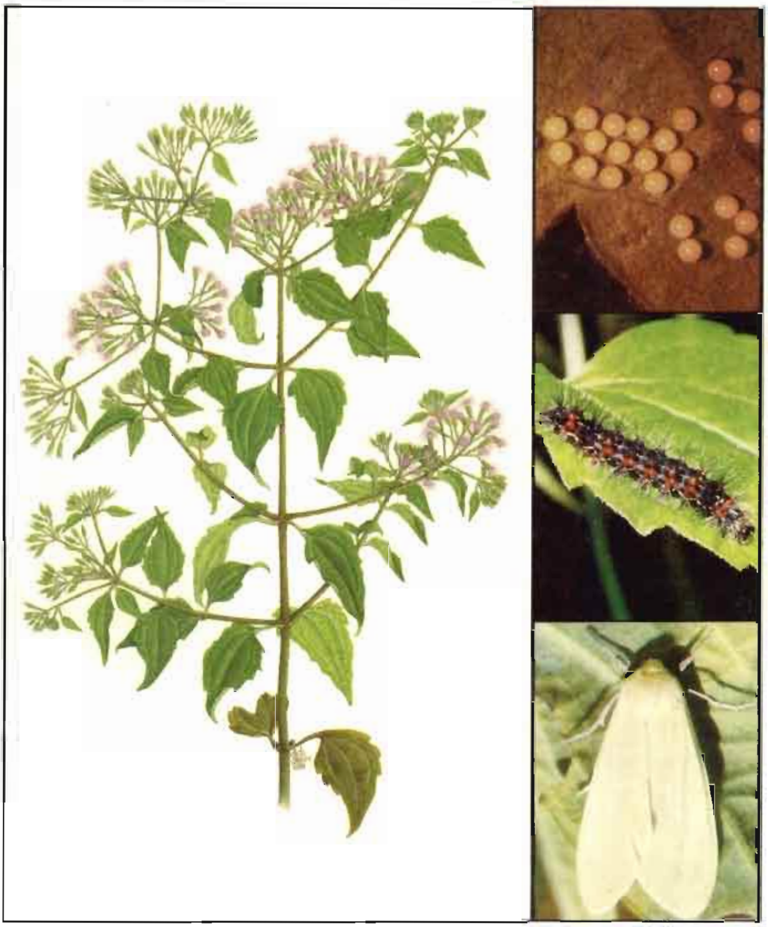
ECOLOGY AND MANAGEMENT OF *CHROMOLAENA ODORATA*



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Southeast Asian Regional Centre for Tropical Biology

P.O. Box 17, Bogor, Indonesia

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PROCEEDINGS OF THE SECOND INTERNATIONAL WORKSHOP ON BIOLOGICAL CONTROL OF *CHROMOLAENA ODORATA*

Bogor, Indonesia, 4 – 8 February 1991

edited by
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PREFACE

The Siam weed, *Chromolaena odorata*, is considered by many as a noxious weed of the humid tropics; however, some consider it useful under certain ecological conditions. This volume is an outcome of the Second International Workshop on Biological Control of *C. odorata* held in Bogor, Indonesia, February 4 - 8, 1991. It contains articles on ecology, chemotaxonomy, cultural, mechanical and biological control and insect plant interactions, recognizing the need for information on different aspects to tackle it effectively and economically without endangering the environment. We hope this publication will induce further research in multi-disciplinary areas not only to suppress this weed but also to tackle problems associated with it.

We acknowledge the support provided by the Australian Centre for International Agricultural Research (ACIAR), Food and Fertilizer Technology Center for the Asian Pacific Region (FFTC), U.S. Department of Agriculture, CSRS Special Grants Section Tropical and Subtropical Agriculture Agreement #90-34135-5182, Southeast Asian Regional Center for Tropical Biology (SEAMEO BIOTROP) and Institut de Recherche pour le Developpement en Cooperation (ORSTOM) for this workshop and preparation of this volume.

Appreciation is extended to J. McConnell and Wilson Ng for computer transfer of files, and to Rhee Orallo and Frances Torres for formating and preparing camera ready copies.

R. MUNIAPPAN

PAUL FERRAR

WELCOME ADDRESS

JOKO PURWANTO
Deputy Director for Administration and Finance
SEAMEO BIOTROP
P.O. Box 17, Bogor, Indonesia

Welcome to BIOTROP and Bogor. On behalf of our Director, Prof.Dr. Hj. Sitti Soetarmi Tjitrosomo, I have the honour and pleasure of welcoming you all to BIOTROP. Our Director is extending her regrets for not being able to be with you today, as she is in the Philippines attending the SEAMEO Conference. The SEAMEO Council, consisting of the Ministers of Education from the SEAMEO member countries is having an annual meeting starting today in Manila.

It is indeed a great privilege for us to host the Second International Workshop on Biological Control of ***Chromolaena odorata***, especially since we are undertaking the SEAWIC project. SEAWIC, or the Southeast Asian Weed Information Centre, was established in 1985 with the initial financial support from the International Development Research Centre (IDRC). SEAWIC, an Inter Program Project of TAgPB and CHI, has completed its first phase of operation, and starting last year it is operating its second phase.

I am confident that your deliberation will provide a very important input to SEAWIC and to the development of weed science in this part of the world. May I also take this opportunity to appeal for help from the scientists present here in supporting BIOTROP SEAWIC activities.

BIOTROP has very modest facilities. I hope you could overlook our deficiencies. All its staff, however, have warm hearts, and are ready to be of service and help you. Please do not hesitate to approach any of us for your needs.

Last but not least, I am wishing you all a fruitful meeting and an enjoyable stay at BIOTROP and Indonesia.

OPENING ADDRESS

CHENG-HWA HUANG
Director, Food and Fertilizer Technology Center for the Asian and Pacific Region
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It is a great pleasure and privilege to be with you here, at the opening ceremony of the Second International Workshop on the Biological Control of *Chromolaena odorata*.

On behalf of Food and Fertilizer Technology Center (FFTC), I should like to extend a cordial welcome to all participants, particularly those who have come from distant countries outside the ASPAC region. I should also like to express my sincere appreciation to all members of the co-sponsoring organization as well as to the BIOTROP headed by Dr. Joko Purwanto, who have all been so generous with their cooperation and support during the work of preparing this workshop. In particular, I am grateful to Prof. R. Muniappan, Guam University, who has spent a great deal of time on the organization of this meeting.

The first International Workshop on the Biological Control of *Chromolaena odorata* was conducted in March, 1988 at Bangkok, Thailand. In the light of the benefit derived from the first workshop, the participants recommended that it would 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.

The Siam weed, *Chromolaena odorata*, is a native of South and Central America, but it has now become a serious weed in South East Asia and Pacific Islands. It is therefore a good candidate for biological control by the introduction of natural enemies. In addition to this, the fact that the tribe Eupatorieae, to which *C. odorata* belongs, has no crop plants or important ornamentals, is a definite advantage for biological control of this serious weed.

I understand that among many potential biological control agents of *C. odorata*, an arctiid moth, *Pareuchaetes pseudoinsulata*, has proven effective in suppressing the weed in some parts of the ASPAC region. We consider that the current trend in research and development, which uses living species rather than manufactured inputs, is particular favourable to small farm development.

I am delighted that we have the opportunity here to bring together such a range of distinguished experts, to present recent research in this important field. I am sure that this workshop will provide a forum for the scientists involved in research on biological control of *C. odorata* to exchange views, update research activities and implementation of biological control, and above all for active collaboration in the international area.

FFTC has always emphasized practical technology suitable for small farms in its work of collecting and disseminating information on new agricultural technology. I hope that your research will be enriched by your experience here, and that you will return home with fresh ideas on how to control the Siam Weed which is such a grave problem for farmers.

I should like to express again my thanks to the distinguished participants and guests assembled here, and to all those many persons whose work has made this meeting possible.

OPENING ADDRESS

PAUL FERRAR
Research Program Co-ordinator (Crop Sciences),
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I feel honoured to be here in this distinguished gathering to welcome you on behalf of ACIAR, because my Centre has only been able to assist this conference in a modest way. ACIAR stands for the Australian Centre for International Agricultural Research, and because we are quite a young organisation I will tell you briefly what we do.

ACIAR does not itself undertake research. We were established to arrange collaborative research projects between Australian agricultural scientists working in State Departments of Agriculture, or universities, or government agencies such as CSIRO, and scientists working on similar problems in developing countries, particularly in Asia and the Pacific. Australia has much agricultural land in the tropics, both wet and dry, and we share many agricultural problems in common with developing countries. We are funded as part of Australia's overseas aid program, and the essence of our mission is to help by transferring expertise, by getting the overseas and Australian scientists working together in partnership to solve agricultural problems of mutual interest.

