is due in part to the absence of those co-evolved natural enemies which attack the plant in its center of origin. In Trinidad, for example, it is a common plant but is not aggressive and insect damage is probably a major reason for this (Cruttwell, 1968). It is therefore a good candidate for classical biological control by the introduction of the natural enemy complex into the outbreak areas (Cock and Holloway, 1982 and Cock, 1984). Several closely related species have been controlled in this way. *A. riparia* has been controlled in Hawaii by the fungus *Entyloma ageratinae* Barreto and Evans (= *Cercospora ageratina*) (Trujillo, 1985 and Barreto and Evans, 1988). *A. adenophora* has been partially controlled in Hawaii and Australia by a combination of the tephritid *Procecidochares utilis* Stone and the fungus *Cercospora eupatorii* Peck (Dodd, 1961). In the Caribbean, the asteraceous vine *Mikania micrantha* Kunthe is attacked by the thrips *Liothrips mikaniae* (Priesner) (Cock, 1982) and this insect is currently being screened by CIBC for release in the Solomon Islands, Malaysia and Vanuatu.

It is notable that two of the agents used successfully have been fungal pathogens despite the fact that, apart from some recent successes in the use of rusts to control weeds in Australia, South Africa, United States of America and South America, attempts at the classical biological control of weeds have concentrated on arthropods. Growth of plants in their center of origin is constrained by a complex of organisms including arthropods, fungal, bacterial and viral pathogens and nematodes, but only a small fraction of this complex has been considered for the classical biological control of *C. odorata* or any other weed.

Arthropods for the Control of *C. odorata*

An intensive survey of arthropods attacking *C. odorata* was carried out in Trinidad and Central and South America by MacFadyen (nee Cruttwell) between 1966 and 1973. The results were published in a series of CIBC Technical Bulletins and summarized in an annotated list of 240 species attacking this plant worldwide (Cruttwell, 1974). She concluded that it was unlikely that many more host-specific ones would be found, although many of those listed required further investigation. Cock (1984) summarized the oligophagous species, two of which have been released in outbreak areas. These are the arctiid moth *Pareuchaetes pseudoinsulata* Rego Barros which was previously referred to as *Ammalo arravaca* Jord. and *A. insulata* (Walker) by Cruttwell (Cock and Holloway, 1982), and the apionid weevil *Apion brunneonigrum* Bethune-Baker. These releases were summarized by Cock (1984) who noted that good establishment had only been achieved for *P. pseudoinsulata* in Sri Lanka. This moth was also released in Sabah and has been recovered there occasionally at widely scattered sites and has also been taken in light traps in Brunei (J.D. Holloway, pers. comm.), suggesting that it has established, but at a very low level. However, successful establishment of the Sri Lankan strain has been achieved recently in Guam (R. Muniappan, pers. comm.) and this strain has also been successfully re-introduced and established in India (Anon., 1986). This suggests a pre-adaptation of the strain had occurred in Sri Lanka so that it subsequently became better able to tolerate the Indian environment. It has also spread to Palawan (Philippines) and from there the introduction to Mindanao is being undertaken by the Philippines Coconut Authority (M.J.W. Cock, pers. comm.).

P. pseudoinsulata is the only agent to have been released extensively and the reasons for its initially limited success were discussed by Cock and Holloway (1982) and Cock (1984). They speculated that it failed to establish in West Africa and India because these areas have a very pronounced dry season, whereas the insect is adapted to its native Trinidad climate where the dry season is less severe. In Sri Lanka it established successfully in a climate more similar to that in Trinidad. Cock and Holloway suggested that populations for future releases in areas with a pronounced dry season, such as West Africa and India, should be collected from North Venezuela which has a similar climate. They also suggested that other species of *Pareuchaetes* could be considered, since their taxonomic studies revealed a greater range of species on the *Eupatoriae* than recorded by Cruttwell. *P. insulata* (Walker), from Central America and Jamaica, also feeds on *C. odorata*. Further collection of populations of *P. pseudoinsulata* and collections of other species such as *P. insulata* from climatic zones better matched to the proposed release zone is a most promising approach. Similar precautions to those taken with the original Trinidad stock would be required with fresh stocks to eliminate the nuclear polyhedrosis virus which attacks *P. pseudoinsulata*.

Larvae of *Apion brunneonigrum* feed in the flower buds, and adults feed on the foliage, usually in shaded situations in Trinidad. Small releases have been made in outbreak areas in West Africa, India, Sri Lanka and Sabah. It persisted only in Sabah but is probably not established and effective control of *C. odorata* has not been reported (Cock, 1984).

The full range of oligophagous species recommended by Cock (1984) for further study and introduction is shown in Table 2. *Mescinia parvula* is a particularly promising agent, but studies are needed to achieve successful mating in captivity so that oviposition specificity tests can be carried out. *Actinote anteas* Doubleday and *Calephelis laverna* Godman and Salvin were rare in Trinidad but Cruttwell (1974) thought them worthy of further attention.

Table 2. Oligophagous arthropods with potential for control of *C. odorata* ¹

Order	Family	Species
Acari	Eriophyidae	<i>Acalitus adoratus</i> Keifer
Coleoptera	Curculionidae	<i>Apion brunneonigrum</i> B.B. <i>Rhodobaenus</i> spp.
	Cerambycidae	<i>Aerenica hirticornis</i> Klug.
	Chrysomelidae	<i>Pentispa explanata</i> (Chap.) <i>Aulocochlamys</i> sp. <i>Chlamisus insularis</i> (Jac.)
Diptera	Cecidomyiidae	<i>Neolasioptera frugivora</i> Gagne <i>Asphondylia corbulae</i> Mohn <i>Contarinia</i> sp. <i>Perasphondylia reticulata</i> Mohn <i>Clinodiplosis</i> sp. <i>Cecidochares fluminensis</i> (Lima) <i>Melanagromyza eupatoriellae</i> Spencer
	Tephritidae	
	Agromyzidae	
Lepidoptera	Arctiidae	<i>Pareuchaetes pseudoinsulata</i> Rego Barros
	Pyrilidae	<i>Mescinia parvula</i> (Zeller)
	Nymphalidae	<i>Actinote anteas</i> Doubleday
	Riodinidae	<i>Calephelis laverna</i> Godman and Salvin

¹From Cruttwell (1974) and Cock (1984).

Rhodobaenus spp. larvae feed within the stems of several *Chromolaena* and *Eupatorium* spp. and also *Bidens pilosa* L. and further host specificity testing would be necessary. *Aerenica hirticornis* appears specific to *C. odorata* but *Chlamisus insularis* adults also feed on *Bidens pilosa*. *Aulocochlamys* sp. adults also feed on *Chromolaena ivaefolia*.

The damage inflicted in Trinidad by the Diptera listed in Table 2 was variable but Cruttwell (1974) commented that all were likely to be genus-specific and could be safely introduced with very little preliminary testing. They include bud and seed-feeding species which could be particularly valuable for limiting further spread since *C. odorata* spreads by seed. The mite *Acalitus adoratus* is an especially promising agent which is host-specific and damaging (Cock, 1984). It cannot be maintained apart from its host but Cock noted that colonies could be raised on *C. odorata* under quarantine in a temperate country. CIBC has facilities in United Kingdom to carry out this work and is currently screening the tetranychid mite *Tetranychus lintearius* Defour for control of gorse in New Zealand.

Pathogens for the Control of *C. odorata*

Fungal pathogens occurring on *C. odorata* were listed by Evans (1987) and are summarized in Table 3. Almost no consideration has been given to bacterial, viral or nematode pathogens for biological control of tropical weeds and there is no information on their occurrence on *C. odorata*. Two groups of fungi, the rusts and *Cercospora* spp., show particular promise. The rust *Puccinia chondrillina* Bubak and Sydnam was released in Australia, United States and Argentina to control the asteraceous weed *Chondrilla juncea* L. in the 1970s after extensive screening by CSIRO. The rust *Phragmidium violaceum* (Schultz) Winter has successfully controlled blackberry in Chile. The success of these programmes has led to greater interest in other pathogens for classical biological control. Rusts can be very host-specific and several are under investigation at CIBC for control of weeds in Australia and Canada.

Table 3. Pathogens recorded on *C. odorata*¹

Species	Distribution
Ascomycotina, Dothidiales <i>Guignardia eupatorii</i> Punithalingam	Sri Lanka
Basidiomycotina, Uredinales <i>Cionothrix praelonga</i> (Wint.) Arthur	Dominica, Tobago, Venezuela
Deuteromycotina, Hyphomycetes <i>Cercospora eupatorii</i> Peck.	North America, Hawaii, Cuba, Cote d'Ivoire, Nepal, India India, Bangladesh
<i>C. eupatoriicola</i> Govindu and Thirumalachar (= <i>Pseudocercospora</i> <i>eupatoriicola</i> (Govindu and Thirum.) (Khan and Shamsi)	
<i>C. eupatorii-odoratii</i> Yan	Malaysia
<i>Pseudocercospora eupatorii-</i> <i>formosani</i> (Sawada) Yen	India, Burma, Thailand, Malaysia, Borneo, Brunei
<i>Phomopsis eupatoriicola</i> Petrak	Not recorded
<i>Phyllosticta eupatoriicola</i> Kab. and Bub.	Not recorded

¹From Evans (1987)

The autoecious rust *Cionothrix praelonga* (Wint.) Arthur attacks *C. odorata* in the Caribbean and Venezuela and can cause conspicuous leaf lesions. Host range testing could begin immediately with this pathogen. Rusts in the genera *Puccinia* and *Coleosporium* occur on related asteraceous species (Evans, 1987) and it is probable that a thorough search in the center of origin would reveal at least one species of the very large genus *Puccinia* on *C. odorata*. The species of *Coleosporium* are all heteroecious with alternate hosts in the genus *Pinus* and would not be suitable for biological control. Some species of *Puccinia* are autoecious and *P. abrupta* Dietel and Holloway var. *partheniicola* (Jackson) Parmelee is currently being screened at CIBC for control of the asteraceous weed *Parthenium hysterophorus* L. in Australia.

Several species of *Cercospora* and *Pseudocercospora* have been recorded on *C. odorata* and related species (Evans, 1987). It is notable that most of these records are from the Old-World, whereas *Chromolaena* as currently constituted is an exclusively New World genus, and for this reason Evans commented that there is some doubt about their host-specificity. However, it is possible that either one or more of these *Cercospora* spp. have been carried with *C. odorata* during its spread in the Old World (although *Cercospora* is not usually a seed-borne pathogen), or that they have invaded *C. odorata* from other closely related plants. For example, the genus *Eupatorium*, which formerly included *Chromolaena*, has some Old World Species (e.g. *E. cannabinum* L. which occurs in Europe, Asia and North Africa). In the case of *Pseudocercospora eupatorii-formosani* Sawada, which is common and damaging on *C. odorata* in Brunei (Peregrine and Ahmad, 1982) and elsewhere in South and Southeast Asia, but not recorded from the New World, an alternative host would seem to be essential (though Chupp (1953) had some doubts that it was a distinct species). Even if they have alternative hosts, these *Cercospora* spp. are probably still sufficiently restricted in host range to make them valuable candidates for classical biological control.

The potential value of *Cercospora* spp. for control of *C. odorata* is illustrated by the establishment of *Cercospora eupatorii* on the closely related weed *Ageratina adenophora* in Australia. The accidental introduction of this fungus was described by Dodd (1961). *C. eupatorii* was first recorded on *A. adenophora* in Australia in an area where the tephritid gall fly *Procecidochares utilis* Stone had been introduced from Hawaii two years previously. The fungus had not been recorded previously in Australia but was present in Hawaii. *P. utilis* can carry viable spores on its legs and body hairs and Dodd commented that it is "... a reasonable assumption" that the insect brought the fungus from Hawaii.

Since the fungus occurs in North America and the Caribbean (Cuba), it is possible that it was carried to Hawaii on the original collection of *P. utilis* made in Mexico.

The most severe effect of the fungus in Australia was seen in areas of very high rainfall (>5000 mm) but it subsequently caused damage "in comparatively dry weather" as well (Dodd, 1961). In shaded areas it had little effect but in exposed areas it caused a great deal of leaf fall, particularly in dry weather. Thus it appears to reduce the weed's ability to withstand stress. It is also notable that this strain of *C. eupatorii* appeared highly host specific: it did not attack the related species *A. riparia* even when the two plants were growing together. Dodd concluded that the level of control achieved was due to the combined effect of the introduced insect and fungus.

Conflicts of Interest in the Biological Control of *C. odorata*

In Nigeria, *C. odorata* is known to attract adults and nymphs of the pyrgomorphid pest *Zonocerus variegatus* (L.), and pest numbers have increased since the arrival of the weed. The attraction is thought to be due to the presence of pyrrolizidine alkaloids in the plant. Pyrgomorphids are known to sequester alkaloids and *C. odorata* is not a favoured food plant of *Z. variegatus*, so it is possible that these compounds are used for non-nutritional purposes, perhaps as an attractant pheromone (Chapman et. al., 1986). This fact may be turned to advantage by using *C. odorata* as a trap plant for the pest (Modder, 1986). However, *Z. variegatus* is also attracted to other plants which could be used for this purpose (Chapman et. al., 1986) and this potential benefit from *C. odorata* does not weigh the many other advantages of a biological control programme against the weed. Also, even if biological control was successful, sufficient *C. odorata* would probably still remain to attract the pest, since the aim of the programme would be to reduce the vigor of *C. odorata*, not to eradicate it.

In Nigeria and other parts of West Africa, *C. odorata* invades traditional cropping systems, forming a dense, tall cover over land during the fallow period, which may be as long as five years between cultivation. In such situations, *C. odorata* can be of some value as it returns a large amount of organic matter to the soil, is easily cleared by burning or cutting, and excludes perennial grasses (eg. *Panicum*, *Pennisetum*, *Andropogon* spp) which would otherwise dominate fallow and which are difficult to remove before cultivation (I.O. Akobundu, pers. comm.). Thus a conflict of interest may arise where *C. odorata* is locally a weed of pastures, plantations and traditional farms, although in principle control agents may be less damaging against the weed on fallow ground, where there is less competition with other plant species than in pastures or plantation. In this case, the desirable properties of *C. odorata* in fallow cropping might be partly conserved even after biocontrol.

It is also probable that *C. odorata* plays a useful role in preventing erosion under some conditions. However, it may also replace grasses, which are usually better candidates for erosion control (Holm et. al., 1977), so its control should not cause conflict in this case.

CONCLUSION: The Need for a Full Complex of Natural Enemies

There is a wide range of biological agents available for testing against *C. odorata*, and, in the case of pathogens, there are probably others that have yet to be discovered. Only one agent, *P. pseudoinsulata*, has been exploited to any extent. The discovery of its apparent adaptation in Sri Lanka may both explain why some earlier introductions failed and also suggest possibilities for improving the success of future introductions, particularly in West Africa, by first pre-adapting the insect in a more favorable part of the region. As an alternative strategy, Cock and Holloway (1982) suggested making collections for India and West Africa in areas such as N. Venezuela with a closer climatic match to these areas than Trinidad. The Northern Venezuelan strain was introduced to India, but was not successfully bred and hence not released (Anon., 1983). Thus there is a need for additional introductions of this strain.