You may wonder why ACIAR should be interested in research on *Chromolaena*, since this weed is not found in Australia. It is, however, quite close on our doorstep, abundantly in Timor, and as I have just learned before the conference started this morning, also in Irian Jaya and perhaps in Papua New Guinea. It is probably only a matter of time before we share this problem too, and we shall be happy to participate in appropriate control programs for the benefit of all of us.

I myself know relatively little about *Chromolaena*, and I have come here this week to learn from you, the experts, who are assembled at this workshop. On behalf of ACIAR I welcome you to this meeting, with which we are very pleased to be associated, and I wish you an informative week and a fruitful outcome to all your discussions on this important problem.

REVIEW OF THE FIRST INTERNATIONAL WORKSHOP ON BIOLOGICAL CONTROL OF *CHROMOLAENA ODORATA* AND RELATED ACTIVITIES SINCE THEN

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The first international workshop on biological control of *Chromolaena odorata* was held at Bangkok, Thailand during February 29 - March 4, 1988, hosted by Dr. Banpot Napompeth. There were nineteen participants from eight different countries. The countries represented were Australia, France, Guam, India, Philippines, South Africa, Thailand and Vietnam.

Some of the topics covered during the workshop were history, distribution, and ecology of *Chromolaena odorata*. Chemical, mechanical, cultural control and different aspects of biological control were described, including past, present and future activities. There was a presentation on insect plant interactions mostly directed towards the interaction between *C. odorata* and *Pareuchaetes pseudoinsulata*.

RECOMMENDATIONS OF THE FIRST INTERNATIONAL WORKSHOP

1. The secretariat be established and located in Guam for the present, and to produce "*Chromolaena odorata* Newsletter".

2. International working group on Biological control of *C.odorata* be formally established and seek an affiliation with the International Organization for Biological Control (IOBC).

3. Countries and organizations that are 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. Encourage exchange of natural enemies of *C. odorata* in conformity with the local and regional regulations.

5. Encourage various donor agencies to support activities that will strengthen biological control of *C. odorata*.

6. Organize a Second International Workshop as a follow up of the first workshop in two to three years time.

ACTIONS TAKEN

1. The secretariat located in Guam produced three issues of *Chromolaena odorata* Newsletter and distributed these free of cost to interested individuals and organizations. The first issue carried a bibliography of *C. odorata*. The second had a list of insects and related organisms reported on *C. odorata*. A main article on *C. odorata* from India and a note each from Thailand and Guam were published in the third issue. The proceedings of the first workshop was also produced and distributed free of charge. Also 75 copies of the Newsletters and proceedings were sent to IOBC secretary, Dr. Jean Paul Aeschlimann for distribution to the IOBC affiliated global organizations.

2. The recommendation to become an international Working Group of IOBC was not actively pursued even though we had some communication with the Secretary of IOBC pertaining to this recommendation. One of the main reasons was that by becoming an affiliated Working Group there is a commitment to organize workshops. As *C. odorata* is a problem mostly in the LDCs of the humid tropical regions, it is difficult to organize workshops without assistance from regional and international donor organizations. IOBC does not provide financial support for such workshops.

3. Secretariat had very good cooperation with various countries and organizations in receiving and disseminating information through Newsletters. The Secretariat assisted in securing seeds of *C. odorata* from various countries for electrophoresis studies in Montpellier, France and Natal, South Africa. Also, it provided copies of reprints to various research personnel upon request.

4. Pertaining to the fourth recommendation, the University of Guam supplied shipments of *P. pseudoinsulata* to South Africa, Ghana, Yap, Pohnpei, Kosrae, Palau and Germany. Shipments of *P. pseudoinsulata* will be sent to Indonesia upon receipt of an import permit from the Government of Indonesia.

5. Since the First Workshop, the South Pacific Commission has provided funding to the University of Guam to assist Yap in biological control of *C. odorata*. Recently, this organization has indicated its willingness to assist the Government of Yap with the same program. Agricultural Development in the American Pacific (ADAP) of USDA has assisted Pohnpei in introduction and establishment of *P. pseudoinsulata*. An EEC funded IIBC and IRHO project on biological control of *C. odorata* is in operation and you will hear more about it during this workshop. FAO has carried out some ecological studies on *C. odorata* in Western Africa. IRHO and IITA have also conducted some ecological studies in West Africa. The Smithsonian Institution has approved a project for R. Muniappan to do some ecological studies in western ghats of India. There are possibilities of CIRAD, ACIAR, GTZ and other organizations ini-

tiating biological control of *C. odorata* projects in some of the LDC's, details of which you may come to know by the end of this workshop.

The first workshop was supported by ACIAR, USDA, and NRC and NBCRC Thailand. The present workshop is supported by BIOTROP, FFTC, ACIAR, USDA, CIRAD, GTZ and the Third World Academy of Sciences. In addition, I would like to recognize the presence of participants from IIBC, FAO, France, Germany, Malaysia, Thailand, Indonesia, Republic of China, Philippines, Pohnpei, Australia and Guam.

6. The sixth recommendation was to organize a Second International Workshop in 2 to 3 years after the first workshop. I am glad to point out that we are participating in the Second International Workshop on Biological Control of *C. odorata* exactly at the end of the third year since the first workshop.

THE ECOLOGY OF *CHROMOLAENA ODORATA* IN THE NEOTROPICS

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ABSTRACT

Chromolaena (Eupatorium) odorata is a perennial scrambling shrub native to the Neotropics, occurring in most areas below 1000 m altitude from southern Florida to north-west Argentina. In the Neotropics *C. odorata* is always found in competition or association with a complex of closely related species not present in Asia or Africa. In the New World, *C. odorata* is common in most habitats except undisturbed rainforest, but is seldom weedy and is never the target of specific weed control measures. It is typically a plant of secondary succession, rapidly invading clearings and persisting until shaded out by the overgrowth of forest trees. Where agriculture and human activity prevent forest regeneration, *C. odorata* persists as a typical plant of forest edges and paths, abandoned fields and pastures, building sites, and along roads, railways and streams.

In the New World, *C. odorata* does not invade pasture nor compete successfully with plantation crops, though it may be a minor problem in the early establishment stages. No control methods other than regular slashing are required in the New World, a marked contrast to the situation in Asia or Africa. This reduced aggressiveness is due to attack by a large complex of insects, other arthropods, and diseases, together with competition with related plants. Soil type is not a factor, and climate is similar in the two areas. The implication is that in the Neotropics, *C. odorata* is largely controlled by these biotic factors.

TAXONOMY OF *CHROMOLAENA ODORATA*

Classification and Nomenclature

The genus *Chromolaena* is in the family ASTERACEAE (formerly COMPOSITAE), which is one of the largest plant families. 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 and are particularly abundant in the Americas. Most species are shrubs or 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 EUPATORIEAE is a well-defined, mostly New World tribe, with white, reddish or blueish flowers lacking ray florets (Robinson & King, 1977). There are no crop plants or important ornamentals in the Eupatorieae, but important weed species are *Mikania micrantha* and *Ageratum conyzoides*.

Eupatorium, before it was split up by King and Robinson in the 1970s, contained over 1200 species, mostly in the Americas (King and Robinson, 1970). Several are important weeds; *Ageratina altissima* (*E. rugosum*) in the eastern USA, *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). *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.

ECOLOGY OF *CHROMOLAENA ODORATA* IN THE NEOTROPICS

Distribution

C. odorata is distributed naturally over a wide area of the tropical and subtropical Americas, from southern Florida to the extreme north 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.

In the Americas *C. odorata* is confined to the tropical zone (Fig. 1) and has not spread into the sub-tropical humid areas as it has done in the Old World, notably in northern India and Nepal across to southern China and in southern Africa. This difference is presumably due to competition with the numerous other *Eupatorium* species occurring in the Americas, and to the effects of attack by insects and diseases found in the Americas and not in Asia and Africa.

In Central and South America, *C. odorata* is common in most cleared or secondary forest areas below 1,500 to 1,000 metres altitude and receiving over 1500 mm annual rainfall. It is found as far south as Paraguay and the extreme north of Argentina, but is not present in southern Brazil. In Guyana and Amazonian Brazil, it is present but scarce, and in Venezuela it is common in shady sites and at higher altitudes. It is also present in most West Indian islands (Fig. 1).

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.

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 most common in abandoned fields and pastures, on building sites and along roads, railways and streams, and is found in these situations throughout Trinidad. 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, and does not grow in seasonally waterlogged soils.

In Trinidad, *C. odorata* forms dense tangled bushes 1.5 to 2 m in height, very occasionally reaching a maximum of 6 m 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 m^2. 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 to 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.

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 to 60 at the tips of all stems, branches, and axillary shoots, and the onset of flowering prevents further growth. 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 West Indian name "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. 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. 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.

Status in plant communities

In the natural rainforest, *C. odorata* was a plant of forest clearings and of the edges of rivers and savannahs. There is, therefore, no store of *C. odorata* seed in the soil of undisturbed rainforest, and during a visit to 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 3 years previously (Cruttwell 1971). Slash-and-burn shifting agriculture traditionally practised in these areas would have provided a succession of short-lived habitats for the plant, which would probably always have been scarce.

In more densely populated areas, where the original vegetation has been completely cleared, *C. odorata* is typically found growing in small patches, discontinuous in time and space. Newly cleared ground is fairly quickly colonised 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. Such land is usually subsequently 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.

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*. *E. 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.

C. odorata is, thus, a plant of open land, where it supersedes 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* never becomes a serious weed. On intensively cultivated land, the seedlings seldom become established. In pasture and along roadsides, growth is usually cutlassed at 3 to 4 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. In abandoned pasture and fallow, *C. odorata* may become dominant in small areas, never exceeding 0.5ha, and this dominance is short-lived, as in a few years it is displaced by the growth of secondary forest. Under citrus or cocoa the plants are etiolated or present only at the edges where they are easily controlled by annual or bi-annual 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.

Mortality factors

In the West Indies, many plants die each year, at all seasons, from a variety of causes, and the maximum length of life is not known. In poor soil, cutlassing to ground level or burning may kill the plant. In good soil, regrowth is rapid, and very few plants die. Plants also die if the soil becomes water-logged; the leaves yellow, the stems blacken and wither, and become susceptible to fungal diseases.

Plants often die when they become shaded by the growth of bushes such as black sage (*Cordia curassavica*) or wild guava (*Psidium guajava*), or by rainforest regeneration. 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 6 metres or higher, except in clearings or along pathways.

Experiments with potted plants clearly demonstrated that *C. odorata* cannot persist in shade in Trinidad. Plants in rainforest survived for less than 4 months while those in less dense shade survived 8 months and plants in full sun steadily increased in size throughout (Table 1). These experiments also showed that the effect of insect attack, measured as the number of damaged buds (growing points), was greater in shade than in sun.

Table 1. Growth & Survival of *C. odorata* in Sun & Shade in Trinidad

	Full Sun	Partial Shade	Forest
Survival (in months)	>8	8	3-4 (n=6)
Stem Length after 6 mths (% of initial)	160	56	0
Total Leaves after 6 mths (% of initial)	166	73	0
Undamaged buds after 6 mths (% of initial)	183	17	0

In the Neotropics, *C. odorata* is attacked by a very large number of insects, over 200 having been recorded on the plant during a 6 year study (Cruttwell 1972). Of these, about half were probably polyphagous, a quarter were restricted to plants in the Asteraceae, and the rest were specific to *Chromolaena*. All stages and parts of the plants were attacked, except for the roots which were not examined.

The cumulative effect of these insects was considerable. Regular weekly samples of stem tip and axillary buds were taken at 3 sites over 2 years, and the results showed that between 25 and 50% of all growing tips were destroyed by insect attack (Fig. 2). Damage was caused by different insects at different sites and seasons, and in general was heaviest in shaded sites. In the cooler northern valleys, there was also significant stem damage by the boring weevil *Rhodobaenus cariniventris*. Seed germination percentages were low, about 17% of filled seed, and many flowerheads failed to produce seeds at all. Seedling survival is reduced by the attack of stem and tip feeding insects, and the growth and competitiveness of established plants is reduced by the insect damage.

Recent surveys by the CAB International Institute of Biological Control have shown that *C. odorata* in the West Indies is also attacked by disease organisms, which further reduce the vigor and competitiveness of this plant.

Control Measures

C. odorata is not a serious weed in the Neotropics and no special control methods are necessary. For example, of the numerous papers quoted in Weed Abstracts regarding the chemical control of *C. odorata*, none refers to its control in the Americas (Table 2)

Table 2. Papers Published in CAB Abstracts (1972 - 1990) on the Control of *Chromolaena* (*Eupatorium*) *odorata*

(All Control Methods)		
C. odorata in Africa	=	66
C. odorata in Asia	=	75
C. odorata in the Pacific Islands	=	5
C. odorata in the Americas	=	0
Total	=	146

Neither climate nor soil type can explain this difference, as *C. odorata* in Asia and Africa occurs in climates exactly similar to those of South and Central America as well as in more sub-tropical areas, and over the same wide range of soil types. The difference in the aggressiveness of this weed is due to the cumulative effect of all the host-specific insects and diseases which attack the plant throughout its range in the Neotropics, but are largely absent from Asia and Africa.

REFERENCES

Anonymous. 1968. Rainfall Reports of Ministry of Works Drainage Division. Statistical Digest, Trinidad and Tobago Govt., Port of Spain.

Anonymous. 1983. Important weeds of the world. 3rd Ed. January 1983. Bayer, A.G. Leverkusen, Germany. 711 pp.

Cruttwell, R.E. 1971. Report on a Survey of the Insects on *Eupatorium odoratum* L. in South America, undertaken in April-May 1971. C.I.B.C. West Indian Station Unpubl. Report. 12 pp.

Cruttwell, R.E. 1972. The insects of *Eupatorium odoratum* L. in Trinidad and their potential as agents for biological control. Ph.D. Thesis, Univ. of West Indies, St. Augustine, Trinidad. 241 pp.

King, R.M. & H. Robinson. 1970. Studies in the Eupatorieae (Compositae). 24: The genus *Chromolaena*. *Phytologia* 20: 196-209.

Robinson, H. & R.M. King. 1977. Eupatorieae - systematic review. *In*: Heywood, V.H., Harborne, J.B. and Turner, B.L. (Eds) The Biology and Chemistry of the Compositae, Vol. I. pp. 437-486. Academic Press, London.

Toelken, H.R. 1983. Compositae. *In*: B.D. Morley and H.R. Toelken (Eds.) Flowering Plants in Australia. pp. 300-314. Rigby Publishers, Adelaide, Sydney.

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

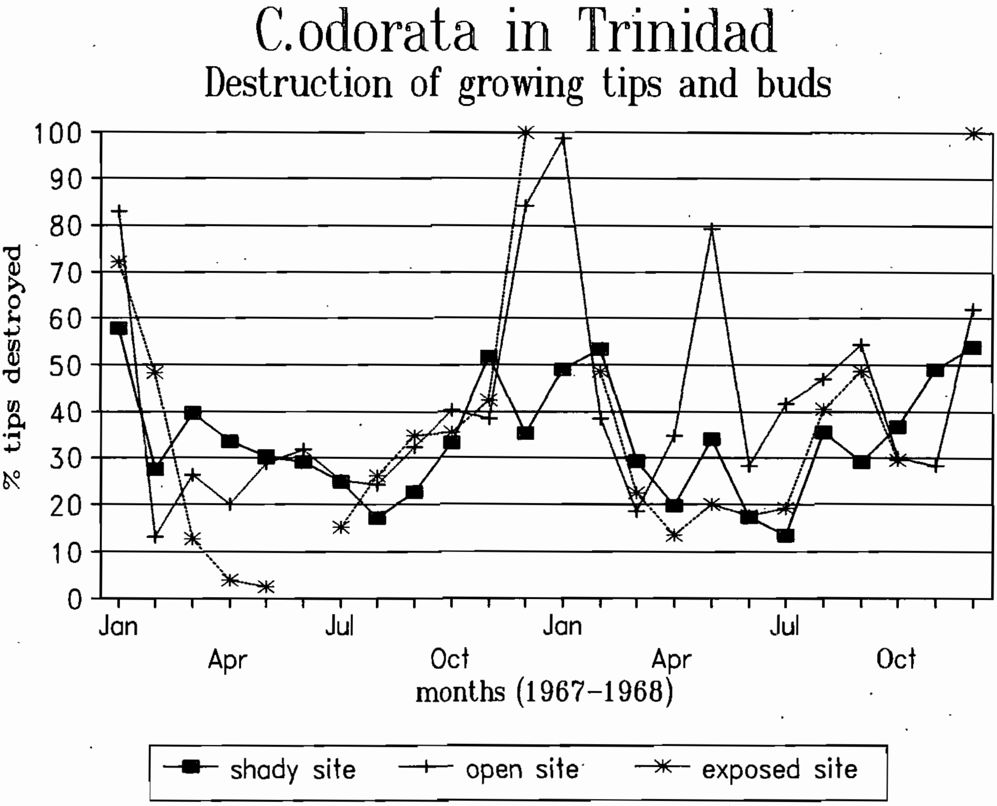

Figure 2.