The only other agents that have been introduced are *Apion brunneonigrum*, which Cock (1984) noted was ineffective, and *Mescinia parvula*, and *Melanagromyza eupatoriellae* (Anon., 1986). The two latter agents were supplied from Trinidad to India (*M. parvula*) and Guam (both) but there is no published information on their establishment. Many of the agents recommended by Cruttwell (1974) and Cock (1984) have great control potential as part of a natural enemy complex, and their specificity should be tested. This is particularly true of the mite *Acalitus adoratus*, which could now be shipped via quarantine in United Kingdom.

The accidental introduction of a strain of *Cercospora eupatorii* into Australia demonstrated the value of a combined attack by arthropods and fungi in reducing weed vigor. It also demonstrated the existence of host-specific strains within *C. eupatorii*, emphasizing the potential value of this genus for classical biological control. This fungus, and the rust *Cionothrix praelonga*, are both potentially very useful candidates for introduction and others probably exist, since no methodical search for pathogens of *C. odorata* has ever been made. While effective biological control has been achieved in some cases by the introduction of a single control agent (Myers, 1986), there are also good reasons to believe that control in many weeds is more likely to succeed by using a range of natural enemies than by choosing just one (Harris, 1979 and 1986). In the past the favoured agent has often been chosen because it is easy to handle and breed rather than because it is known to be particularly effective. *C. odorata* has a large range of natural enemies and more attention should be given to the introduction of a truly representative spectrum of them for effective biological control.

CIBC is particularly well placed to carry out further work on the identification and screening of such agents. The CIBC Station in Trinidad is situated within the center of origin of *C. odorata* and was the base for Cruttwell's original searches. The CIBC Headquarters in United Kingdom has full quarantine facilities for the maintenance and transfer of arthropods and fungal pathogens. CIBC is most willing to collaborate with other agencies on the exploitation of biological control agents for this weed.

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A REVIEW OF MECHANICAL AND CHEMICAL CONTROL OF *CHROMOLAENA ODORATA* IN SOUTH AFRICA*

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ABSTRACT

The introduction of *Chromolaena odorata* (L.) King and Robinson to South Africa in the 1940s was unintentional and probably occurred via Durban harbor. Since then it has spread rapidly and now occurs along most of the Natal coast. Fairly extensive infestations are also present in the north eastern Transvaal. It is evident that further spread is inevitable.

Mechanical control has been the most widely used control measure and although generally effective, the escalating labour cost is making this method prohibitively expensive. Tools generally used are picks, hand hoes, and mattocks. Motorized brushcutters and tractor-drawn mowers are sometimes used where possible.

The use of herbicides for the control of *C. odorata* has been under investigation. Results obtained have shown that foliar application of triclopyr is particularly effective. The dosage of herbicide required to elicit an acceptable level of control was lower where application was made to regrowth less than 1.5 m tall. Other herbicides showing high efficacy include 2, 4-D amine, glyphosate, 2, 4-D/ioxynil and picloram/2, 4-D. Herbicide application by mistblower to mature plants, regrowth and seedlings is worthy of consideration; both glyphosate and triclopyr are effective. Where plants of comparatively large stem diameter occur, herbicide application to stumps was found to be effective. Triclopyr in diesel oil, imazapyr in water and ready-to-use 2, 4-D mix provide an acceptable level of control.

The use of fire combined with other control methods and the use of grasses to rapidly establish a dense cover are under investigation. Preliminary observations are encouraging.

INTRODUCTION

Chromolaena odorata, commonly known in South Africa as triffid weed (English) or paraffienbos (Afrikaans), is thought to have been unintentionally introduced into South Africa in achene-contaminated packing materials off-loaded at Durban harbor during the early 1940s (Pickworth, 1976). The weed spread rapidly along the Natal coastal belt, probably in response to the prevailing north/south wind direction and by 1960 was present from Port Shepstone in the south to Stanger in the north (Figure 1). Since this time triffid weed has spread rapidly and has encroached as far south as Hluhleka Nature Reserve located south of Port St. John on the Transkei coast and north as far as Kosi Bay on the South Africa-Mozambique border (Liggitt, 1983 and MacDonald, 1984). However, the invasion of this weed into the cool moist midland regions of Natal has been curtailed by the occurrence of frost. Thus its limited presence in the

*Presented by S. Nesor, Plant Protection Research Institute, Pretoria.

Pietermaritzburg, Karkloof and Melmoth areas (Figure 1) is marginal and restricted to habitats protected from severe or frequent frost. Further north, the weed's spread inland has probably been restricted by insufficient rainfall. It is however present in the moist habitats of the Hluhluwe and Mkuzi Game Reserve regions (Figure 1).

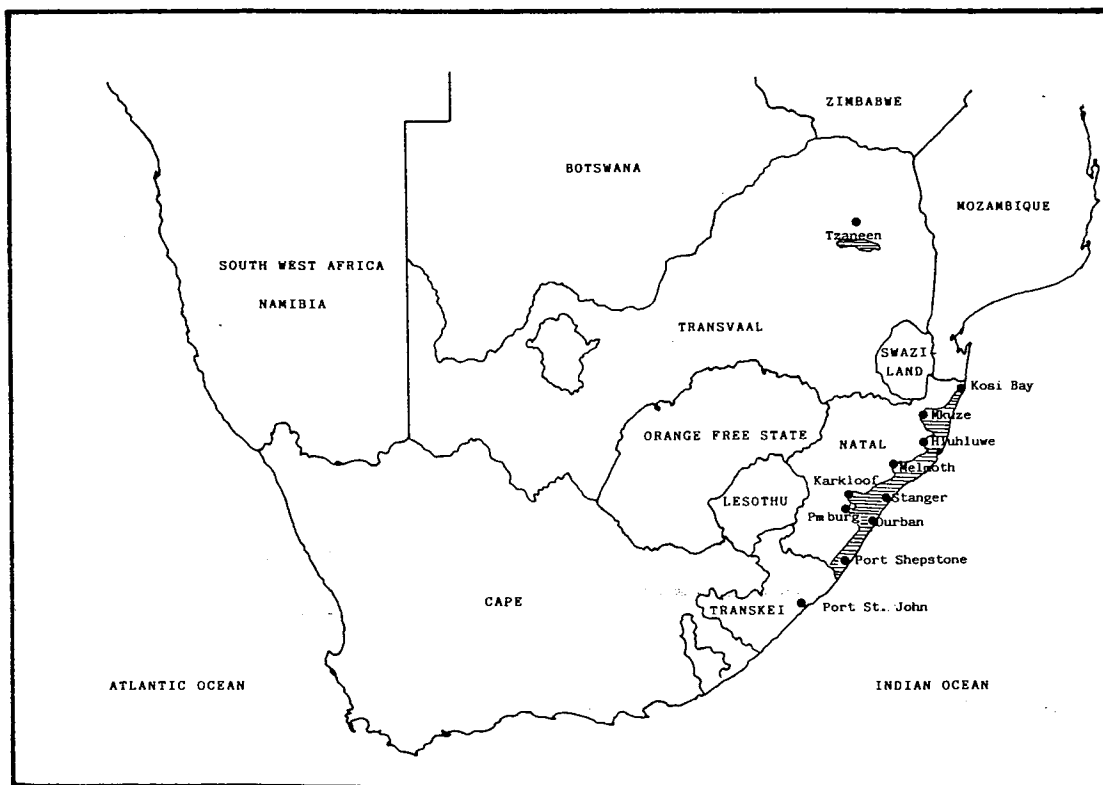


Figure 1. The Current Distribution of *Chromolaena odorata* in South Africa.

Unfortunately triffid weed is not restricted to Natal province. Extensive infestations of the weed are also present in the Tzaneen region of Transvaal province (Figure 1). As yet there is no clear explanation as to its presence here. It is evident that this weed has not yet reached its full range of distribution and many areas, including the Kruger National Park, are threatened by invasion

Although South Africa has many troublesome alien invader plants, triffid weed is ranked as one of the top priorities, especially in Natal province (MacDonald and Jarman, 1985). It is primarily a weed of conservation areas where it frequently suppresses the indigenous vegetation and successfully competes for natural resources. The scrambling habit of the plant eventually results in virtual strangulation of other species. Consequently, the density, and ultimately the diversity, of the indigenous flora declines. This has important implications for the local fauna which can be expected to follow a similar pattern. In the recreational context, dense infestations along roadsides and trails in parks obstruct game and bird viewing.

Although the potential problem of triffid weed in agriculture has previously been identified (Egberink and Pickworth, 1969 and Wells and Stirton, 1982), the problem is only now being manifested. The major problem is the encroachment of natural pastures (veld) in areas of livestock production. As with invasion of conservation areas, the density and diversity of

desirable palatable grass and browse species are being reduced with a concomitant loss in livestock (beef and venison) production. In the sugar cane belt stretching along most of the Natal coast and hinterland, dense infestations of trifid weed in uncultivated areas harbor wild pig which can cause much damage to crops. The weed also invades fallow land resulting in increased land preparation costs.

As in many of the countries where trifid weed is a problem, the weed has invaded commercial timber plantations in both Natal and Transvaal provinces. Its rapid growth results in severe suppression of timber seedlings and markedly increases costs of weeding operations. Access for silvicultural and harvesting operations is restricted and its presence undoubtedly increases the cost of timber production.

The fire hazard potential of trifid weed is frequently emphasized in South Africa. For example, it is believed that the replacement of previously fire-excluding fringes of riverine forest communities by trifid weed has made these communities vulnerable to fire (MacDonald, 1984). The presence of this weed in timber plantations and vacant land in urban areas reportedly also constitutes a fire-hazard (Liggitt, 1983).

In some situations trifid weed infestations are largely monospecific. However, the weed also occurs in association with other problem weeds such as *Lantana camara* L., *Pereskia aculeata* Mill. and *Melia azedarach* L. In other situations, trifid weed occurs in close association with desirable forage, indigenous and 'crop' species. These factors have important implications for the development of control strategies.

MECHANICAL CONTROL

Mechanical control has been the predominant measure implemented for the control of trifid weed. In some cases, for example in timber plantations, manual slashing is carried out annually. Although only effective in the short-term, this action does prevent seeding. In conservation areas, the initial slashing operation is followed by uprooting. For slashing, tools used include slashers and more often, cane knives. For uprooting, picks, hand hoes and mattocks are used. In a few situations use is made of motorized brushcutters and tractor-drawn mowers for the slashing operation. The use of the latter is restricted by accessibility in harsh terrain and by the occurrence of desirable species.

The cost of manual control is frequently under-estimated. A workstudy investigation revealed that slashing of dense infestations required 32.5 man days ha^{-1} ; uprooting required a further 52 man days ha^{-1} (Erasmus, 1988). At approximately R13 per man day for unskilled labor, the cost of this form of mechanical control is over R1000 ha^{-1} (one S.A. rand = 50 US cents).

Notwithstanding these restraints on mechanical control, this method is still widely used especially where a plentiful and comparatively cheap labor supply is available. With judicious weedings, notable achievements have been attained. In a number of the smaller Natal Parks Board reserves, dense infestations of trifid weed have been cleared. At present only annual sweeps are conducted to hand-pull any plants which may have become established from the propagules originating from an external source. Manual efforts in urban areas have also been successful in controlling small infestations.

CHEMICAL CONTROL

The reported use of herbicides for the control of triffid weed in South Africa is sparse. The earliest reported study was conducted by Egberink and Pickworth (1969). It was concluded from demonstration trials, that picloram and 2, 4-D were 'effective' while 2, 4, 5-T was only 'moderately effective.' The problem of controlling triffid weed in the trial was complicated by the presence of other species resistant to the cheaper 2, 4-D treatment, while the persistence of the picloram suppressed colonization of the treated area by desirable species.

The registration of a herbicide for use on a specific weed species is mandatory in South Africa. In 1983 only one herbicide, tebuthiuron (a granular soil-applied formulation containing 200 g ai kg⁻¹), was registered for use on triffid weed. However, the use of this product is restricted to industrial weed control situations only. In 1983, field trials were initiated to screen candidate herbicides for efficacy on triffid weed. These trials were conducted on regrowth 1.5 - 2.0 m tall. It was found that 1000 l ha⁻¹ of mix had to be applied to obtain suitable coverage of the plants. The results obtained showed that of the herbicides tested, 2.4 kg ai ha⁻¹ triclopyr (480 g ai l⁻¹), 6.15 kg ai ha⁻¹ 2, 4, 5-T (615 g ai l⁻¹), and the registered rate of tebuthiuron, 4 kg ai ha⁻¹, were consistently effective, regardless of application time or site (Erasmus and van Staden, 1986a). Similar results for triclopyr were obtained by Brink and Clayton (1984). With the demise of 2, 4, 5-T in South Africa, only triclopyr was registered.

In subsequent trials, the efficacy of various foliar applied herbicides sprayed on to actively growing regrowth 0.5-1.0 m tall was assessed (Erasmus, 1987 and Erasmus and van Staden, 1987). It was found that the dosage of triclopyr required to obtain greater than 90% mortality was markedly reduced from that required to elicit a similar response in the earlier trials. Acceptable control was obtained with the following treatments: 0.48 kg ai ha⁻¹ triclopyr, approximately 1.50 kg ai ha⁻¹ glyphosate (359 g ai l⁻¹), 3.84 kg ai ha⁻¹ 2, 4-D amine (480 g ai l⁻¹) and 3.00/0.50 kg ai ha⁻¹ 2, 4-D (iso octyl ester)/ioxynil (600/100 g ai l⁻¹). These results show that the cost of chemicals to control triffid weed can be reduced by application of herbicides to shorter regrowth. In addition, access for spray operators is greatly improved. The registration of some of these treatments is pending.

Trials were recently conducted in an attempt to identify the optimum height of regrowth to which herbicides should be applied. Plants were manually slashed at various times to provide three stages of regrowth at time of application. These were: plants upto 0.5 m tall, plants between 0.5-1.0 m tall and plants 1.0-1.5 m tall. Treatments applied were: 0.48 and 0.96 kg ai ha⁻¹ triclopyr; 1.077 and 2.154 kg ai ha⁻¹ glyphosate; and 0.051/1.248 kg ai ha⁻¹ picloram/2, 4-D (17/416 g ai l⁻¹). With the exception of the 1.077 kg ai ha⁻¹ glyphosate, all treatments resulted in 100% mortality (unpublished data). It is thus proposed that the stage of regrowth is not crucial; application can therefore, within reason, be made when convenient.

The use of a mistblower for the control of triffid weed has also been investigated. For seedlings up to 30 cm tall it was found that 0.718 kg ai ha⁻¹ glyphosate and 0.48 kg ai ha⁻¹ triclopyr resulted in 100% mortality (unpublished data). The triclopyr treatment is currently being used for practical control operations as the selectivity of this herbicide ensures that establishing grass species are not killed. Application by mistblower is more rapid than by knapsack and inaccessible areas such as are found amongst indigenous vegetation are easily reached by the spray emanating from a mistblower. For mature, unslashed triffid weed, 0.72-0.96 kg ai ha⁻¹ triclopyr and 1.436-2.513 kg ai ha⁻¹ glyphosate resulted in greater than 90% control (unpublished data). Therefore where access is not severely restricted, the preparatory

slashing operation required for knapsack sprayer applications to regrowth can sometimes be avoided. The use of a mistblower has been found to be particularly useful in clearing triffid weed encroaching on roads.

It can be concluded from these investigations on the chemical control of triffid weed that for foliar application, triclopyr is the most suitable herbicide. However, a major disadvantage of this herbicide is its lack of efficacy on *L. camara*. As this weed commonly occurs in close association with triffid weed, either a two stage operation is required where the two weeds are treated with different herbicides, or a different herbicide effective on both species must be used, for example, glyphosate.

Where triffid weed occurs in close proximity to desirable species (indigenous and 'crop'), foliar applications are risky. However, where target specific application is not possible, the desirable plants are generally sacrificed. Research has been conducted on the use of a shield to 'contain' the spray and although favorable results were obtained (Erasmus and van Staden, 1987), this apparatus is only likely to be of use in small infestations as it is cumbersome.

In some situations where triffid weed has not been subjected to frequent burning or slashing, stem diameters of 20-60 mm are common. Field trials were conducted to investigate the possibility of using stump applications of herbicides to such plants. The herbicide mixtures were applied to 100-150 mm tall stumps by a narrow (25 mm) paintbrush. The treatments which resulted in an acceptable level of control (80% mortality) were 1% triclopyr in diesel oil, 1.5% imazapyr (250 g ai l⁻¹) in water and ready-to-use 2, 4-D mix (2, 4-Dichlorophenoxyacetic acid + 2-(2,4-D Dichlorophenoxy) propionic acid, 11.9 and 11.7 g ai l⁻¹ respectively) (Erasmus, 1987). The dosage was dependent on the plant and stem densities of the treatment plots. The dosage of triclopyr ranged from 0.168 - 0.355 kg ai ha⁻¹; 0.088 - 0.263 kg ai ha⁻¹ for imazapyr; and 0.619/0.608 - 1.523/1.498 kg ai ha⁻¹ for the 2, 4-D mix. Clearly these rates are comparatively lower than some of those reported above and this technique of herbicide application therefore provides a useful alternative for the control of triffid weed. The added advantages of the technique include: 1) treatment can be applied during the preparatory slashing operation, 2) herbicides can be applied target specific, and 3) herbicides can be applied during windy conditions when foliar application is unsuitable.

The research conducted thus far has shown that, as in many other countries, triffid weed can be controlled chemically. However, the cost of chemical control in South Africa is prohibitive as reinfestation of cleared areas invariably occurs. The eventual solution, in the absence of effective biological control, is likely to be a strategy of integrated control. An attempt at providing an answer is described below.

MECHANICAL/CHEMICAL/CULTURAL CONTROL

An investigation currently in progress is examining the use of an integrated approach to controlling triffid weed. The trial comprised three blocks. In block A, the infestation was slashed and the regrowth sprayed with 0.768 kg ai ha⁻¹ triclopyr. The plants in block B and C were slashed and uprooted. Block C was further treated by burning the plant material when dry. All three blocks were then oversown/planted with the following grass species which are commercially available: *Panicum maximum* Jacq., *Chloris guayana* Kunth, and *Cynodon dactylon* (L.) Pers (K11). Seedlings of *Setaria megaphylla* Stapf ex Stapf & C.E. Hubb., a naturally occurring broad-leaved grass, were also planted. The planting of grass is based on the assumption that the rapid establishment of a dense ground cover would reduce germination of

trifid weed achenes (Erasmus and van Staden, 1986b) and suppress the growth of any seedlings which might become established.

Preliminary assessments have shown the following: in the burnt block, initial reinfestation was markedly reduced probably as a result of achene and seedling mortality while the germination and establishment of indigenous species was promoted; in the unbrunt blocks where grass establishment has been successful, minimal reinfestation by trifid weed has occurred. No conclusions can as yet be made concerning which of the grass species is likely to be the most suitable.

The cost of oversowing/planting with grasses is expensive. This approach, if successful, is only likely to be used where intensive livestock production is proposed. The use of naturally occurring plant species may also be considered for use in rehabilitating weed dominated communities.

CONCLUSION

C. odorata is a serious weed problem in South Africa and the likelihood of further spread is a distinct probability. Limited attention has been paid to *C. odorata* as it has not been considered a weed of major economic importance. However, increasing concern is being expressed and this has prompted research aimed at its control. Investigations have shown that the weed can be controlled mechanically and chemically. But, rapid reinfestation occurs in cleared areas and this aspect has been identified as a priority for research.

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REARING, RELEASE AND MONITORING OF *PAREUCHAETES PSEUDOINSULATA*

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The biology of *Pareuchaetes pseudoinsulata* in Trinidad, Sabah, (Malaysia), Bangalore (India) and Guam have been studied by Bennett and Cruttwell (1973), Syed (1977), Muniappan et. al., (1988), and Seibert, (1985), respectively. Eggs are laid in groups and the caterpillars up to third instar stage remain feeding on the leaves during day and night. However, after third instar they tend to be nocturnal feeders. Most caterpillars crawl down from the plants at sunrise and hide in debris and dried leaves beneath the plant. At sunset, they climb up the plant and feed during night time.

Rearing of caterpillars of *P. pseudoinsulata* in the laboratory using ice cream cups has been reported by Muniappan et. al. (1988), and in 25 gallon trash cans by Seibert (1985). The latter method has been found to be easy to maintain and effective for rearing. This method is currently used for mass rearing *P. pseudoinsulata* caterpillars in the laboratories on Guam and Thailand.

Mass releases of caterpillars of *P. pseudoinsulata* in India, Nigeria and Ghana in early 1970s have been reported as unsuccessful in field establishment (Simmonds, 1976). However, at the same time field establishment and defoliation of *C. odorata* has been achieved in Sri Lanka (Dharmadhikari, et. al., 1977). It was established in Malaysia in 1977, however it has been reported not to be effective (Syed, 1977). Eventhough no release of *P. pseudoinsulata* was made in the Philippines, its establishment was reported in the Palawan Island (Torres, 1986 and Aterrado, 1987). Subsequently it has been reported from Mindanao and Visayas (Aterrado and Talatala-Sanico in a later chapter of this proceedings).

P. pseudoinsulata has been established on Guam in 1985, Rota in 1986, Saipan, Tinian and Aguijan in 1987. Field releases have been made in Yap and Thailand in 1988. Recently the establishment of *P. pseudoinsulata* at Trichur, India has been reported (Joy, P.J. pers. comm.).

Mass release of caterpillars at one site on thick bushes of *C. odorata* seems to favor the establishment of *P. pseudoinsulata*. Predatory insects such as ants were reported to be the primary cause for non-establishment of *P. pseudoinsulata* in India (Simmonds, 1976).

Our experience in establishing *P. pseudoinsulata* in the fields on Guam, Saipan, Rota, and Tinian indicated that mostly a nucleus culture seemed to establish at one place and eventually it spreads in expanding concentric circles until overlapping generations of the population occur. Wind, host density and light at night seems to influence the direction and intensity of the spread. Detailed monitoring of spread of *P. pseudoinsulata* has been conducted on Guam by Seibert (1985 and 1986).

Feeding of *P. pseudoinsulata* causes the leaves of *C. odorata* to change from green to yellow. These yellow leaves are not preferred by *P. pseudoinsulata*. As a result quite often population crashes of *P. pseudoinsulata* occur when *C. odorata* is sparsely distributed.

However, the same result is not noted when *C. odorata* occurs in monospecific as the caterpillars are able to migrate from the defoliated and yellow plants to normal green plants.

Defoliation causes most shoots of *C. odorata* to dry up. Continuous defoliation of new sprouts from basal clumps will result in total death of *C. odorata* bushes.

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ASSESSMENT OF *CHROMOLAENA ODORATA* BEFORE RELEASE AND AFTER ESTABLISHMENT OF NATURAL ENEMIES

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Chromolaena odorata normally becomes a dominant weed in the newly introduced environment that is congenial for its growth. Its introduction, establishment and distribution in Asia, Africa and the Pacific have been reviewed in the earlier chapters of this proceedings. In the neotropics, the place of its origin, this weed is kept under control by its natural enemies. In the old world tropics when this weed was introduced without its natural enemies, it has become a menace. Its allelopathic chemicals suppress neighboring plants and inhibit the germination of seeds underneath it. During the dry season, ie. January to May in most humid tropical regions in Asia, Africa and the Pacific in the northern hemisphere, *C. odorata* becomes a fire hazard. The dried shoots of *C. odorata* readily burn but the basal clumps remain alive. Soon after the onset of the rainy season, *C. odorata* clumps sprout and become the dominant vegetation.

It is desirable to assess the importance value of *C. odorata* in different ecosystems within a given region wherein the introduction of *Pareuchaetes pseudoinsulata* has been planned. Assessment of the importance value of *C. odorata* before release and after the establishment of *P. pseudoinsulata* would provide quantitative data for analysis and interpretation. Sampling procedures such as plot sampling and point quarter sampling and other methods are well illustrated in Brower and Zar (1977) and Mueller-Dombois and Ellenberg (1974).

Seibert (1985, 1986 and 1988) estimated *C. odorata* population before introduction of *P. pseudoinsulata* using one square meter quadrats. He was able to assess the mean stem diameter at the time of release and after the establishment. He has also worked out the relationship between $x =$ stem diameter and $y =$ total capitula to be $y = 120.2654 * 10^{(0.0916x)}$; $r = 0.82$ for *C. odorata*. One square meter quadrats were found to be too small for this purpose and we would like to recommend that five square meter quadrats be used.

Since the establishment of *P. pseudoinsulata* on Guam in June 1985, its spread has been closely monitored and reported by Seibert (1988). Further studies on succession of different species of plants wherein *C. odorata* was monospecific before the introduction of *P. pseudoinsulata* is being continued.

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INTERACTION BETWEEN *CHROMOLAENA ODORATA* AND *PAREUCHAETES PSEUDOINSULATA*: A PRELIMINARY STUDY

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Various interactions between plants and herbivorous insects have been recognized by biologists. A host specific insect is a good candidate of biological control agent of weeds. Upon insect feeding, plants often demonstrate their defensive responses. Physical and physiological changes in plants could occur to protect further attack by natural enemies.

Pareuchaetes pseudoinsulata was the first insect to be considered as a biological control agent of *Chromolaena odorata* (Bennett and Rao, 1968 and Cruttwell, 1968). Although in many countries the establishment of *P. pseudoinsulata* were not successful (Cock and Holloway, 1982). It was established on Guam and three other islands in the Marianas in controlling *C. odorata* (Seibert, 1986). While caterpillars of *P. pseudoinsulata* feed on plants, various changes have been observed such as yellowing leaves and the development of toughened tissues. Both damaged and undamaged leaves of the same plant turn yellow. This phenomenon might have been caused by physiological changes in plants due to the presence of chemical stimulus produced by insects. Possible mechanisms of plant changes are: 1) induction of new compounds in plants by insect attack, 2) relocation of nitrogen or other nutrient elements from leaves to other parts of plant, e.g., roots, 3) changing forms of nitrogen or other elements to cause yellowing leaves. Palatability and insect survival may also be altered as physiological and physical changes of plants. This paper presents results of preliminary experiments conducted to understand the interaction between *P. pseudoinsulata* and *C. odorata*.

STUDY 1. SIMULATE PLANT RESPONSE TO INSECT DAMAGES

There are two experiments in Study 1. The first is the artificial clipping of leaves to induce yellowing and the second is the induction of yellow leaves with artificial infestation of *P. pseudoinsulata* in an enclosed condition. The first experiment would reveal if any stimuli are produced and released by the insect to cause leaf yellowing. It would reveal whether the artificial removal of leaves by hands trigger the same responses of the plant to insect feedings. The second experiment would clarify the process of leaf yellowing influenced by the insect feeding. The second experiment is currently in progress. The results of the first experiment is presented in this report.

Materials and methods: Leaves of naturally grown *C. odorata* in a field were clipped by scissors leaving predetermined proportions of leaf area. Figure 1 shows five treatments applied in this experiment which included; no clipping, 25% removal of the leaf, 50% removal of the leaf, 75% removal of the leaf, and 100% removal of the leaf. Each treatment was replicated five times. The first artificial clipping was done on August 6, 1987, and was repeated on August 18, 1987 and September 6, 1987 because new leaves kept growing. On September 11, 1987 leaves of all treatments except the treatment of the 100% removal were sampled. Five grams of leaf tissues was blended in 100 ml of 80% acetone. After filtering, the extract was diluted 10 times and the absorbance at 430 nm was measured using a spectrophotometer as an estimate value of chlorophyll content. Yellow leaves from insect infested plants were also examined as a reference in comparison with leaves from artificially defoliated plants. On September 24, 1987

newly developed leaves from the fifth treatment were sampled and were subjected to the same analysis.

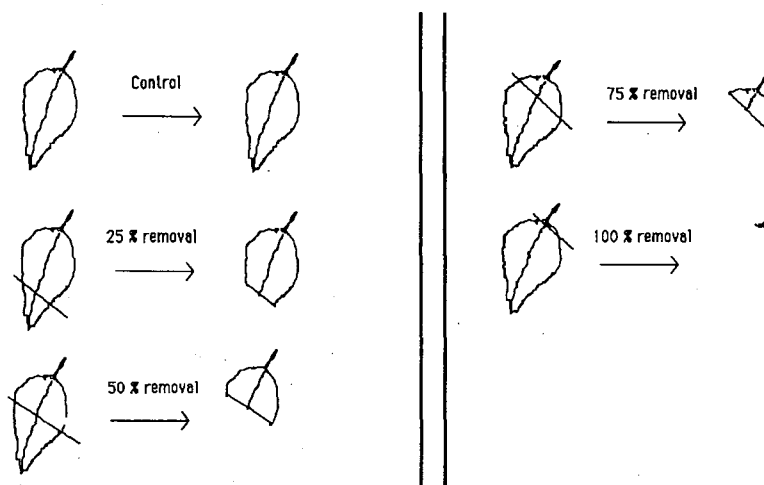


Figure 1. Diagram of five treatments in the experiment of Study 1. A leaf was clipped by scissors leaving 25, 50, 75, and 100 per cent of the leaf area. There was no clipping in control.

Results: Table 1 shows the result of chlorophyll content in leaves from the five treatments including the yellow leaves. Chlorophyll content was much lower in insect infested leaves than leaves from artificially defoliated plants. New leaves from the 100% removal of leaf treatment became yellow, however, the amount of chlorophyll content was much higher than that of insect infested leaves. The result indicated that artificial defoliation could not produce the same yellow leaves caused by the insect. This led us to believe that some insect-plant interactions were responsible for leaves yellowing.