***Chromolaena odorata* in Trinidad: Percentage destruction of growing tips**

THE ECOLOGICAL ROLE OF THE EXOTIC ASTERACEOUS *CHROMOLAENA ODORATA* IN THE BUSH FALLOW FARMING SYSTEM OF WEST AFRICA

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ABSTRACT

Ecological dynamics of *Chromolaena odorata* during two years of cultivation and two years of fallow, under two different systems of land management, are presented. *C. odorata* is a noxious weed during the cultivation period, but subsequently becomes an important component of the fallow regrowth community. According to its frequency, density, average height, biomass and nutrient content, it is the predominant species of the early fallow successional stage. It is concluded that *C. odorata* may exert a considerable influence on today's bush fallow successional processes in West Africa, and that further enquiry should be made before a biological control program is launched.

INTRODUCTION

Chromolaena odorata (L.) R.M. King and H. Robinson (Family Asteraceae; Tribe Eupatorieae), a native of the tropical and subtropical Americas, was accidentally introduced into Southeast Asia early in this century, where it established itself as a serious weed (McFadyen 1988). Introduced into West Africa around 1940, it has spread throughout the rain forest zone and the bordering edges of Guinea Savannah zones from Cameroon to Cote d'Ivoire. The pest status of *C. odorata* in Africa is not straightforward; in the literature it has been alternately condemned as a weed and praised for its nurse-plant and mineral-cycling properties (Agbim 1987, CAB 1988, Ivens 1974). Pyrrolizidine alkaloids in the flowers of *C. odorata* attract and probably support the polyphagous variegated grasshopper, *Zonocerus variegatus* (L.) (Acrididae). This adds another facet to the already complicated discussion concerning the pest status of *C. odorata* and whether and how it should be controlled.

Before a biological control program is instituted against *Chromolaena odorata* in West Africa, the ecological role of this plant should be better elucidated. While agroforestry systems may be envisaged and promoted in which the transition from arable to tree crops occurs without natural fallow, the fact remains that the vast bulk of fallow land in West Africa regenerates naturally. The question of what role *C. odorata* plays in this regeneration, and what would occur in the absence of *C. odorata* should be answered before a control program is launched.

This submission reports on ecological dynamics of *C. odorata* during two years of cultivation and two years of fallow, under two different systems of land management. The data reported in this paper were gathered in the framework of a larger study on fallow succession in West Africa.

MATERIALS AND METHODS

Site characterization

Location: Field trials were conducted on the grounds of the International Institute for Tropical Research (IITA)'s experimental farm in southwestern Nigeria (7 30'N, 3 54'E), located thirty kilometers south of the northern limit of the lowland rain forest zone of the West African tropics. Elevation of the experimental farm varies from 190 to 230 m, and the rolling topography is dominated by slopes that are 3 to 10%; the field trials of this study were located on essentially flat benches.

Climate: Rainfall distribution is bimodal, with maxima in May to June and in September, separated by a short but comparatively cool, dry period. The main dry period from November to April includes at least five "arid" months, defined as those with less than 100 mm precipitation in a month. Mean annual rainfall is 1280 mm, with a striking variation in the rainfall pattern from year to year (1983: 921 mm, 28% below normal; 1984: 1360 mm, with almost no August break in rainfall; 1985: 1772 mm, the wettest year ever recorded at the IITA Ibadan weather station, with rainfall 30% above the 30 year average; 1986: 1232 mm, close to normal, although rains during both growing seasons ended earlier than usual).

Geology and Soils: Soils in the trial fields were Ferric Luvisols of the Egbeda series, developed on colluvium and residium derived from pre-Cambrian banded biotite-muscovite gneiss alternating with micaceous schist (Moorman et al. 1975). The soil is of coarse to medium texture in the surface horizon, with sandy clay to clayey subsoil, and a layer of angular and subangular quartz gravel below the A horizon. Under secondary forest, the surface soil has a fairly constant pH value around 5.8 to a depth of 150 cm.

Land-use history: The land was used intermittently for agriculture before IITA was established in 1968. Until that time the area was characterized by a mosaic of land uses, from cocoa plantations (largely neglected), to cultivation, to bush regrowth thicket (Smyth and Montgomery 1962). From 1968, when local villages were relocated outside the premises of IITA, until 1982, the forest was permitted to regenerate. By 1982, a well-developed fallow vegetation had grown around scattered high-forest trees which had been preserved by previous cultivators.

DATA COLLECTION

In the fall of 1982, as a demonstration during a land-clearing conference held at IITA, a portion of this forest was completely cleared of regrowth vegetation and high forest trees by caterpillar tractors and tree pushers. From this clearing, a 30 m x 45 m plot was reserved for this study. An adjacent 30 m x 90 m of the regrowth forest was cleared at the same time by traditional methods: woody plants were removed by machete and overstory trees were thinned. On both plots of land, cleared brush was distributed across the ground and burned.

Both plots were cultivated in the 1983 and 1984 growing seasons. Cassava (*Manihot esculenta*) was planted in densities of 1 plant per square meter, and then interplanted with maize (*Zea mays*). Maize was harvested at the end of the 1983 growing season while cassava was harvested at the end of the 1984 growing season. To continue the traditional vs. mechanical comparison, the soil of the field plot cleared by tractor was also initially cultivated by tractor. In the manually-cleared plot, workers were asked to cultivate as they would their own farms. In particular, when weeding, workers were careful to protect any resprouting or germinating species which they might favor in their own farms. Because clearing and cultivation effects were thus combined, the results of this study must be considered purely descriptive of the implications of different management techniques, and not as functional investigations.

The emergent weed and crop community during the two years of cultivation, and the subsequent fallow regrowth community occuring in the first two years of abandonment were sampled. Samples were taken, once each year, during the late growing season (September to October), eight weeks after the last weeding. Plant species were identified according to Hutchinson and Dalziel (1972). Structural profiles on 20-m permanent transects, and species composition and biomass within 25 square meter plots were recorded in each field. Nutrient stocks in soil and in the five most predominant species from each field were sampled in the first year of fallow regrowth, using the analytical methodology outlined by Black (1965).

RESULTS

Species composition

C. odorata was the most predominant species, throughout both the cultivation and the fallowing period. *C. odorata* had the highest average density per square meter, and the greatest frequency of any species, throughout this study (Table 1).

Life-form analysis

C. odorata is sometimes called an "herbaceous" plant (McFadyen 1988), and in other contexts a shrub (Akobundu and Agyakwa 1987). For the purposes of this study it has been assigned to the shrub life form. *C. odorata* stems do become woody with age, and the plant is a perennial; the herbaceous category, in terms of life-form analysis, is best left to wholly herbaceous annual plants.

Although an initial herbaceous stage in fallow succession has been recorded in other West African sites (Richards 1953, Clayton 1964), a predominantly herbaceous period never occurred in the present study. If such a community was present, it occurred on a time frame less than one year, and was not captured by the study's late-season sampling dates. Although herbaceous weeds made up an important component in both fields, woody or semi-woody vegetation was equally or more important in all structural profiles. The dominance of the "shrub" life form throughout the cultivation land fallow period is also seen in density and mean height data (Table 2). And as can be seen from this table, *C. odorata* is the most important contributor to the predominance of the shrub life form, in terms of height if not always in density.

Population dynamics

C. odorata initially occurred at much lower densities in the machine-cultivated field than in the traditionally cultivated field, the space in the former being largely filled by grasses and herbaceous weeds during the cultivation period. Population densities of *C. odorata* increased over time of fallowing in the machine-cultivated field, and decreased over time in the traditionally cultivated plot.

Species interactions

The abundance of the different life-forms in the presence or absence of *C. odorata* was analyzed (Fig 1a and b). *C. odorata* did not emerge as a noxious weed retarding succession. Its presence did not preclude the establishment of high forest tree individuals; in fact more tree individuals occurred in plots where *C. odorata* was established than in its absence. An examination of plot diagrams shows that in almost every plot where a high forest tree established, it was surrounded by *C. odorata* which grew not necessarily abundantly, but taller than average; and the surrounding *C. odorata* was uniformly taller than the tree seedling.

In the absence or reduction of *C. odorata*, such as would be the aim of a biological control project on the weed, one would hope that other woody species which also encourage tree establishment would increase in importance, such as *Lecaniodiscus cupanoides*. However, negative species association analysis only showed that there were significantly more grass individuals in the absence of *C. odorata*.

Biomass

Biomass trends of *C. odorata* over time and by treatment followed basically the same trends as those of population densities during cultivation (Fig 2). As the population densities of *C. odorata* decreased from the cultivation to the fallow period in the traditional field, the biomass of the species increased, indicating that a thinning process was resulting in fewer but larger individuals. This did not occur in the machine cultivated field, where relatively smaller individuals continued to increase in number in the fallow.

Interestingly, biomass of *C. odorata* had no relation, positive or negative, to aboveground crop biomass.

Nutrient stocks

The contribution of *C. odorata* to nutrient stocks in the first year of fallow is recorded in Table 3. Again, the contribution is very high in the traditionally managed field, and considerably less so in the machine-cultivated field.

DISCUSSION

C. odorata has been readily recognized as a weed in part because it is an extremely visible plant; it occurs abundantly along roadsides, and may predominate in the plant community in fallow fields. What is needed, however, is a more precise assessment of its dynamics during both the cropping and fallowing period.

The following is a summary of observed *C. odorata* dynamics emerging from this particular study.

Although it is generally believed that weeds increase with the duration of cultivation, the contrary was true during the short cultivation period (2 yr) of this study. Cultivated plots were extremely weedy initially and weed densities decreased with each successive weeding. During the cropping period, *C. odorata* was the most predominant weed species, especially in the traditionally managed field. Its biomass, however, did not appear to affect the aboveground crop biomass, comparing occurrence in meter-square plots at the end of each growing season. This of course reflects competition between established plants; *C. odorata's* effect on newly established sprouts of cassava may be more deleterious. The fact that crop establishment and biomass is considerably lower in the traditionally-managed field, with its denser weed population, than in the machine-cleared and cultivated fields, suggests that there is a very real problem of weeds in traditional bush fallow farming systems.

Conventional wisdom has it that one of the functions of the fallow is to reduce weed populations (Ewel 1986; Moody 1974). If *C. odorata* is considered as a weed, this process occurred only in the traditionally-managed field, where fallowing saw an increase in trees and shrub-trees at the expense of dense *C. odorata* stands. In the heavily-disturbed mechanically cultivated field, *C. odorata* could flourish only in the fallow recovery period.

The growth, establishment and even the possible breaking apart of a dense woody thicket so characteristic of fallow regrowth is the most salient feature to arise from the fallow successional study from which these data are derived. The process occurs rapidly in the traditionally-managed field, and may be occurring at a much more retarded rate in the machine-cultivated field. Thickets commonly occur in tropical forests in response to disturbance (Bourgeron 1983, Brunig 1983). Unfortunately we do not have a very clear conception of the significance of thicket formation in fallow succession. For instance, we do not know whether a bushy thicket is a stage which of necessity must precede the establishment of high forest tree species, or whether forest trees surpass the thicket in spite of its presence. Neither is it apparent whether a thicket or a well-stratified formation is more efficacious in the restoration of nutrient reserves and soil structure over a fallowing period. What is evident is that *C. odorata* has a life form which lends itself extremely well to the formation of thickets, and in this sense probably contributes to, rather than deflects, the natural course of succession following disturbance in fallow forests. In addition, while we cannot generalize for all species in the thicket, we can say that *C. odorata* appears to facilitate the establishment of high forest tree species in the fallow succession. The contribution of *C. odorata* to nutrient stocks in fallow vegetation is also substantial, and exceeds its contribution of biomass.

It is hoped that the information presented here will be considered in characterizing the role of *C. odorata* in West Africa. As a preliminary to a biological control program, the question of how fallow ecological dynamics would be altered in the absence of *C. odorata* should be answered. And since this is an inquiry which much be made in the context of a long-term study, time is of the essence.

REFERENCES

Agbim, N.M. 1987. Carbon cycling under *Chromolaena odorata* (L.) K.&R. canopy. Biological Agriculture and Horticulture 4:203-212.

Akobundu, I.O. & C.W. Agyakwa. 1987. A Handbook of West African Weeds. IITA, Ibadan, Nigeria.

Black, C.A. 1965. Methods of Soil Analysis. Vol. 2, Agronomy. American Society of Agronomy, Madison, Wisconsin.

Bourgeron, P.S. 1983. Spatial aspects of vegetation structure. pp. 29-47. In: F.B. Golley, ed. Tropical Rain Forest Ecosystems: Structure and Function. Ecosystems of the World Volume 14A. Elsevier Scientific Publishing Co., New York.

Brunig, E.F. 1983. Vegetation structure and growth. pp. 49-75. In: F.B. Golley, ed. Tropical Rain Forest Ecosystems: Structure and Function. Ecosystems of the World Volume 14A. Elsevier Scientific Publishing Co., New York.

CAB. 1988. Prospects for the biological control of *Chromolaena odorata* (L.) R.M. King and H. Robinson. pp. 25-33. In: R. Muniappan, (ed.) Proc., First Intl. Workshop on Biological Control of *Chromolaena odorata*. Ag. Expt. Station, University of Guam, Mangilao, Guam.

Clayton, W.D. 1964. Secondary vegetation and the transition to savanna near Ibadan, Nigeria. J. Ecol. 46:217-238.

Ewel, J. 1986. Designing agricultural ecosystems for the humid tropics. Ann. Rev. of Ecol. and Syst. 17:245-71.

Hutchinson, J. & J. M. Dalziel. 1972. Flora of West Tropical Africa. 2nd edn. Crown Agents, London.

Ivens, G.W. 1974. The problem of *Eupatorium odoratum* L. in Nigeria. PANS 20:76-82.

McFayden, R.E. Cruttwell. 1988. History and distribution of *Chromolaena odorata* (L.) R.M. King and H. Robinson. pp. 7-12. In: R. Muniappan, ed., Proc., First Intl. Workshop on Biological Control of*Chromolaena odorata*. Ag. Expt. Station, Mangilao, Guam.

Moody, K. 1974. Weeds and shifting cultivation. In: Shifting Cultivation and Soil Conservation in Africa. Soils Bull. 24:155-66. FAO, Rome. 248 pp.

Moorman, F.R., R. Lal & A.S.R. Juo. 1975. The soils of IITA. IITA Technical Bulletin No. 3. IITA, Ibadan, Nigeria.

Richards, P.W. 1953. Ecological studies on the rain forest of southern Nigeria. I. The Structure and floristic composition of the primary forest. J. Ecol. 27:1-61.

Smyth, A.J. & R.F. Montgomery. 1962. Soils and Land use in Central Western Nigeria. Ministry of Agriculture and Natural Resources, Ibadan.

Table 1. Average density and frequency of the most abundant species.
(years and fields pooled together)

Species	Life-form class	Average density per m^2 (+S.D.)	%Frequency
Chromolaena odorata	Shrub	3.75 (+5.22)	59.2
Sida veronicifolia	Herb	1.91 (+2.38)	44.8
Spigelia anthelmia	Herb	0.84 (+5.43)	20.8
Solanum verbascifolium	Shrub	0.33 (+0.72)	20.0
Phyllanthus floribundus	Shrub/climber	0.47 (+3.24)	19.5
Brachiaria deflexa	Grass	0.70 (+2.89)	19.2
Paspalum orbiculare	Grass	0.41 (+1.47)	19.2
Lecaniodiscus cupanoides	Shrub/tree	0.27 (+0.92)	19.2
Albizia zygia	Tre	0.25 (+0.85)	17.5
Hippocratea pallens	Shrub/climber	0.17 (+0.35)	14.8
Cnestis ferruginea	Shrub/climber	0.21 (+0.98)	14.5
Mallotus oppositifolius	Shrub	0.24 (+1.35)	14.0
Indigofera hirsuta	Shrub	0.26 (+1.65)	14.0
Dombeya buettneri	Shrub	0.21 (+1.04)	13.2
Rauvolvia vomitora	Shrub	0.13 (+0.45)	11.5
Newbouldia laevis	Shrub/tree	0.13 (+0.33)	11.2
Talinum triangulare	Herb	0.37 (+2.11)	11.2
Combretum hispidum	Shrub/climber	0.17 (+1.09)	10.8
Chassalia kolly	Shrub/tree	0.14 (+0.74)	10.0
Deinbollia pinnata	Shrub/tree	0.15 (+1.02)	9.5
Alchornea laxiflora	Shrub	0.21 (+2.20)	8.8
Motandra guineensis	Shrub/climber	0.31 (+2.97)	8.0
Synedrella nodiflora	Herb	2.05 (+24.60)	8.0
Tridax procumbens	Herb	0.24 (+9.03)	4.0

Table 2. Changes in density and mean height by life form class in 25 meter-square plots in the machine-cleared and cultivated field (field 1) vs. the traditionally cultivated field (field 2), during two years of cultivation (year 1 and 2) and two years of fallow (year 3 and 4).