Table 1. Absorbance of leaf extract (in 80% Acetone) at 430 nm

Treatment	Absorbance at 430 nm	Treatment	Absorbance at 430 nm
No clipping	0.47 ± 0.11	75% clipping	0.50 ± 0.10
25% clipping	0.54 ± 0.11	100% clipping	0.30 ± 0.03
50% clipping	0.56 ± 0.08		

STUDY 2. EXAMINE PHYSICAL AND METABOLIC DIFFERENCES OF GREEN AND YELLOW LEAVES CAUSED BY INSECT DAMAGES

The examination on physical and metabolic differences of green and yellow leaves caused by insect damages were investigated in five different aspects in Study 2. They were:

- a.) Differences in calories
- b.) Differences in leaf toughness
- c.) Differences in leaf tissue analysis
- d.) Differences in enzymen activities
- e.) Differences in the presence in the secondary compounds such as flavonioids and terpenoids

Currently, the fourth and fifth experiment are being conducted. The results of first, second and third experiments are presented in this report.

First Experiment: Calories

Materials and methods: A collection of green and yellow leaves were dried and ground. The ground leaves were measured for calories per mg ash free dry weight with a calorimeter. Two samples of ground green leaves and three samples of ground yellow leaves were used to determine the weight of calories in comparison.

Results: The green leaves had 4.83 ± 0.13 cal/mg ash free dry weight and the yellow leaves had 4.87 ± 0.09 cal/mg ash free dry weight (Table 2). There were no significant difference in the measurement of calories found between the green and yellow leaves. The experiment indicated that insect feeding did not alter the amount of calories stored in leaf tissues.

Table 2. Calories of green and yellow leaves

Color of Leaves	Calories/ mg as free dry weight (mean \pm sd)
Green	4.83 ± 0.13
Yellow	4.87 ± 0.09

Second Experiment: Breaking tensile strength

Materials and methods: When insects fed on leaves, the leaves appeared to become tough. To test the toughness of leaf tissue a breaking tensile strength was measured. Figure 2 illustrates the device used to measure the breaking tensile strength in this experiment. Each piece of leaf tissue (1cm x 3cm) was held by paper clamps. A string was attached to a clamp tied to a stationary object while the other end of the string held various amount of weight. The thickness of the leaf was measured prior to recording the minimum weight to break a leaf tissue. Measurement was replicated eight times for both green and yellow and leaves.

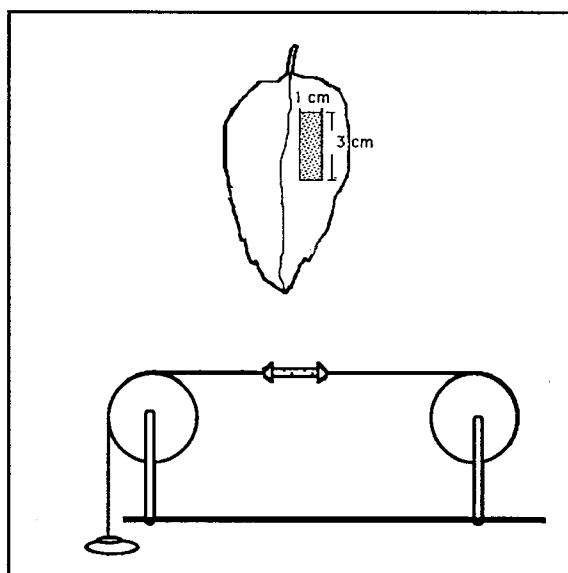


Figure 2. Apparatus used to measure the breaking tensile strength of leaf tissues.

Results: Table 3 shows the result of the experiment. The breaking tensile strength of green leaves was 58.8 ± 14.8 g/mm² and the yellow leaves was 68.3 ± 10.6 g/mm², however, the difference was not significant. The yellow leaves were observed to be tough.

Table 3. Comparison on breaking tensile strength between green and yellow leaves

Color of Leaves	Breaking tensile strength (g/mm ²) (mean \pm sd)
Green	58.8 ± 14.8
Yellow	68.3 ± 10.6

Third Experiment: Leaf tissue analysis

Materials and methods: A collection of green and yellow leaves were dried and ground to analyze the total-N, P, Na, K, Ca, Mg, Zn, Fe, Mn, Cu and nitrate-N. Two of the eleven elements were measured twice and others were tested once.

Results: Table 4 shows the results of tissue analysis except nitrate-N. The amount of total-N, P, Na, K, Ca, Mg, Zn, Cu did not differ between the green and yellow leaves while Fe and Mn showed differences. The element Fe happens to be in higher concentration in yellow leaves than green leaves. Nevertheless, it was not possible to generate any definite conclusion from this experiment due to the small number of replication or no replications. Comparisons of nitrate-N and total-N between green and yellow leaf tissues were shown in Table 5. Although the amount of total nitrogen did not differ in green and yellow leaf tissues, the amount of nitrate-N was much higher in yellow leaves than green leaves. A follow-up tissues analysis will be conducted to confirm the results of this preliminary report.

Table 4. Nutrient concentration of green and yellow leaves of *C. odorata*

Color of Leaves	Total N	Percentage					ppm			
		P	Na	K	Ca	Mg	Zn	Fe	Mn	Cu
Green	2.99	0.22	0.07	0.89	2.25	0.78	37.5	75.0 74.8	117.2 126.3	16.7
Yellow	2.72	0.21	0.07	1.06	2.14	0.68	44.0	116.6 99.3	50.9 183.8	16.7

Table 5. Concentration of total-N and nitrate-N in green and yellow *C. odorata*

Color of Leaves	Total-N (%)	Nitrate-N (ug/g)
Green	2.99	54.2
Yellow	2.72	911.4

STUDY 3. STUDY OF PALATABILITY AND INSECT SURVIVAL ON GREEN AND YELLOW LEAVES

In Study 3 insect responses to green and yellow leaves were compared in three aspects:

- a.) Palatability - to examine whether the insect favor green or yellow leaves.
- b.) Survival and growth rate of insects by feeding green or yellow leaves.
- c.) Change in insect population on green and yellow leaves at field.

First Experiment: Palatability

Materials and methods: Three pieces of green and yellow leaf tissues (2cm x 3cm) were placed in a petri-dish. Each leaf tissue was placed in an order of green and yellow leaf and was arranged alternately. Ten first instar larva were placed randomly in each petri-dish at the beginning of the experiment and on the second to the fourth day nine caterpillars fed on leaves. Since the amount of leaves fed by insects increased, the number of caterpillars was reduced as they mature. From the fifth to eighth day five caterpillars were utilized and on the ninth to the fourteenth day three caterpillars were used. Leaf areas consumed by caterpillars were measured daily to determine which kind of leaves only favored.

Results: Figure 3 shows the result of leaf area consumed by caterpillars for 14 days. The study indicated that caterpillars favored green leaves at both young instar and older stages. However, when caterpillars were in the stage of third instar or older they could consume yellow leaves.

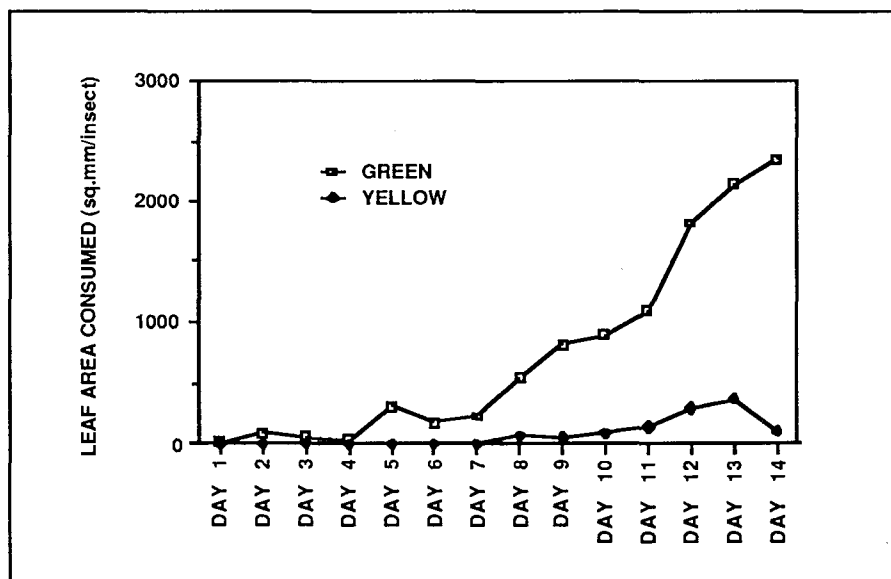


Figure 3. Daily leaf area consumption by *P. pseudoinsulata*. The caterpillars were fed on either green or yellow leaves.

Second Experiment: Survival and growth rate of caterpillars by feeding green and yellow leaves

Materials and methods: Twenty five caterpillars were placed of the first instar on either green or yellow leaves in petri-dishes on November 25, 1987. The mortality of the caterpillars was examined daily by counting the number of insects dead. The length of twelve caterpillars was measured on December 1, 1987 to study the rate of their development.

Results: High mortality of caterpillars was seen when they were grown on yellow leaves (Table 6). In contrast, all larvae survived when they were fed on green leaves. Comparison on the length of larva is shown in Figure 4. The result clearly showed that the growth rate of caterpillars was much greater when they were fed on green leaves. Yellow leaves inhibited the development of insects.

Table 6. The number of caterpillars died during the experiment

Date	Green Leaves	Yellow Leaves	Date	Green Leaves	Yellow Leaves
Nov. 25 - Dec. 3	0	0	Dec. 9	0	0
Dec. 4	0	3	Dec. 10	0	0
Dec. 5	0	0	Dec. 11	0	1
Dec. 6	0	5	Dec. 12	0	0
Dec. 7	0	11	Dec. 13	0	2
Dec. 8	0	3			
TOTAL	0	22	TOTAL	0	3

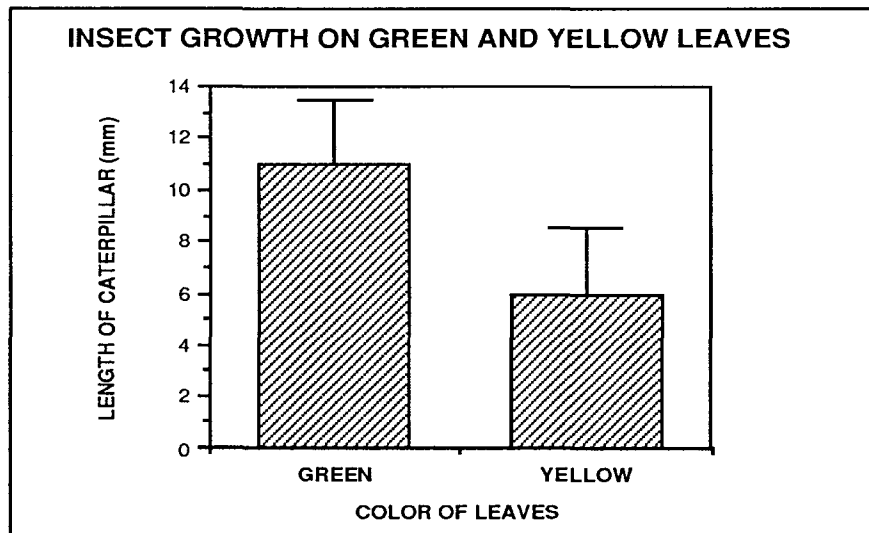


Figure 4. Average and standard deviation of the length of 12 caterpillars fed on either green or yellow leaves. Data were taken on December 1, 1987 (the sixth day of the experiment).

Third Experiment: Change in insect population on yellow and green leaves in the field

Materials and methods: The third experiment in Study 3 focused on insect population in the field. Diurnal change in insect population on green and yellow leaves was the main interest in this study. Green and yellow bushes of *C. odorata* were chosen at the experimental sites. Both bushes were naturally infested by *P. pseudoinsulata*. In each bush, five branches with six to nine nodes (the average number of nodes=7) were marked and the number of caterpillars on each branch was counted once during the daytime from noon to 4:00

p.m. and once at night between 7:00 p.m. and 9:00 p.m. Observation started on September 25, 1987 and continued for eight days.

Results: The average number of caterpillars per branch of green and yellow bushes is presented in Figure 5. The regular diurnal pattern was found during the first five days on branches with green leaves. The number of caterpillar was less during daytime than at night. This regular pattern became irregular after the sixth day. In yellow bushes there were no regular pattern of insect movement observed. Green leaves gradually started to turn yellow with insect feeding in the later part of the experiment. The irregular pattern seen from the sixth to eighth day may indicate that insects had been responding to changes in plants which were initially caused by insect feeding on green leaves. In general, there were more caterpillars found in yellow branches than in green branches. Difference in quality of green and yellow leaves could have been a cause of different behaviors of insects.

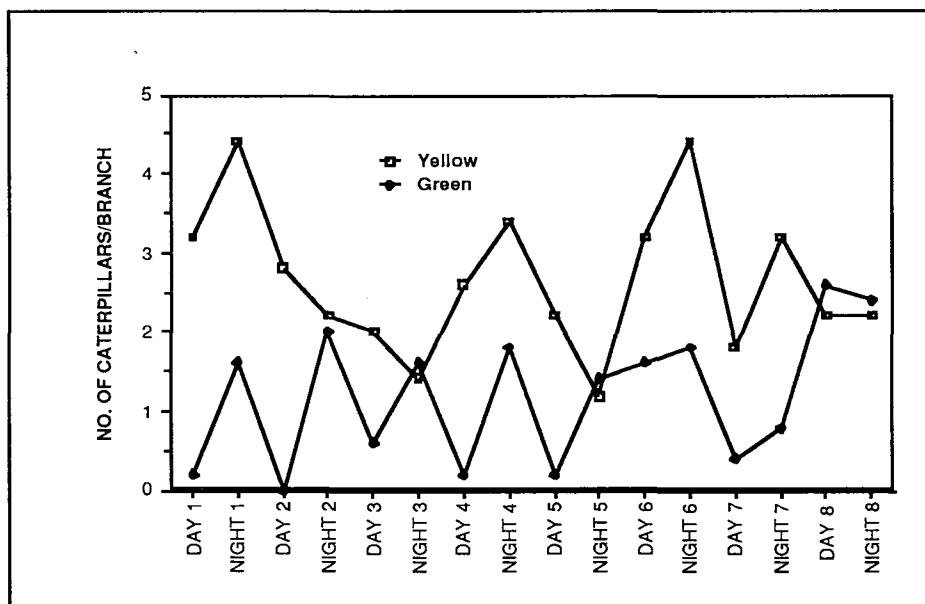


Figure 5. The number of caterpillars observed in branches of green and yellow leaves of *C. odorata* during daytime and at night.

DISCUSSION

Our preliminary study on the interaction between *C. odorata* and *P. pseudoinsulata* indicated that the weed had changed metabolically after it was grazed by insects. Toughening and yellowing of leaf tissues are two obvious changes of the plant upon the insect attack. The metabolic changes responding to the insect attack had led to a reduction in acceptability of damaged leaves by insects. Development of caterpillars was significantly reduced when insects were fed only yellow leaves. Investigation on types of physiological changes occurred in plants would be the focus in the further study. Difference in the amount of nitrate-N between green and yellow leaves found in the Study 2 should be investigated in more details. The higher level of nitrate-N in yellow leaves could be one of causes for reduction of acceptability of *C. odorata* by *P. pseudoinsulata*.

Identification of the secondary compounds induced by plants responding to insect attacks is another important subject in this research. Leather et. al. (1987) reported that significant difference in the monoterpene levels in defoliated and undefoliated pine trees (*Pinus contorta*)

greatly influenced the oviposition preference of the pine beauty moth (*Panolis flammea*). They also pointed out that levels of soluble tannins were different in previously defoliated and undefoliated trees. Another approach for understanding the interaction between *C. odorata* and *P. pseudoinsulata* is to conduct protein analysis or enzyme study. Green and Ryan (1972) demonstrated the formation of proteinase inhibitors to prevent synthesizing trypsin and chymotrypsin in tomato when leaves were wounded. Information on relationship between *C. odorata* and *P. pseudoinsulata* is still scarce. It is hoped that results of the further research will provide us the details of their interaction mechanism.

ACKNOWLEDGEMENTS

We thank Drs. C.T. Tseng and O. Levand for technical assistance to measure the breaking tensile strength of leaf tissues and biochemical studies in this research. We also thank Dr. R. Richmond for conducting the experiment to measure calories of leaf tissues. The *Chromolaena* research was funded by a grant from Tropical and Subtropical Agriculture Program of CSRS, USDA.

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STATUS OF *CHROMOLAENA ODORATA* RESEARCH IN THE PHILIPPINES

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Chromolaena odorata (L.) King and Robinson is a native of South and Central America but thoroughly naturalized in parts of Africa, India, Ceylon, Indochina, Malaysia and Indonesia. It migrated into the Philippines some 20 years ago. It might have found its way into the country either through some air packing materials during the World War II or through traders from South Borneo where it is growing abundantly in borders of abaca plantations (Pancho and Plucknett, 1972). Locally in the Philippines, the plant is known as *daladay* (Balabac), *talpus palad* (Tagbanua); *hulohagonoy* (Negros); *gonoi* (Palawan), *lahuneri* (Marinduque); *hintatakao* (Visayas); *bungarngar* (Mindoro) and *hagonoy* in many other parts of the country. The common name in English is devil weed.

The weed was first noted in the 1960s in the southern peninsula of Zamboanga but farmers paid little attention to it. Within a short period, it has attained weed status in majority of field and plantation crops like coconut, corn, sweet potato, cassava, sugarcane and rice. *C. odorata* principally invades open fields and pasture lands, frequently forming an almost impenetrable pure stand, out-competing and excluding all forage species. Both its rate of growth and spread are quite rapid. The species is avoided by livestock because it has exceptionally high nitrate content in the leaves and young shoots (Sajise et. al., 1972 and 1974) enough to poison animals feeding on its foliage. The species is believed to cause diarrhea and in extreme cases, death of livestock as reported by ranchers in the southern Philippines.

Initial observations have suggested that the non-susceptibility of the plant to insect attack may be due to oils which have insect-repellent properties (Holm et. al., 1977). Moreover, chemical control is highly expensive and prohibitive. As a result of these, large tracts of pasture lands have to be abandoned simply because of the invasion of this species, which at present, is causing much grave concern in the southern areas of the Philippines.

DISTRIBUTION OF *C. ODORATA* IN THE PHILIPPINES

C. odorata was first noted in Zamboanga and then shortly thereafter in Palawan and Mindoro. From there, it spread very rapidly northward to Luzon, covering thousands of acres of range and crop lands per year.

Recent survey of the weed showed that it has spread extensively in Mindanao island (except the northeastern region), in most islands in the Visayas, Palawan and in areas surrounding Manila.

In Mindanao, the spread of the weed appears to be originating from important port areas of Davao and Zamboanga, and progressing toward the northeastern region.

STATUS OF CONTROL *C. ODORATA*

Chemical Control: So far, there has been only one report on evaluation of herbicides against *C. odorata* at different growth stages. Madrid (1974) noted that seedlings were susceptible to 2, 4-D while mature stands were satisfactorily controlled by 2, 4-D combined with either 2, 4, 5-T, picloram or dicamba.

Biological Control: Practically nothing has been done yet on the biological control of *C. odorata*. Previous survey in 1985, however, showed the occurrence of a voracious leaf feeder in an isolated *C. odorata* patch in the Palawan island. The discovery turned to be a new record of insect feeding on *C. odorata* (Aterrado, 1987). The leaf feeder turned out to be *Pareuchaetes pseudoinsulata* Rego Barros (Lepidoptera:Arctiidae).

Subsequent surveys showed the existence of *P. pseudoinsulata* in Zamboanga City, and in Bohol and Northern Leyte provinces in the Visayas islands.

A couple of adults were brought to the laboratory and mass reared to some degree of success.

LIFE HISTORY OF *P. PSEUDOINSULATA*

Study on the life history of the natural enemy showed five larval, pre-pupal, pupal and adult stages. Upon hatching, the larva measured two mm in length growing to about 22 mm when fully grown.

Incubation period lasted for about 4.1 days, larva to pupa, 19.8 days; pupa to emergence, 8.8 days. The total life cycle from egg laying to adult emergence lasted for 32.7 days. In the laboratory, adults survived for 4.1 days.

Detailed observations or other studies were not carried out due to high mortality.

OTHER NATURAL ENEMIES OF *C. ODORATA*

Survey of other natural enemies revealed the presence of a species of aphid on young shoots and mites on the leaves. However, these agents appear to be of minor importance to weed control.

A leaf spot disease was also observed in Palawan but its occurrence was isolated and had little effect on the *C. odorata* population.

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IRREGULAR RECOVERY OF *PAREUCHAETES PSEUDOINSULATA* IN SABAH, MALAYSIA

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ABSTRACT

Siam weed or *Chromolaena odorata* is a widespread weed in Sabah. In 1970, *P. pseudoinsulata* was introduced from India into Sabah. Following field releases around four towns, it appeared that the insect has failed to establish. However, after more than ten years, pockets of *P. pseudoinsulata* have appeared at irregular intervals scattered over Sabah. Outbreaks of this arctiid would occur suddenly and after causing severe damage to the stand of *C. odorata*, it would disappear as suddenly. Another surprising thing is that the insect has been recovered in localities which are far from the sites of original releases. This paper records the irregular recovery of the insect and attempts to suggest possible causes of such irregular occurrence. It is hoped that this observation in Sabah will stimulate further research that will benefit future programs using *P. pseudoinsulata* as well as the development of a better biological control program for the Siam weed.

ATTEMPTS ON BIOLOGICAL CONTROL OF SIAM WEED, *CHROMOLAENA ODORATA* IN THAILAND

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ABSTRACT

In Thailand, biological control of Siam weed, *Chromolaena odorata* (Asteraceae), was initiated in 1975 with a survey and evaluation of native natural enemies which might be of potential use as biological control agents. Only an eriophyid mite, *Acalitus adoratus* Keifer (Acari: Eriophyidae) was found as a potential agent for further investigation. An arctiid moth, *Pareuchaetes pseudoinsulata* Rego Barros (Lepidoptera: Arctiidae) was introduced from Guam during 1986-87 for quarantine screening and host specificity tests. Apparently the insects released on experimental basis in 1987 failed to become established and additional releases were made in 1988. Their establishment was yet to be confirmed. It was found that most eggs obtained after four generations of laboratory rearing failed to hatch. A more detailed biological study on this arctiid was apparently lacking and was thus highly needed for further exploitation in biological control of Siam weed.

INTRODUCTION

The Siam weed, *Chromolaena odorata* (Asteraceae), is one of several exotic weeds introduced to Thailand, and thus conducive and amenable to classical biological control. It is vernacularly known as "Saab Sua" (Tiger's odor) and "Yah Sua Mop" (Crouching tiger grass). *C. odorata* is also referred to as *Eupatorium odoratum* (L.f.) Koster in other publications. Although its introduction from the West Indies into Singapore in the ballasts of cargo ships is well documented (Bennett and Rao, 1968, Syed, 1979, and Muniappan and Siebert, 1987), the common name "Siam weed" could be misleading. The name Siam weed is probably derived from its introduction via Thailand, formerly known as Siam until 1947, to Indonesia, hence called Siam weed (Soerjani et. al., 1987). It was not known if such naming is to rebut Thailand where the water hyacinth introduced via Indonesia was called "Pak Tob Java" or "Javanese water hyacinth".

According to Holm et. al. (1977), *C. odorata* is a weed of 13 crops in 23 countries, and in Thailand it is a weed in corn, cotton and rubber plantations. The weed is wide spread all over the country from the sea level to an elevation of 1,000 meters. The purpose of this paper is to review some attempts being made in the biological control of *C. odorata* in Thailand.

WEED STATUS OF *C. ODORATA* IN THAILAND

In Thailand, *C. odorata* is found on cultivated lands associated with upland crops and other plantation crops such as coconut and rubber. It is also found in teak and other forest tree plantations, and forest trails. Other areas infested by the weed are roadsides, riverbanks, ditchbanks, abandoned fields, grazing lands, waste and marginal lands. Control is normally by slashing and burning. Poisoning of livestock has also been reported. It was also a weed of

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amenity areas noted in Khao Yai National Park forming solid stands in clearings which hide the wildlife from tourists (Cock, 1984). During the dry season, *C. odorata* grown along the highways through forests could be a fire hazard.

On the contrary, beekeepers claim *C. odorata* as a source of nectar and pollens. It was also being investigated as a source of natural pesticides, and whose alcoholic extracts are potent fish poison having chalcone as an active ingredient (M. Loevinsohn, pers. comm.). However, in spite of such unavoidable "conflict of interest" which is more characteristic than exceptional in most biological control of weed programs, it was not adequately realized that *C. odorata* also serve as alternative host plants for various aphid species, most of which are known crop pests and vectors of plant pathogens. The aphid species found on *C. odorata* in Thailand are *Aphis craccivora* Koch, *Aphis gossypii* Glover and *Aphis spiraecola* Patch, all of which are known agricultural pests. Assessing from the prevalent situation, biological control is likely to be the most suitable management strategy for the management of *C. odorata*.

SURVEY AND EVALUATION OF BIOTIC AGENTS

Initiated in 1975, the biological control program for *C. odorata* concentrated on the survey and evaluation of native biotic agents which are likely for further utilization augmentatively before any introduction could be made. A survey carried out during 1975-78 did not yield any potential biotic agents. Other than negligible damage caused by an unidentified cicindellid larva, *A. gossypii* was observed to cause characteristic phyllodies to the plant (Napompeth, 1982). A limited survey made in Trinidad in 1978 resulted in the introduction of the top shoot miner, *Melanagromyza eupatoriella* Spencer (Diptera: Agromyzidae). However, no field release was made because the cultures perished under quarantine. As a result, the project was abandoned for a while until 1986 when a shipment of a culture of *Pareuchaetes pseudoinsulata* Rego Barros (Lepidoptera: Arctiidae) was made available from Guam.

Insects and mites found associated with *C. odorata* in Thailand to date are given in Table 1. Although detected for quite some time, the identity of eriophyid mite, *Acalitus adoratus* Keifer (Acari: Eriophyidae) was not confirmed until an observation and examination were made by R.E. McFadyen (pers. comm.). It was obvious that all aphid species found were undesirable as biological control agents, and the cicindellid was also unlikely to be of any use. *A. adoratus* is therefore a potential candidate for further utilization. It has also been suggested as a biological control agent worth further investigations and introduction (Cock, 1984). The mite was found widely distributed in Thailand and observed to cause appreciable damage to the weed.

Table 1. Insects and mites found associated with *Chromolaena odorata* (L.) in Thailand

Insect and mite species	Remark
HOMOPTERA: Aphididae	
<i>Aphis craccivora</i> Koch	Leaf feeder, known crop pest
<i>Aphis gossypii</i> Glover	-do-
<i>Aphis spiraecola</i> Patch	-do-
COLEOPTERA: Cicindellidae	
An unidentified cicindellid	Stem boring grub
ACARI: Eriophyidae	
<i>Acalitus adoratus</i> Keifer	Leaf feeder

INTRODUCTION OF *P. PSEUDOINSULATA*

Introduction of *P. pseudoinsulata* for biological control fo *C. odorata* in Thailand was suggested by R.A. Syed in 1975 but was not then materialized. Further assessment of *C. odorata* problems in Thailand was also made by D.J. Greathead and M.J.W. Cock in late 1970s and early 1980s. It was not until 1986 when *P. pseudoinsulata* was introduced to Thailand from Guam where introduction was made from Trinidad and establishment obtained in 1985, that attempt on biological control of *C. odorata* was revived again.

P. pseudoinsulata was earlier introduced for biological control of *C. odorata* in Ghana and Nigeria in Africa; and India, Sri Lanka and Sabah, Malaysia (Cock, 1984). It became established in Sri Lanka and Sabah. The insects have been recovered in Brunei far from the sites of original releases (Cock, 1984). And, recently, *P. pseudoinsulata* was also recovered from the Palawan Island in the Philippines (E.D. Aterrado, pers. comm.) where no introduction or releases have been made.

During 1986-87, a total of five shipments of *P. pseudoinsulata* were received from Guam. The first three shipments were utilized for quarantine screening, biological study as well as host specificity tests under quarantine conditions at NBCRC. Subsequent shipments were used for laboratory mass rearing and field releases. The dates of receipts, numbers of insects received, numbers of moths obtained and numbers of generations maintained are presented in Table 2. Altogether 320 eggs and 712 pupae were received.

Table 2. Introduction of *P. pseudoinsulata* Rego Barros from Guam to Thailand during 1986-1987

Number of consignment	Date received	Number of insects	Number of moths obtained	Number of generations kept
1.	March 7, 1986	63 pupae	3	0
2.	May 12, 1986	135 pupae	42	4
3.	November 27, 1986	94 pupae	80	4
4.	July 9, 1987	64 pupae	35	1
5.	November 5, 1987	320 egg 356 pupae	300	4
Total = 320 eggs,		712 pupae		

The first consignment of 63 pupae was found heavily parasitized by tachinids and only three adult moths were obtained. The moths failed to produce any offsprings. Heavy parasitization by tachinids is normally observed in field-collected materials (R. Muniappan, pers. comm.). As a result, laboratory-reared pupae were used in subsequent shipments and the cultures received were free from tachinid parasitization. Of all the subsequent shipments received except shipment number four consisting of 35 pupae, laboratory rearing was quite successful up till the fourth generation when almost all eggs obtained failed to hatch inspite of successful mating observed in the egg laying cages. It was not known if such phenomenon is common or it was due to certain physiological effect. It was also not known if such a phenomenon could be responsible factor for causing in part irregular recovery of the moths reported from Sabah and elsewhere.