	Year 1		Year 2		Year 3		Year 4	
	Field 1	Field 2	Field 1	Field 2	Field 1	Field 2	Field 1	Field 2
mean number of individuals per life form class, per square meter:								
high forest trees	.04	.80	.16	.75	.60	.71	.85	1.23
understory trees	.84	.16	.04	.24	.52	.20	.76	.88
shrub/trees	.80	1.12	.76	1.14	.40	2.00	.80	3.45
shrubs	2.20	11.56	1.24	9.10	3.16	5.75	6.87	4.69
(C. odorata)	**1.76**	**9.12**	**.36**	**6.20**	**2.04**	**3.04**	**4.56**	**1.93**
shrub/climber	2.00	3.08	1.68	1.81	1.52	2.30	1.69	2.13
climber	.36	.88	.16	.24	.24	.40	.50	.81
grass	1.20	.132	1.08	.95	1.80	1.15	2.63	.46
herbs	3.56	5.92	4.36	2.00	16.56	3.40	10.26	1.81
mean height, in cm., per life form class, per square meter:								
high forest trees	1.62	17.53	8.23	27.54	16.80	29.28	19.65	32.10
understory trees	18.45	13.43	4.00	20.47	10.04	12.55	12.53	11.57
shrub/trees	15.66	28.13	12.10	16.07	18.23	57.99	25.30	72.63
shrubs	47.03	93.79	23.96	46.97	122.26	184.61	134.60	226.50
(C. odorata)	**96.67**	**109.80**	**25.00**	**67.24**	**183.10**	**238.22**	**156.38**	**273.20**
shrub/climber	19.32	56.00	34.19	22.23	31.65	90.00	65.54	127.32
climber	20.80	26.26	3.00	71.43	8.20	10.87	16.52	32.31
grass	13.00	8.84	9.27	4.28	57.00	18.00	65.44	15.60
herbs	18.99	23.00	13.32	32.14	49.65	14.50	51.60	9.82

Table 3. Total nutrient stocks in aboveground vegetation of a year-old fallow, and percent of this contributed by *C. odorata*.

	Total in g/m2 (=100%)		Contribution of *C. odorata* %	
Element	field 1*	field 2	field 1	field 2
C	206.9	477.91	4.8	50.5
N	5.7	13.3	4.9	64.5
P	.5	1.2	5.2	73.9
Ca	3.3	3.1	3.4	24.8
Mg	.9	1.3	8.0	52.8
K	9.9	14.8	4.8	74.2

(field 1 = machine cultivated field; field 2 = traditionally cultivated field).

in the presence of:

there are significantly:	SHRUB/TREES	Chasalia kolly	Holarrhena floribunda	Lecaniodiscus cupanioides	SHRUBS	Alchornea laxiflora	**Chromolaena odorata**	Dombeya buettneri	Mallotus oppositifolius	Solanum verbascifolium	SHRUB/CLIMBERS	Cnestis ferruginea	Motandra guineensis	Phyllanthus floribundus	HERBS	Sida veronicifolia	Spigelia anthelmia	Synedrella nodiflora
more high forest tree individuals				*			*											
more understory tree individuals			*															
taller understory tree individuals				*														
more shrub/tree individuals												*						
taller shrub/tree individuals										*				*				
more shrub individuals														**				
taller shrub individuals		**												**				
taller shrub/climber individuals		***				*												
taller climber individuals			*															
more herb individuals								**										
taller grass individuals								**									*	***
more *Chromolaena* individuals									*	*			*	**		***		
taller *Chromolaena* individuals		*				*												*

Figure 1a. Chi-square analysis of species and life form association.
(*:significant at p > .01; **: p > .001; ***: p > .0001)

in the absence of:

there are significantly:	SHRUBS	***Chromolaena odorata***	SHRUB/CLIMBERS	*Hippocratea pallens*	GRASSES	*Paspalum orbiculare*	*Brachiaria deflexa*	HERBS	*Spigelia anthelmia*	*Synedrella nodiflora*	*Talinum triangulare*
more high forest tree individuals				**		*					
more shrub/tree individuals						*			*	*	
taller shrub/tree individuals											*
more shrub individuals				*		*	*		*		**
taller shrub individuals											*
more grass individuals		*									
more *Chromolaena* individuals				*			*				*

Figure 1b. Chi-square analysis of species and life form associations. (*: significant at p > .01 level; **: p > .001; ***: p > .0001)

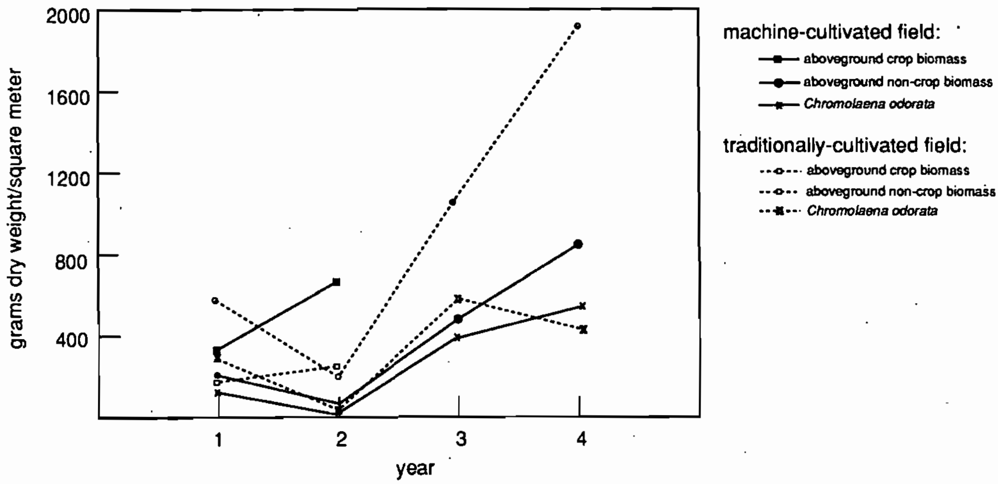

Figure 2. Changes in above ground biomass over time.

CHROMOLAENA ODORATA AND DISTURBANCE OF NATURAL SUCCESSION AFTER SHIFTING CULTIVATION: AN EXAMPLE FROM MAYOMBE, CONGO, CENTRAL AFRICA

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ABSTRACT

In Mayombe rain forest, shifting cultivation is the only cultivation system used by local people in order to produce cassava, their staple food. Fields are let to natural fallow after about two years, when all tubers have been harvested. Until now, abandoned fields were rapidly overgrown with fast growing trees like *Musanga cecropioides*, which within a few years made up the infrastructure of a real forest, 15 to 20 meter high. This pioneer forest constituted the first phase of a succession leading to the rebuilding of the rain forest. But in fact, such a succession could not occur, as fallow vegetation is usually cut by peasants after 5 to 15 years and enters a new phase of cultivation. *Chromolaena odorata*, for which local names account for its recent arrival and its striking invading power, is disturbing at an increasing rate this alternate cycle of cultivation and tree fallow: in abandoned fields after slash and burn of pioneer forest, regrowth is now made up almost exclusively of dense thickets of *C. odorata*. Preventing the intrusion of pioneer tree species, these thickets stop the natural succession for many years and are thus becoming the main vegetation type near villages. This new expanding feature of a traditional cultivation system is usually considered by local people as a threat; nevertheless, based upon various field observations, suggestions are made here about the potential positive effects of *C. odorata* fallows in shifting cultivation systems.

INTRODUCTION

The neotropical shrub *Chromolaena odorata*(L) R.M. King and H. Robinson is perceived by agriculturists in two contradictory ways: for most of them, it is one of the worst weeds in the world, while for a few others it is a plant with promising agronomic properties.

As in many countries of humid tropical Asia and Africa, *C. odorata* can now be found in large quantities in the Congolese Mayombe. Its expansion may be compared to a true invasion, and in some areas *C. odorata* thickets already make up the larger part of the rural landscape.

The present paper is an attempt to answer the following main questions posed by this very quick and intense spread regarding the processes involved in *C. odorata* invasion and its impact on natural and cultivated vegetation:

Which vegetation types are replaced by *C. odorata*, how are they replaced, and at what speed ?

What could be the future extension of *C. odorata* in Mayombe ?

What are the present and potential effects of this invasion on cultivation, and what are the agronomic potentialities of invaded areas ?

THE MAYOMBE MASSIF: SITUATION

The Mayombe is a low altitude hill range, lying parallel to the Atlantic coast from Gabon at the N.W. to Zaire at the S.E (figures 1 & 2). The highest ridges are situated in Congo, and reach 900m. Owing to its vigorous Appalachian relief, and despite its low altitude, the Mayombe massif forms a real obstacle between coastal and inland savannah plains. In the Congolese Mayombe, one may distinguish a western part formed by a set of hills and ridges gently sloping down to the coastal plain, and an eastern part with a regular succession of high sandstone-quartzite ridges intersected by schist valleys, which finally dips steeply to the large Niari and Nyanga valleys (Schwartz, et al. 1991).