BIOLOGICAL STUDY OF *P. PSEUDOINSULATA*

Life cycle study of *P. pseudoinsulata* carried out under laboratory conditions revealed durations of various developmental stages as shown in Table 3. The egg, larval, pupal and adult stages ranged from four, 15-20, 7-11, and four to six days respectively. The total life cycle averaged 50.8 ± 5.2 days and ranged from 44-64 days. The growth increment in successive larval instars, using the width of the head capsules, was 1.475 (pooled $\chi^2 = 0.0093$, d.f. = 4, $P > 0.99$).

Table 3. Duration of various development stages of *P. pseudoinsulata* Rego Barros under laboratory condition ($28 \pm 1^\circ\text{C}$ and $63 \pm 2\%$ RH).

Stage of Development	N	Mean \pm SD (days)	Range (days)
Egg:	100	4.00 ± 0	4
Larva: Instar I	73	3.81 ± 0.63	3-4
Instar II	73	3.00 ± 0	3
Instar III	73	2.17 ± 0.61	2-3
Instar IV	73	3.49 ± 0.93	2-7
Instar V	73	5.00 ± 0.92	4-6
Total	73	17.37 ± 1.13	15-20
Pupa:	73	8.23 ± 1.0	7-11
Adult:	71	5.03 ± 0.84	4-6
Total:	71	50.82 ± 5.27	44-64

HOST SPECIFICITY TESTS

Although adequate host specificity tests were carried out and *P. pseudoinsulata* was found to restrict its feeding on *C. odorata* and few members of Asteraceae of the genus *Eupatorium* (Bennett and Cruttwell, 1973, Syed, 1979 and Cock, 1984). There was a necessity to perform host specificity tests on *P. pseudoinsulata* in Thailand to confirm and verify its safety as a biological control agent. Being redundant and repetitious, such tests are nevertheless required and adopted as standard measures for all introduced biological control agents.

Of all 48 species of plants in 25 families tested and screened, no feeding was observed and larvae died after two days of exposure on all test plants except *Ageratum conyzoides* L. and *Ageratina adenophora* Sprengel, both are members of Asteraceae. Other Asteraceae plants tested were not fed upon.

FIELD RELEASES OF *P. PSEUDOINSULATA*

An experimental field release was made using about 2,000 full grown larvae at Khao Yai National Park which is one of the four sites recommended as suitable release localities by Muniappan and Seibert (1987). This is a desirable site that could support profuse vegetative growth of *C. odorata* through most part of the year to support populations of *P. pseudoinsulata*.

Although no recovery was made from experimental release sites due probably to small number of larvae thus released, further extensive releases were made in the northern highland areas of Chiang Mai and Chiang Rai as well as supplemental releases at Khao Yai National Park a year later. Records on field releases of *P. pseudoinsulata* made during 1987-88 are given in Table 4.

Table 4. Field releases of *P. pseudoinsulata* Rego Barros in Thailand during 1987-88

Date	Location	Number released
February 18, 1987	Khao Yai National Park	2,000 larvae
January 4, 1988	Km # 1 Chiang Mai-Prao Road	600 larvae
February 5, 1988	Km # 50 Chiang Mai-Prao Road	200 larvae
	Km # 86 Chiang Mai-Prao Road	200 larvae
February 7, 1988	Tha Ton, Chiang Rai	200 larvae
	Fang, Chiang Mai	200 larvae
	Chiang Dao, Chiang Mai	200 larvae
February 21, 1988	Khao Yai National Park	600 pupae
	Prachinburi	200 pupae
March 3, 1988	Khao Yai National Park	3,000 larvae

Follow-up evaluation of field released *P. pseudoinsulata* at all release sites did not reveal encouraging results as far as the anticipated establishment is concerned. Although characteristic damage on the foliage caused by *P. pseudoinsulata* was observed at the release site in Khao Yai National Park, it will be too early to confirm field establishment at this point of time.

CONCLUSION

Being an introduced weed species in Thailand, *C. odorata* is amenable to classical biological control. None of the insects found associated with the weed in Thailand could be utilized as biological control agents for augmentative purpose, except the eriophyid mite, *A. adoratus*. Introduction of *P. pseudoinsulata* from Guam and subsequent field releases are at present not very encouraging due probably to the lack of needed basic biological information to support the mass rearing programs. There exists an urgent need to investigate further its biology, ecology and effectiveness as a biological control agent. There is also a need to explore and evaluate other potential biotic agents for future use if the biological control program for *C. odorata* will become substantial, effective and successful.

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CHROMOLAENA ODORATA IN VIETNAM

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The Siam weed, *Chromolaena odorata*, is known vernacularly as "Co Hoi" while the English common name in Vietnam is "communist weed". It is not known when *C. odorata* was introduced to the country but it is now widespread from the northern part of the country through the central region and all the way down to the southern part including the Mekhong Delta area. It was not known how serious the weed is in the country and it was also likely that no economic assessment has been made on the impact of this weed.

C. odorata was found growing profusely on the hill slopes in the central region of the country and in rubber plantations in the southern region. It was also observed in the cattle grazing lands.

Accounts on *C. odorata* were also not easily available except those of Do Tat Loi (1969 and 1977) who reported a closely related species, *Eupatorium staechadosmum*, having medicinal values. Le Thi Hoan and Davide (1979) in Grainge et. al. (1985) reported that an aqueous extract from leaves of *C. odorata* possesses a nematocidal property on the root-knot nematode, *Meloidogyne incognita*, but it was not certain if the materials were of the Philippines or Vietnamese origin.

Apparently there are no attempts made to control this weed in the country because herbicides are not available at present. In the problem areas, hand and mechanical weeding are usually employed.

A quick survey made on insects associated with *C. odorata* revealed characteristic phyllodies caused by aphids which were mainly *Aphis gossypii* and *Aphis craccivora*. There exists a good opportunity to launch a biological control program for this weed in Vietnam especially the introduction of *Pareuchaetes pseudoinsulata*.

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THE MENACE OF *CHROMOLAENA ODORATA* IN KODAGU, INDIA

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The weed *Chromolaena odorata* has many common names in different parts of India and in Kodagu it is called as Gandhi Gulabi. It was first reported in Kodagu in 1970. It is widespread in the western ghats region covering Karnataka, Goa, Kerala and Tamil Nadu states. It is primarily a noxious weed in cashew, rubber, and coconut plantations, grazing land and disturbed forest areas.

C. odorata is a rapid growing plant and reaches a height of two to three meters in a season and it forms bushy thickets. It blooms during cool dry months of November-December. Each plant produces thousands of seeds, which are dispersed by wind.

C. odorata requires full sunlight to survive. It does not grow under shaded conditions as observed in coffee or cardamom plantations.

Cultural methods of control such as slashing and chemical methods like use of herbicides were uneconomical. Therefore, economically sound and practical method of control seems to be biological control.

The Commonwealth Institute of Biological Control, Bangalore center introduced the insect *Pareuchaetes pseudoinsulata* in early 1970s and 1978 in Kodagu. Unfortunately, this insect did not establish under field conditions.

BIOCONTROL ATTEMPTS AGAINST *CHROMOLAENA ODORATA* IN INDIA - A REVIEW

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ABSTRACT

Chromolaena odorata is an introduced weed in India. It is a menace in plantations such as rubber, tea, coffee, cardamom and teak, citrus orchards, marginal grazing lands and open areas. Attempts at biological control of the weed have been made by introducing *Pareuchaetes pseudoinsulata* and *Apion brunneonigrum* from the West Indies, but with little success. A strain of *P. pseudoinsulata* introduced recently from Sri Lanka is reported to be established. In light of the ecology of the weed and that of the insects introduced so far, suggestions for combating this weed are made.

INTRODUCTION

Chromolaena odorata (L.) King and Robinson (= *Eupatorium odoratum* L.) (Asteraceae), commonly called Siam weed, is a native of West Indies, Central America and tropical South America. In India it is a serious weed, mainly in plantations of rubber, tea, coffee, cardamom and teak and citrus orchards. It covers marginal grazing lands and open areas. It can grow on many soil types, even on poor soils and rocky areas, but seems to prefer well-drained sites. It does not survive in plantations or forests where the canopy has closed in. At times it assumes a climbing form, often reaching a height of 4.5 to 6.0 meters, covering the lower branches of teak and bamboo (Bennett and Rao, 1968).

It was accidentally introduced to Bangladesh, Burma, India, Indonesia, Laos, Malaysia, Nepal, Singapore, Sri Lanka, Thailand and elsewhere in Southeast Asia (Biswas, 1934) and to South Africa, Nigeria and possibly elsewhere in West Africa (Simmonds, 1965). The introduction to Asia apparently took place via Singapore from the West Indies in the ballasts of cargo boats (Biswas, 1934). The occurrence of *C. odorata* in India was first reported by Ramachandra Rao (1920). It is now common in many states of India, particularly Assam, Karnataka, Kerala, Maharashtra, Orissa, Tamil Nadu and West Bengal. In Assam dense stands occur in tea estates and citrus orchards (Moni and George, 1959). It was accidentally introduced to Kerala from Assam after the Second World War; apparently the seeds adhered to the clothing and bedding of returning laborers (Bennett and Rao, 1968).

The possibilities of biological control of *C. odorata* have been discussed by Bennett and Rao (1968) and Cock (1984). Intensive surveys of the natural enemy complex of *C. odorata* were made in Trinidad (Cruttwell 1968, 1972 and 1974) and in Central and South America (Cruttwell, 1969, 1971 and 1974). *Pareuchaetes pseudoinsulata* Rego Barros (earlier incorrectly known as *Ammalo arravaca* (Jordan) and *A. insulata* (Walker) (Lep., Arctiidae)) was studied as a potential biocontrol agent of *C. odorata* by Bennett and Cruttwell (1973). They tested its host-specificity and recommended its introduction into other areas where the weed

occurs as a pest. Other organisms recommended for introduction are *Apion brunneonigrum* B.B. (Col., Apionidae) (Cruttwell, 1973), *Mescinia parvula* (Zeller) (Lep., Pyralidae) (Cruttwell, 1977a) and *Acalitus adoratus* Keifer (Acarina, Eriophyidae) (Cruttwell, 1977b).

WORK DONE IN INDIA

Since a nuclear polyhedrosis virus infected *P. pseudoinsulata* in Trinidad, the latter was introduced to India with a view to supplying healthy cultures to Malaysia and Nigeria. Cultures were raised and host-specificity tests were conducted by Giriraj and Bhat (1970) on leaves of 18 plants. They observed nibbling on *Eucalyptus citriodora* Hk. and slight feeding on *Sesamum orientale* L., but the larvae failed to develop normally.

Following a request by the Karnataka Agricultural Department to explore the possibilities of biological control of the weed in coffee, citrus and cardamom plantations in Kodagu District, Sankaran and Sugathan (1974) conducted detailed host specificity tests with *P. pseudoinsulata* using a large number of economic plants, including those tested earlier by Giriraj and Bhat (1970). In all 85 species of plants, representing 46 families and including forest plants which are common in Kodagu and some food crops and plantation crops were tested by them (Appendix 1). For these tests they used two different stages of the larvae, newly-hatched and ten-days-old. No feeding occurred on 85 species of plants. Slight feeding was noticed on nine species, indicating that these plants initially incited a feeding probe (Appendix 2). Ten day old larvae fed and survived on *Sesamum indicum* L. (= *S. orientale*) up to 31 days, but their development was retarded and they failed to pupate while freshly hatched larvae survived only for one to four days. One caterpillar completed development to the adult stage feeding on *Daucus carota* L. However, in additional tests larvae did not feed or nibble on carrot leaves (Appendix 3).

Sankaran and Sugathan (1974) also conducted field trials with *P. pseudoinsulata* at many localities in Kodagu. About 33,000 larvae of different stages, 6,700 eggs and over 600 moths were released in 1973. But no recoveries could be made. The release sites were situated at different altitudes, ranging from 120 to 915 meters above sea level and receiving an annual rainfall of 125 to 250 cm. The failure to establish was suspected to be due to detrimental activities of more than one species of predatory ant.

In 1978, propagation of *P. pseudoinsulata* was started at the Central Horticultural Experiment Station (CHES) in Kodagu with cultures obtained from CIBC Indian Station and a local naturalist (Singh, 1980). Between September 1978 and April 1979, 20,750 larvae and 600 gravid females were released in the field. Although feeding was observed at the release sites, recovery could be made only up to 10 days. Singh (1980) has attributed the failure of establishment to a granulosis virus in the laboratory cultures and predacious ants in the field. He also reported that the duration of the egg stage was five to nine days (average 7), larval stage 30 to 51 (39.6), pupal stage eight to 22 (15.4) and adult two to 20 (8.3).

Later additional introduction of *P. pseudoinsulata* from Venezuela and Trinidad were made by the All India Coordinated Research Project on Biological Control (AICRP) and a culture of the Trinidad strain was sent to Kerala Agricultural University (KAU) at Trichur and to CHES. The Venezuelan population petered out after a few months with poor emergence of adults and infertile eggs in the laboratory, but the other one was maintained (Anon., 1983).

In 1984, the senior author brought the Sri Lankan strain of *P. pseudoinsulata* to India and supplied it to AICRP. About 7,500 larvae and 350 moths of this strain were liberated in the

field by KAU at Trichur (Anon., 1984). The strain was evaluated by AICRP and it was reported that it appeared to be superior to the strain introduced from Trinidad (Anon., 1984).

C. odorata was recorded for the first time in Bangalore at four localities in 1984 (Anon., 1985a). The Trinidad strain was released, but it did not establish. Later the Sri Lankan strain was released. Caterpillars were located in the field up to one month after release. The plants were heavily damaged (Anon., 1985a).

At Trichur about 40,000 larvae and 400 moths of the Sri Lankan strain were released in 1985. Signs of establishment and partial control of the weed were evident at one of the sites (Anon. 1985b). Further release in rubber plantations in Kerala resulted in establishment and clearance of the weed in about two hectares (Anon., 1986a). It was observed that all leaves of infested plants turned yellow. In 1986 more than 16,000 larvae were released in Chikmagalur, Kodagu and Bangalore Districts of Karnataka, but establishment has not been observed (Jayanth, 1987).

The CIBC Indian Station sent a nucleus culture of the Sri Lankan strain to the University of Guam (Chacko, 1984-85). It has now destroyed over 4000 hectares of *C. odorata*. (Anon., 1986b).

Apion brunneonigrum was introduced to India from the West Indies in 1972 and 1976 (Sugathan, 1972 and 1976) by CIBC. In 1976, 33 species of plants belonging to 22 families were screened. The weevil neither fed nor oviposited on these. Field releases were made in Kodagu, but there are no reports of its establishment. Additional introductions were made later from Trinidad (Yaseen and Murphy, 1982-83) and released in Kerala, but again there was no establishment (Anon., 1983-84).

Mescinia parvula was sent from West Indies to India (Yaseen, 1986), but no reports are available on further work.

Muniappan et. al. (1988) studied in detail the distribution of *C. odorata* in India and the biology of the Sri Lankan strain of *P. pseudoinsulata*. They also made studies on the consumption and utilization of food by *P. pseudoinsulata* and its efficacy in defoliating *C. odorata*. Their studies on distribution have shown that the weed is limited to areas in southwestern and eastern parts of India which receive an annual rainfall of 150 cm or more.