The rainfall increases from the west (1200 mm/year) towards the highest ridges (1980 mm/year), then decreases to low levels again (1200 mm/year) at the edge of the Niari plain. Rainfall is distributed over 8 months, from October to May, but mist and drizzle are very abundant during the so-called dry season, allowing the preservation of a certain soil humidity. The amount of sunshine is very low, especially during the dry season, totalling less than 1000 hours/year (Clairac, et al. 1989). Given the low rainfall cited above, these features of the dry season in south Congo are very important, as they allow the presence of rain forest, as well as its tendency to colonize savannahs (de Foresta 1990).

Soils are mainly "ferrisols" (Duchaufour 1983): soils subjected to ferrallitic alteration, but in which still remain, owing to their relatively young age, unaltered primary minerals such as illites or micas (Gras 1970, Jamet 1975 - 1978; Lanfranchi & Schwartz, in press). These soils generally possess good physical characteristics but are chemically poor, highly desaturated and strongly acid, with a very low surface pH between 3.5 to 4.5 (Misset 1989). In about 80-90 % of the soil cover in Mayombe, these soils contain a 5 cm to 2 m depth horizon showing a considerable enrichment in residual rough elements, which can be a real obstacle for agriculture when situated at low depth. This stone-line, generally located between the B horizon and the alteration horizon, can be found at extremely varying depth, from 0 to 6 m, but usually between 0.5 and 2 m.

vegetation is markedly dominated by evergreen rain forest, with a lesser tendency towards semi deciduous rain forest (White 1983). To the west, one passes from the Mayombe rain forest to the coastal savannahs through a very progressive mosaic; to the East, the transition towards the Niari savannahs is very sharp and occurs within a few kilometers (figure 3). Nevertheless, the forest cover is sprinkled with numerous included savannahs, whose distribution, origin and dynamics are beginning to be better understood (de Foresta 1990, Schwartz et al. 1990, Schwartz et al. 1991). The Mayombe forest is at present highly degraded by agriculture around villages, and also in other parts, owing to an already long period of logging (Gibert & Sénéchal 1989). However, despite a long history of human occupation and migration, traces of which are sometimes encountered, undisturbed or almost undisturbed forest still occupies large areas (Cusset 1989).

The Congolese part of Mayombe was very poorly populated until the construction of the railway "Congo-Ocean"; after its opening to traffic in 1934, the population increased continuously, reaching about 30, 000 inhabitants in 1987, still a mean density of only 4 inhabitants/km2. This population is irregularly distributed, with half living in a small number of "village-gares" along the railway lines in the central district of Mvouti. This district, in which density still reaches only 5.8 inh/km2, has seen a threefold increase of its population during the last 50 years, and is at present the most populated rural area of the whole Congo. However, from a district area of 3,200 km2, only 900 km2 are actually used by man for plantations or shifting cultivation, 2,300 km2 of rain forest being left almost undisturbed (Boungou et al. 1989).

LES SARAS: THE ZONING OF VEGETATION AROUND A "VILLAGE-GARE"

After a comprehensive survey along the main traffic axis crossing the Mayombe massif, the "village-gare" Les Saras was chosen as a model for a study on the evolution of natural vegetation subjected to local agriculture, aiming at the assessment of both the impact of human activities on natural forest regeneration and the constraints imposed by natural vegetation upon the cultivation systems. Les Saras, located in the middle of the central Mvouti district, along both the Congo Ocean railway and the N1 road joining Brazzaville and Pointe-Noire (figure 3), is probably the most active rural area of Congo in terms of agricultural production (Mapangui & Sénéchal 1989).

Agriculture, which occupies about 75% of the working population, is devoted mainly to the cultivation of sweet banana (mainly the "Gros-Michel" variety) and cassava (tubers and leaves), which crops are conveyed by train to be sold in Pointe-Noire and Brazzaville markets (Kouba 1987). However, the larger part of cassava tuber production (by far the main staple food in Congo) is still locally used for household consumption.

Because of the lack of aerial photographs, the zoning of land use was studied along six transects following roads, railway, and small tracks; the village itself is characterized by an abundance of fruit trees, dominated by the "safoutier" (*Dacryodes edulis*), which are cultivated by almost every household in well developed home gardens. Next to the village, the landscape appears as a complex mixture of cultivated fields and natural fallows; the combination of two kinds of criteria, namely the proportion of each type of natural vegetation and the proportion of each type of agricultural plantation, allows the characterization of four main land use patterns, globally arranged in concentric rings from village fringes to undisturbed forest (figure 4):

A : a mosaic of very old, more or less abandoned banana plantations, oilpalm groves, *C. odorata* bushes, and a few cultivated fields make up the first vegetation belt. As in the second belt, fields are very small in area (about 400 to 600 m2), always devoted to an association of maize, groundnut and cassava, which is sometimes extended to other vegetables such as eggplant or spices such as chilli, and are abandoned to fallow after one year.

B :the second belt is mainly occupied by *C. odorata* thickets, again with some oilpalm groves as well as some cultivated fields; a few scattered primary forest trees (very hard timber trees belonging mainly to the family Irvingiaceae) recall that this area was once occupied by rain forest.

C : the third belt is characterized mainly by a mosaic of pioneer tree fallows at various stages of development and more or less well maintained banana plantations, with some small patches of "primary" forest as well as a few cultivated fields and *C. odorata* dominated bushes. Here, fields are larger than in A and B (about 1 ha.), almost exclusively devoted to cassava, and gradually abandoned to fallow after one to two years.

D : the fourth belt forms a progressive transition zone, with new cassava fields and banana plantations, progressing at the expense of the undisturbed forest.

Although the extension of each vegetation belt can vary from one village to another, the global distribution pattern of natural and cultivated vegetation around Les Saras may be considered as fully representative of the situation prevailing along the Congo-Ocean railway in the Mvouti district.

From this schematic description of the rural landscape around Les Saras, one may appreciate the important place already occupied by *C. odorata*, especially near the village (A and B belts). However, this description only gives an account of the present situation, and, with the history of rural landscape and agricultural practices as a reference, some information about the dynamic processes of vegetation evolution is needed to explain this present importance and to forecast its future.

THE HISTORICAL BACKGROUND OF *C. ODORATA* INVASION

The history of the Mayombe massif was greatly affected by the opening of the Congo-Ocean railway. The railway approximately follows the layout of an old forest track, the so-called "piste des caravanes", which previously joined the coastal and the interior populations. During the building works, from 1922 to 1934, the central Mayombe saw an intense and tragic activity: because of the fairly low number of local inhabitants, the colonial administration ordered "forced work" for local people and recruited about 40,000 people from Oubangui-Chari and Tchad (Nguembo and Sénéchal 1989). Sanitary conditions were very bad and, within 13 years, about 20 000 people died.

With the completion of the railway, most of the foreigners left but local people stayed in the newly built "village-gares", which became important immigration centers for populations from inside and outside Mayombe(Vennetier 1968).

The opening of this new communication axis led to a new era for forest exploitation and commercial cultivation. Large banana plantations owned by colonists appeared as early as 1936, and extended until 1961; with the independence of the country in 1958, banana cultivation for trade was resumed on old or new plantations by local people, and to the present this crop still represents their main source of income. From 1934 to 1956, as firewood was the main fuel for railway engines, large tracts of primary and secondary forest were cut along the railway (Gibert & Sénéchal 1989). Moreover, the railway opening allowed the expansion of selective timber exploitation, which became the major economic activity of central Mayombe until 1974 (Gibert and Sénéchal 1989), the most important present traces of which lie in the road network centered on some "village-gares".

Until the railway building, the villages were small and few; they were occupied for a certain number of years and then shifted to other places following events such as the death of an important member of the community or epidemic diseases; agriculture was exclusively devoted to shifting cultivation for household purposes, with small temporary fields (about 0.5 ha.) scattered inside the undisturbed forest and linked together and to the village by small paths running under the forest cover.

Since 1934, the railway and the associated N1 road, as well as the concession roads network, gradually provided a means of forest penetration, allowing local people to gradually colonize new areas for cultivation.

From an ecological point of view, two main transformations have been brought by the railway opening:

- local intensifications of human impact upon vegetation, with the introduction of permanent plantations and the expansion of cultivated fields - fields which are no longer separated by tracts of undisturbed forest but only by various stages of fallow vegetation;
- expansion of more or less wide strips supporting only a heavily disturbed and easily invaded vegetation, a direct consequence of the settling of roads and railway.

These transformations obviously paved the way for the invasion of *C. odorata*.

According to Cruttwell McFadyen (1988), *C. odorata* appeared for the first time in Central Africa around 1940, with Nigeria as the first affected country; it became a major weed there by the late 1960's, and since then has spread to Ghana, Ivory Coast and Cameroon.