A number of insects and mites have adapted themselves to *C. odorata* in India. These are:

Order/Family	Insect/Mite	Reference
Acarina		
Eriophyidae	<i>Calacarus</i> sp.	Muniappan and Viraktamath, 1986
Oribatidae	<i>Eremulus flagellifer</i> Berlese	Ramani and Haq, 1983
	<i>Galumna</i> sp.	Ramani and Haq, 1983
	<i>Lamellobatus palustris</i> Hammer	Ramani and Haq, 1983

continued...

Order/Family	Insect/Mite	Reference
	<i>Paralamellobatus bengalensis</i> Bhaduri and Raychaudhuri	Ramnai and Haq, 1983
	<i>Pelokylla malabarica</i> Clement and Haq	Ramnai and Haq, 1983
Tarsonemidae	<i>Schelorbates</i> sp. <i>Polyphagotarsonemus latus</i> Banks	Ramnai and Haq, 1983 Muniappan and Viraktamath, 1986
Tetranychidae	<i>Tetranychus</i> sp.	Muniappan and Viraktamath, 1986
Coleoptera		
Apionidae	<i>Apion</i> sp.	Anon., 1983-1984
Bruchidae	<i>Caryedon</i> sp.	Anon., 1983-1984
Chrysomelidae	<i>Corynodes</i> sp.	Anon., 1983-1984
Curculionidae	<i>Amblyrrhinus</i> sp. <i>Astycus aurovittatus</i> Heller	Anon., 1983-1984 Anon., 1983-1984
Meloidae	<i>Mylabris</i> sp.	Anon., 1983-1984
Diptera		
Agromyziidae	Unidentified	Anon., 1983-1984
Hemiptera		
Aleyrodidae	<i>Bemisia tabaci</i> Genn.	Anon., 1983-1984
Aphididae	<i>Aphis fabae</i> Scolopi <i>A. spiraecola</i> Patch	Joy et. al., 1979 Bennett and Rao, 1968 Joy et. al., 1979
	<i>Brachycaudatus helichrysi</i> (Kaltenbach)	
	<i>Rhopalosiphum maidis</i> Fitch	Ganguli and Raychaudhuri, 1980
	<i>Toxoptera odinae</i> (v.d. Goot)	Yadav et. al., 1981
Cicadellidae	<i>Tettigella ceylonica</i> Melich	Anon., 1983-1984
Coccidae	<i>Saissetia</i> sp.	Muniappan and Viraktamath, 1986
Coreidae	<i>Leptocorisa acuta</i> (Thunberg)	Anon., 1983-1984
	<i>Riptortus pedestris</i> (Fabricius)	Anon., 1983-1984
Membracidae	<i>Cocostrephus</i> sp. <i>C. minutus</i> (Fabricius)	Anon., 1983 Muniappan and Viraktamath, 1986
	<i>Leptocentrus</i> sp.	Anon., 1983
Ortheziidae	<i>Orthezia insignis</i> Browne	Sankaran and Sugathan, 1974 Muniappan and Viraktamath, 1986
Plataspidae	<i>Coptosoma</i> sp. <i>Sepontia nigrofusca</i> Dist.	Anon., 1983-1984 Anon., 1983-1984
Pyrrhocoridae	<i>Dysdercus koenigii</i> Fabricius	Anon., 1983-1984

continued...

Order/Family	Insect/Mite	Reference
Lepidoptera		
Arctiidae	<i>Diacrisia obliqua</i> Walker	Anon., 1983-1984
	<i>Pericallia ricini</i> (Fabricius)	Anon., 1983-1984
Geometridae	<i>Hyposidra talaca</i> (Walker)	Muniappan and Viraktamath, 1986
Noctuidae	<i>Chrysodeixis chalcites</i> (Esper)	Muniappan and Viraktamath, 1986
Tortricidae	<i>Archips micaceanus</i> (Walker)	Muniappan and Viraktamath, 1986
Orthoptera		
Pyrgomorphidae	<i>Neorthacris acuticeps</i> (Bolivar)	Muniappan and Viraktamath, 1986
Thysanoptera		
Phlaeothripidae	<i>Haplothrips gowdeyi</i> Franklin	Anon., 1983-1984

According to Muniappan and Viraktamath (1986), only *O. insignis* caused significant damage. They suggested the use of *Calacarus* sp. as a potential biocontrol agent if it proved to be host-specific. The indigenous *Apion* sp. was scarce and inflicted no serious damage (Anon., 1983-1984).

DISCUSSION AND FUTURE WORK

A complex of natural enemies of *C. odorata* occurs in its original habitat. Cruttwell (1974) has listed the phytophagous insects and mites recorded on *C. odorata* throughout the world and has given a key to the type of damage in Trinidad and also illustrated the main types of injury. She recorded some 240 species feeding on *C. odorata*, 15 of them in Asia and the rest in Continental America and the West Indies. However, she did not claim that the list was exhaustive, as there were only scanty records from many areas where the weed occurs. The majority of the species listed were polyphagous.

Of the many natural enemies of *C. odorata* recommended for introduction, only *P. pseudoinsulata*, *A. brunneonigrum* and *M. parvula* have been introduced to India so far. *P. pseudoinsulata* introduced from Trinidad failed to establish. However, the same stock of *P. pseudoinsulata* sent from India to Sri Lanka has become established there (Kanagaratnam, 1975, 1976, Dharmadhikari et. al. 1977 and Cock, 1984). No further introductions were made to Sri Lanka (Kanagaratnam, per. comm.). In 1984, a nucleus culture of *P. pseudoinsulata* was brought to India from Sri Lanka. It is interesting to note that establishment occurred in India when an introduction was made from Sri Lanka. This strain has established in Guam, when introduced from India in 1985 (Anon., 1986b). When introduced to Sri Lanka, the Trinidad strain appeared to have evolved into a better adapted strain. This phenomenon points to the need for additional introductions of different strains of *P. pseudoinsulata*. Cock (1984) suggested introductions to India from northern Venezuela where there is a pronounced dry season. Since

the Venezuelan strain introduced to India could not be tried in the field, additional introductions and trials are necessary. Another suggestion of Cock (1984) was investigations on the closely related *P. insulata* (Walker) from the Pacific coast of Central America and the undescribed species of *Pareuchaetes* from the drier parts of eastern Brazil. Cock and Holloway (1982) discussed the possibility of *P. pseudoinsulata* being adapted to a riverine microclimate and suggested a strategy of introduction at sites where *C. odorata* occurs in riverine situations in the Old World so that any establishment there might lead to dispersal. However, in view of reports of successful establishment in India of the Trinidad strain when introduced from Sri Lanka, it would appear that it is not always necessary to select strains from ecologically homologous areas. Harris (1971) advocated release of weed control agents with broad ecological tolerance and cautions against over emphasis in selecting ecoclimatically well-adapted biotypes with narrow tolerance. Though *P. pseudoinsulata* has established in Sri Lanka and causes extensive defoliation of *C. odorata*, the plants recover afterwards. In view of the plants' rapid growth rate, *P. pseudoinsulata* alone cannot be expected to solve the problem.

Releases of *A. brunneonigrum* in India were made in June (Sugathan, 1976) and in February (Anon., 1982-1983). The potential of this weevil as a biocontrol agent lies in its ability to destroy flower buds. Although the weevil feeds on the young growth of *C. odorata* in shaded habitat from March to November in the Neotropics (Cruttwell, 1973), this damage is negligible since the weed is aggressive, particularly in open areas. Releases of *A. brunneonigrum* in open as well as caged conditions at the time of formation of flower buds may help in its establishment. If established, its habits should be studied.

As stated earlier, no reports of any work on *M. parvula* are available, though it was sent from the West Indies to India in 1986. Larvae of *M. parvula* bore into axillary or terminal buds and then into the stem, destroying the meristematic tissue and preventing further growth. In view of its brief life-cycle and breeding throughout the year causing considerable damage and host-specificity, Cruttwell (1977a) recommended its introduction. Cock (1984) states that *M. parvula* is potentially a most effective biocontrol agent for *C. odorata*. *M. parvula* could play a key role in the control of *C. odorata* since profuse branching habit is one of the factors leading to the success of this weed. Since no fertile eggs could be obtained, development of a method to breed *M. parvula* under caged conditions would be advantageous.

Heavy attacks of *Acalitus adoratus* cause stunting and distortion of leaves and even stunting of stems. Being specific to *C. odorata*, Cruttwell (1977b) recommended its introduction.

Since cecidomyiids tend to be host-specific, Cock (1984) advocated further investigations on *Neolasioptera frugivora* Gagne and *Contarinia* sp. which are achene feeders, *Asphondylia corbulae* Mohn which causes the achene to swell into a thick-walled, hollow chamber and *Perasphondylia reticulata* Mohn and *Clinodiplosis* spp. which attack buds.

Others which merit further investigations are the weevils *Rhodobaenus* spp., larvae of which feed on the stem, the Agromyzid *Melanagromyza eupatoriella* Spencer, the larva of which attacks and destroys the stem tips and the Tephritid *Cecidochares fluminensis* (Lima), which feeds on the capitula (Cock, 1984).

C. odorata has deep and massive tap roots. When soil moisture is plentiful, even if the plants are slashed and burnt, there is a rapid regeneration from the roots. Hence a survey for natural enemies damaging roots of *C. odorata* is suggested.

Yet another line of investigation is a search for pathogens that attack *C. odorata*. Hardly any work has been done on this aspect and no systematic survey for pathogens in the native habitat of the weed has been made.

Since no species alone can be expected to suppress this weed, introduction, simultaneously if possible, of several species causing different types of injury should be attempted.

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Appendix 1

Test plants on which there was no feeding by *P. pseudoinsulata*

Sl. No.	Family of Test Plant	Test Plant	Larvae survived (in days)	
			Newly hatched	Ten-days-old
1.	Anacardiaceae	<i>Anacardium occidentale</i> L.	2-6	2-3
2.	Annonaceae	<i>Annona reticulata</i> L.	2-4	1-3
3.	Apocynaceae	<i>Rauwolfia canescens</i> L.	2-4	1-2
4.	Araceae	<i>Amorphophallus campanulatus</i> (Roxb.) Blume ex Dene.	2-4	3-4
5.	Araceae	<i>Colocasia esculenta</i> (L.) Schott	2-4	3-5
6.	Bigoniaceae	<i>Tabebuia spectabilis</i> Nichols	3-4	1-4
7.	Bigoniaceae	<i>Tecoma stans</i> (L.) H.B. and K.	2-3	3-5
8.	Bombacaceae	<i>Bombax ceiba</i> (L.)	2-4	2-5
9.	Caesalpiniaceae	<i>Adenantha pavonina</i> L.	2-4	1-3
10.	Caesalpiniaceae	<i>Cassia siamea</i> Lamk.	2-3	2-4
11.	Caesalpiniaceae	<i>Samanea saman</i> (Jacq.) Merr.	2-4	2-3
12.	Caesalpiniaceae	<i>Saraca cauliflora</i> Baker	3-4	2-5
13.	Caesalpiniaceae	<i>Tamarindus indica</i> L.	3-4	3
14.	Caricaceae	<i>Carica papaya</i> L.	2-4	2-4
15.	Casuarinaceae	<i>Casuarina equisetifolia</i> L.	2-4	2-4
16.	Chenopodiaceae	<i>Beta vulgaris</i> L.	1-4	2-5
17.	Combretaceae	<i>Terminalia arjuna</i> (Roxb. ex DC) Wight and Arn.	1-4	2-3
18.	Combretaceae	<i>Terminalia bellirica</i> (Gaertn.) Roxb.	1-3	2-4
19.	Combretaceae	<i>Terminalia tomentosa</i> Wight and Arn.	2-3	2-3
20.	Compositae	<i>Helianthus annuus</i> L.	1-5	1-5
21.	Cruciferae	<i>Brassica juncea</i> (L.) Czern and Coss.	2-3	2-3
22.	Cruciferae	<i>Brassica oleracea</i> L. var. <i>gongyloides</i> L.	2-4	2-4
23.	Cucurbitaceae	<i>Momordica charantia</i> L.	2-3	2-5
24.	Dipterocarpaceae	<i>Hopea parviflora</i> Bedd.	2-5	2-5
25.	Dipterocarpaceae	<i>Hopea</i> sp.	1-3	1-5
26.	Ephretiaceae	<i>Cordia dichotoma</i> Forst. f.	2-4	3-4
27.	Euphorbiaceae	<i>Bischofia javanica</i> Blume	2-6	2-3
28.	Euphorbiaceae	<i>Emblica officinalis</i> Gaertn.	2-4	2-3
29.	Euphorbiaceae	<i>Hevea brasiliensis</i> (H.B. and K.)	2-6	2-4
30.	Euphorbiaceae	<i>Manihot esculenta</i> Crantz	2	2-4
31.	Euphorbiaceae	<i>Ricinus communis</i> L.	2	2-3
32.	Gramineae	<i>Bambusa arundinacea</i> (Retz.) Willd.	2-3	2-4
33.	Gramineae	<i>Cymbopogon citratus</i> (DC.) Stapf.	3-4	1-4
34.	Gramineae	<i>Dendrocalamus strictus</i> (Roxb.) Nees	2-3	1-3

continued...

Test plants on which there was no feeding by *P. pseudoinsulata*

Sl. No.	Family of Test Plant	Test Plant	Larvae survived (in days)	
			Newly hatched	Ten-days-old
35.	Gramineae	<i>Pennisetum purpureum</i> Schum.	2-4	3-4
36.	Labiatae	<i>Mentha arvensis</i> L.	3-5	2-4
37.	Labiatae	<i>Lavandula officinalis</i> Chaix	2-4	2-3
38.	Magnoliaceae	<i>Michelia champaca</i> L.	2-3	2-4
39.	Malvaceae	<i>Abelmoschus esculentus</i> L.	1-4	3-4
40.	Malvaceae	<i>Gossypium arboreum</i> L.	2-3	2-3
41.	Malvaceae	<i>Hibiscus furcatus</i> Roxb.	2-5	3-4
42.	Meliaceae	<i>Azadirachta indica</i> A. Juss.	3-6	2-4
43.	Mimosaceae	<i>Acacia nilotica</i> (L.) Del. (= <i>arabica</i> Willd.)	2-3	2-4
44.	Mimosaceae	<i>Acacia furnesiana</i> (L.) Willd.	2-3	2-4
45.	Moraceae	<i>Artocarpus heterophyllus</i> Lamk.	2-3	2-3
46.	Moraceae	<i>Artocarpus lakoocha</i> Roxb.	2-4	3-6
47.	Moraceae	<i>Broussonetia papyrifera</i> (L.) L'Heritier in Vent.	2-3	2-3
48.	Moraceae	<i>Ficus glomerata</i> Roxb.	2-6	2-4
49.	Moraceae	<i>Morus australis</i> Poir.	2-3	2-3
50.	Moringaceae	<i>Moringa oleifera</i> Lamk.	3-4	2-5
51.	Musaceae	<i>Musa paradisiaca</i> L.	1-3	2-4
52.	Myrtaceae	<i>Eucalyptus citriodora</i> Hk.	2-3	2-3
53.	Myrtaceae	<i>Pisidium guajava</i> L.	3-6	1-4
54.	Myrtaceae	<i>Syzygium jambos</i> (L.) Alston	2-3	2-4
55.	Palmaceae	<i>Areca catechu</i> L.	2-4	2-3
56.	Palmaceae	<i>Cocos nucifera</i> L.	2-3	2-4
57.	Papilionaceae	<i>Arachis hypogaea</i> L.	3-6	3-6
58.	Papilionaceae	<i>Crotalaria mucronata</i> Desv.	2-4	1-3
59.	Papilionaceae	<i>Dalbergia latifolia</i> Roxb.	1-3	2-3
60.	Papilionaceae	<i>Erythrina indica</i> Lamk.	2-4	2-4
61.	Papilionaceae	<i>Medicago sativa</i> L.	1-3	2-3
62.	Papilionaceae	<i>Phaseolus aureus</i> Roxb.	1-3	2-4
63.	Papilionaceae	<i>Pisum sativum</i> L.	2-4	1-3
64.	Papilionaceae	<i>Pongamia pinnata</i> (L.) Pierre	3-5	1-3
65.	Papilionaceae	<i>Pterocarpus marsupium</i> Roxb.	1-3	2-3
66.	Piperaceae	<i>Piper nigrum</i> L.	2-3	2-4
67.	Proteaceae	<i>Grevillea robusta</i> A. Cunn.	2-3	1-3
68.	Punicaceae	<i>Punica granatum</i> L.	3-4	1-4
69.	Rubiaceae	<i>Coffea arabica</i> L.	2-3	2-4
70.	Santalaceae	<i>Santalum album</i> L.	2-3	1-3
71.	Sapindaceae	<i>Dodonaea viscosa</i> (L.) Jacq.	2-3	2-3
72.	Sapindaceae	<i>Sapindus emarginatus</i> Vahl.	2-3	2-5
73.	Sapotaceae	<i>Achras zapota</i> L.	2-4	1-3
74.	Solanaceae	<i>Nicotiana tabacum</i> L.	1-3	2-3
75.	Solanaceae	<i>Solanum melongena</i> L.	2-3	3-5

continued...

Test plants on which there was no feeding by *P. pseudoinsulata*

S1. No.	Family of Test Plant	Test Plant	Larvae survived (in days)	
			Newly hatched	Ten-days- old
76.	Solanaceae	<i>Solanum tuberosum</i> L.	2-5	1-3
77.	Sterculiaceae	<i>Sterculia campanulata</i> Wall. ex Master	1-3	2-3
78.	Ternstroemiaceae	<i>Camellia sinensis</i> (L.) O. Kuntze.	2-4	2-3
79.	Tiliaceae	<i>Corchorus capsularis</i> L.	1-5	2-4
80.	Verbenaceae	<i>Gmelina arborea</i> L.	2-4	1-3
81.	Verbenaceae	<i>Tectona grandis</i> L.f.	2-3	2-4
82.	Vitaceae	<i>Vitis labrusca</i> L.	1-4	2-4
83.	Zingiberaceae	<i>Curcuma domestica</i> Valet.	2-5	2-4
84.	Zingiberaceae	<i>Elettaria cardamomum</i> (L.) Maton	2-3	2-4
85.	Zingiberaceae	<i>Zingiber officinale</i> Rosc.	2-3	2

Appendix 2

Test plants on which nibbling or slight feeding occurred but larvae failed to develop to adult stage of *P. pseudoinsulata*

S1. No.	Family of Test Plant	Test Plant	Remarks
1.	Compositae	<i>Lactuca sativa</i> L.	Newly hatched larvae survived for one to three days but no feeding occurred. Slight feeding by ten-days-old larvae for one to two days. Larvae survived for four days.
2.	Cruciferae	<i>Brassica oleracea</i> var. <i>capitata</i> L.	Newly hatched larvae survived for three days but no feeding occurred. Slight feeding by ten-days-old larvae for three days. Larvae survived for two to six days.
3.	Cruciferae	<i>Raphanus sativus</i> L.	Slight feeding by both stages of larvae for two to six days. They survived for two to nine days.
4.	Meliaceae	<i>Melia composita</i> Willd.	Newly hatched larvae survived for two to four days. No nibbling or feeding. Slight nibbling by ten-days-old larvae only on third day. They survived for three to four days.
5.	Papilionaceae	<i>Gliricidia maculata</i> H.B. and K.	No nibbling by newly hatched larvae, which survived for two to four days. Slight nibbling by ten-days-old larvae for a day. They survived for one to three days.
6.	Pedaliaceae	<i>Sesamum indicum</i> L.	Slight nibbling by newly hatched larvae only on first day. Larvae survived for one to four days. Slight feeding by ten-days-old larvae for 21-22 days. Larvae survived for two to 31 days. One of the larvae moulted four times. Another moulted only once.
7.	Rhamnaceae	<i>Ziziphus oenoplia</i> Mill.	No nibbling by newly hatched larvae, which survived for two to three days. Slight nibbling by ten-days-old larvae on first and second days. Larvae survived for two to four days.
8.	Solanaceae	<i>Lycopersicon esculentum</i> Mill.	No feeding by newly hatched larvae, which survived for two to four days. Slight feeding by ten-days-old larvae on the first day. Larvae survived for one to five days.
9.	Umbelliferae	<i>Coriandrum sativum</i> L.	No feeding by newly hatched larvae, which survived for two to three days. Slight feeding by ten-days-old larvae for first two days. Larvae survived for three to four days.

Appendix 3

Test plant on which feeding occurred and a larva of *P. pseudoinsulata* developed to adult stage

S1. No.	Family of Test plant	Test Plant	Remarks
1.	Umbelliferae	<i>Daucus carota</i> L.	No nibbling or feeding by newly hatched larvae, which survived for two to four days. Feeding by ten-days-old larvae was observed. Twenty-three larvae survived for only three to four days. On fifth and ninth days of the test moulting by the remaining two larvae was recorded. One of these survived for only 11 days. On 16th day the other larvae stopped feeding and on the 18th day it pupated. Thirteen days after pupation a moth emerged. In additional tests using potted carrot plants newly hatched larvae did not nibble or feed. All were dead by the fifth day of the test.

DEVELOPMENT OF A BIBLIOGRAPHIC DATABASE

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All of us maintain collections or lists of some kind. Specifically today I will discuss maintaining lists of references. By references I am referring to books, journals, and copies of articles. We keep these items for reference at a later time. The goal is to organize the references in a way that allows us to access the information quickly and efficiently. But as lists grow they can become especially difficult to manage and utilize.

There are many different ways to organize your references to access them more efficiently. The standard way was to keep the citations on index cards. More recently people have been maintaining their lists on computers. However, people were accustomed to keeping index cards and commonly use the computer in an inefficient manner. Most computer users are familiar with word processors and so they type the citations into a list in their word processor. This produces a rather crude database. Problems arise as to how to organize the file. Commonly the file is sorted by author and the references can be grouped into subject categories. When storing a database in a word processor, once a format is established it is difficult to switch to another format without starting all over again. Also a word processor is generally not that efficient in search capabilities. As the list grows the file becomes large and slow in operation. This makes editing and updating the file cumbersome. If you wish to locate a few select references it is difficult to list only the selected references. All of these problems make the process time consuming and often not much benefit is gained from computerizing the list. Basically a word processor is not the right tool for the job.

Database managers are computer programs that were developed to store, organize, and summarize information in a computer. Database managers are available with different levels of capabilities. Some are rather simple list organizers. The more advanced programs can be customized for specific needs. The list organizers allow you to type in the references and sort and search for certain references. Generally you can search on several different types of information. Information in a database is stored as a collection of records. A single record would consist of a single citation. A record is comprised of a collection of fields. Each field is a piece of information about the record. Some examples of fields are authors, year, title, journal, and keywords.

The advantage to having the information stored in different fields is that searches can be made using different fields. This gives the user greater flexibility in summarizing the information. For example you can produce a list of references about a certain topic by searching by keyword and printing a list after sorting it by author. There is a disadvantage to using a database that is just a list. The information needs to be entered into each record. An improvement on this can be made using a Relational Database.

Relational database managers allow you to keep separate files of information that will be used repeatedly. There can be a master file of Journals and another of Authors. This way the information only needs to be entered once. The database manager "learns" from the information you enter. After entering one time, only a part of the name is necessary to fill in the information. This greatly reduces typing errors. This also helps by allowing a standard list of keywords for

all of the citations in your collection. The other advantage to this is that the data can be displayed in many different ways. It does not have to be displayed in the same format as when it was entered. You can develop several reports using the same fields in different formats. The reports can contain which ever fields are desired.

The Bibliography of *Chromolaena odorata*, which has been published in the newsletter, is a collection of references that were entered into a program that runs on a Macintosh computer. The program is called 4th Dimension. This is a very powerful relational database manager. This database consists of four files: citations, journals, authors and keywords. This database manager allows very complex searches so very specific groups of citations can be selected. The list was sorted within Fourth Dimension and then exported to a word processor for the final formating and printing.

ON THE PATTERN OF DISTRIBUTION OF TWO PERNICIOUS WEEDS, *AGERATINA ADENOPHORA* AND *CHROMOLAENA ODORATA* AND THE BIOLOGICAL CONTROL MEASURES TAKEN IN YUNNAN PROVINCE, CHINA

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ABSTRACT

Ageratina adenophora and *Chromolaena odorata* (Asteraceae), are two pernicious weeds which were introduced into Yunnan Province from North America aboriginally by way of Southeast Asia about twenty or more years ago. They are different in morphology habitat and geographical distribution. The authors suggest the following seven methods of control this weed.

- 1) Suppression of these weeds by planting such shortgrasses as Bermudagrass (*Cynodon dactylon*), carpetgrass (*Axonopus compressus*), *Paspalum* spp., etc.,
- 2) Using high and medium grasses such as, *Miscanthus* spp., *Phragmites karka*, *Capillipedium glaucopsis*, etc., as suppressing agents,
- 3) Utilization of inhibiting legumes grown in tropical and subtropical areas of Yunnan, such as, *Pueraria* spp. and *Butea frondosa*.
- 4) Dense planting of grain crops, such as, wheat, barley and others in between rows in the fields to shade out the young seedlings of these weeds.
- 5) Spring sowing prior to the advent of rainy season some of the superior forage crops such as ryegrasses (*Lolium perenne* and *L. multiflorum*), rescuegrass (*Bromus catharticus*) and purple vetch (*Vicia benghalensis*) for the establishment of grasslands instead of weeds.
- 6) Building-up of three layers of plant community in the form of trees, bushes and herbs by making use of fast growing plants such as *Anthocephalus chinensis*, *Cassia siamea*, *C. spectabilis*, and *Desmodium* spp., which provide fuel and timber for people in addition to suppressing the weeds.
- 7) Strengthening of managerial and feeding techniques of domestic animals to use them for suppressing weed growth.

RECOMMENDATIONS OF THE WORKSHOP

The first International Workshop on Biological Control of Siam weed, *Chromolaena odorata*, was conducted in Bangkok, Thailand during February 29 through March 4, 1988. The workshop was jointly organized by the University of Guam (UOG), National Biological Control Research Center (NBCRC), and the South and East Asia Regional section of the International Organization for Biological Control (SEARS/IOBC). There were 17 participants from Australia, France, India, Philippines, South Africa, Thailand and Guam.

1. The participants felt that it would be very useful to produce a newsletter periodically and disseminate the information on various aspects of research being carried out to the interested researchers and scientists involved with *C. odorata*.

As a result the participants of the workshop recommended that the Secretariat be established and located in Guam for the present, and to produce the "*Chromolaena odorata* Newsletter".

2. The participants realized that the International Organization for Biological Control (IOBC) has formed affiliated International Working Groups on various subject areas of biological control and IOBC Newsletter provides recognition and publicity to these affiliated working group on the global basis.

Hence the participants recommended that the International Working Group on Biological Control of *Chromolaena odorata* be formally established and seek an affiliation with IOBC.

3. For the planned "*Chromolaena odorata* Newsletter" to be more useful to the members, countries and organizations currently active or planning to initiate biological control program of *C. odorata* should inform the Secretariat or the members of the working group to disseminate the information and to maximize cooperation and collaboration.
4. Among many potential biological control agents of *C. odorata* known to date, the arctiid, *Pareuchaetes pseudoinsulata*, has proven effective in suppressing the weed on Guam and parts of the Northern Mariana Islands. It has also been released in Sri Lanka, India, Malaysia and Thailand but also recovered in the Philippines with no release was made. Currently Thailand, India and other countries are maintaining culture of *P. pseudoinsulata* for biological control purposes. Some countries and organizations are also planning to introduce more natural enemies of *C. odorata*.

The workshop participants recommended that the exchange and availability of natural enemies be encouraged to maximize their usefulness in the suppression of *C. odorata*. However, such research transactions should conform to the local and regional regulations. All relevant information such as identity, origin, number of organisms received, location of releases, date of release, etc. should be documented. It is also recommended that the pre-release and post-release evaluations be carried out to assess the agent's effectiveness.

5. *C. odorata* is a serious problem in many LDCs in the humid tropics. Most countries require technical and financial support and assistance to carry out introduction, establishment and evaluation of natural enemies. Being a neotropical weed there is a need for evaluation of natural enemies that have not yet been surveyed, identified and assessed in the native home of *C. odorata*, i.e., Latin American region.

The participants recommended to encourage various donor agencies to help support various research activities that will help strengthen biological control programs of *C. odorata*.

6. In the light of the benefit derived from this workshop, it will be much more useful to organize another workshop on biological control of *C. odorata* in the next two or three years to follow up current activities and accomplishments. It will provide a stage for evaluation of the achievements made since the first workshop, to review progress made or obstacles encountered in the biological control of *C. odorata*, and to formulate future plans and necessary recommendations and action.

SUMMARY OF RECOMMENDATIONS:

The participants of the workshop recommended that:

1. The Secretariat be established and located in Guam for the present, and to produce a "*Chromolaena odorata* Newsletter".
2. An International Working Group on Biological Control of *Chromolaena odorata* be formally established and seek an affiliation with the International Organization for Biological Control (IOBC).
3. Countries and organizations active or planning to initiate biological control of *C. odorata* programs should inform the Secretariat or the working group to disseminate the information and to maximize cooperation and collaboration.
4. To encourage exchange of natural enemies of *C. odorata* in conformity with the local or regional regulations, the researchers must document all relevant information pertaining to identity, origin, numbers received, numbers released, locations and dates of releases together with pre-release and post-release evaluation of the natural enemies concerned.
5. Various donor agencies be encouraged to support activities that will strengthen biological control of *C. odorata*.
6. In the light of the benefits derived from this workshop, it will be more useful to organize another one in the next two or three years to follow up current activities and to review the progress made as well as to formulate future action plans.

ACKNOWLEDGEMENTS

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