Although information about its arrival in Congo is lacking, according to local people, *C. odorata*, which is called locally "matapa mbala" (the invader) or "Lantana Ngouabi" (a combination of the previously important colonizing plant and the name of a previous Congo president), arrived in Mayombe during the early 1970's after a rapid progression along the railway. From then on, it has been gaining more and more importance in the rural landscape, owing to its biological properties.

C. odorata is a fast growing heliophilous shrub, reaching sexual maturity after a few months. Probably owing to the constantly high relative humidity characterizing the Mayombe climate, *C. odorata* shrubs never wilt on the stalk, even during the dry season; branches supporting flowers and fruits die, but are quickly replaced by new ones.

In Mayombe, *C. odorata* flowers and fruits during the dry season, from July to mid-September, releasing each year an enormous number of small, wind dispersed seeds; although recently released seeds can germinate in heavy shade (Marks & Nwachuku 1986), the germination of soil embedded seeds requires the red/far red light ratio characteristic of open vegetation (Erasmus & van Staden 1986).

As it has already been reported by some authors, *C. odorata* seeds can make up an important proportion of the surface soil seed banks (Yadav & Tripathi 1982, Epp 1987). Around Les Saras[1], although absent from the large areas of undisturbed forest which surrounds the agricultural landscape, viable *C. odorata* seeds appear in the small remnants of undisturbed forest located in the "C" belt, as well as in old pioneer forest, although there they are still largely out numbered by pioneer tree seeds (Table I).

In the "parcelle Likibi", the history of which is described below, the thicket already shows the tremendous dominance of *C. odorata* within the soil seed bank, with more than 1000 seeds/m2 after only two years of fallow. This number still increases in the fallows that follow cultivation on *C. odorata* thickets located in the "B" belt, reaching about 2000 seeds/m2 two years after the abandonment of the field.

THE LINKS BETWEEN SHIFTING CULTIVATION AND *C. ODORATA*

A comparative survey of the vegetation associated with the two main agricultural systems shows that the invasion of *C. odorata* is closely linked to shifting cultivation, banana plantations showing only rare and minor signs of disturbance.

[1] Six plots with different vegetation types were tested. In each plot, 8 sites were selected at random and in each site, 6 elementary surface soil samples were taken using a 3.2cm radius and 8cm long cylinder, and mixed together. Samples taken in Les Saras on February 10, 1989, were brought to Pointe-Noire the same day. The next day they were placed on a 2cm layer of sterilized soil in germination trays. These 48 germination trays (6 plots, 8 samples per plot), placed under slight shade and a plastic cover to protect from rain were watered every day and checked bi-monthly for new seedlings for 6 months, i.e. until August 4, 1989. After each counting identified seedlings were removed and the others were mapped.

Bearing in mind the main biological features linked with the settling and growth of *C. odorata*, four main reasons, linked to local agricultural practices, may account for the relative preservation of banana plantations from *C. odorata* invasion.

According to local people, the best soils for banana cultivation are those supporting undisturbed forest; therefore new plantations are almost exclusively opened on primary or old secondary forest lands, areas located at the fringes of the cultivated zone, where *C. odorata* is still lacking, even in the soil seed bank.

Usually, some tall trees are preserved during the forest clearing, and banana trees are therefore planted extensively under light shade, in microclimatic conditions which are not favorable to the growth of *C. odorata*.

The cleared forest is not burnt, allowing, between the banana trees, a rapid recovery of a dense cover of pioneer trees, lianas, and forest herbs which hamper an early colonization by *C. odorata*.

Owing to periodic cleanings (usually once a year), fast growing species able to support repeated cutting are progressively favoured; the regrowth associated with banana trees evolves quickly and reaches its equilibrium as soon as the fifth year, staying unchanged or almost so until the abandonment of plantation (the oldest productive plantations are about 30 years old). This stable vegetation is dominated by large rhizomatous herbs belonging to the Marantaceae family (especially *Thaumatococcus daniellii*) and by ferns (mainly *Cyclosorus afer*); these plants grow vigorously after each cleaning, restoring within a few weeks a very dense cover, which protects plantations from any new settling of *C. odorata*.

In cassava cultivation, on the contrary, in every dry season almost every household opens a new field and abandons an old one, leaving every year large areas with almost bare soil susceptible to invasion by *C. odorata*; in addition, more and more pioneer forest and *C. odorata* thickets (with their high number of soil embedded *C. odorata* seeds), are now used for this temporary cultivation.

C. ODORATA AND THE DISTURBANCE OF NATURAL SUCCESSION

At present, the general trends of natural succession following slash and burn cultivation of fields opened on undisturbed forest still follow the classical scheme encountered everywhere in the humid tropics (Richards 1952, Hallé et al. 1978, among others).

The abandoned fields are invaded first by herbs which achieve their cycle within a few weeks, and are then quickly replaced by a few pioneer tree species, almost always largely dominated in Mayombe by *Musanga cecropioides*.

Two years after the abandonment, the fallow makes up a real forest with an already dense canopy, some 8 to 10 m high; as the number of species increases gradually (Table 2), owing to the settling of sciaphilous species under the already dense canopy, the relative importance of pioneer species, estimated by such parameters as relative density or relative basal area, slowly decreases until the progressive death of the upper canopy layer after about 20 to 25 years.

The structure of this pioneer forest evolves with time, mainly because of natural thinning and individual tree growth, and may be characterized as early as the second year by two layers: an upper one made up almost exclusively of *Musanga* trees culminating at about 15 m height and quickly stabilizing at around 22-25 m, and a lower one showing large floristic variations from site to site, but mainly dominated by some Rubiaceae and some *Macaranga*. This undergrowth, inside which even after 16 years of fallow the constant presence of cassava should be noted, densely occupies the space from the ground level to various heights, from 3 to 8 m depending on its local composition, and has its development largely hampered by the *Musanga* canopy.

In the past, 10 to 15 years old fallows were often chosen for new cultivation owing to their relatively easy clearing, starting then a new and almost identical succession. When villages, and with them their cultivated areas, were abandoned, the succession could extend: after the death of the *Musanga* canopy, the pioneer forest was replaced by a secondary forest which itself led after a more or less long period (100-150 years or more?) to the regeneration of a "primary" forest floristically and structurally similar to the initial one.

In Mayombe, as well as in most parts of the humid tropics, this classical succession can no longer be achieved as fields are reopened after less and less years, owing mainly to permanent settling of villages and to increasing population densities. Fallows of shorter duration lead to floristic and structural transformations, favouring species able to reach maturity earlier and to deliver seeds in greater amounts. In Mayombe, although other traces of past shortening in the fallow-field cycle can be encountered, as *Pteridium aquilinum* or *Dicranopteris linearis* formations, the most obvious evidence of the increasing cultivation intensity is given by the occurrence of large tracts of *C. odorata* dominated thickets.

At present, when a plot of pioneer forest, whatever its age and previous vegetation ("primary", secondary or pioneer forest), is opened for cassava cultivation, the colonizing vegetation following the abandonment of the field is largely dominated by *C. odorata*.

This process has been clearly shown on the "parcelle Likibi": half of the field was set up on a previously undisturbed forest, the other half on a five years old pioneer forest succeeding directly to undisturbed forest. After two years of fallow, the regrowth on the first half is a typical young pioneer forest 8 to 10 m high, with a tree density of 7650 ind/ha and a basal area of 25 m2 (Table 2); on the second half, the fallow is made up of a few scattered pioneer trees emerging 3 to 5 m above a 2 m high thicket. Although this thicket presents a relatively important species richness (47 species were counted on a 25 m2 plot), *C. odorata* is by far the dominant species, as shown by its aerial biomass[2] accounting for 57 % of the total above ground phytomass of the thicket (Table 3).

2 Biomass was used as the more meaningful parameter to assess the relative importance of species or groups of species in *C. odorata* thickets. In each fallow, a 25m^2 representative plot was chosen, in which species or groups of species were cut to ground level, sorted and weighed on the spot. Samples were then brought to the laboratory and dried in an oven at 105 C for constant weight to assess the dry/fresh weight.

The importance of *C. odorata* within the regrowth is naturally much more pronounced when the vegetation slashed and burnt for cultivation is already dominated by *C. odorata* (Table 3): after one year of fallow, the 2 m high thicket is mainly composed of *C. odorata* (only 8 species were counted on 25 m2), which accounts for about 67 % of the phytomass (trees excluded). After three years, the vegetation is still very dense and species poor (only 10 species counted on 25 m2), reaching 2.5 to 3 m high, with a very few slightly emerging or completely included trees. *C. odorata* here accounts for about 76 % of the biomass (trees excluded).

In the oldest thickets found around Les Saras (7 years old), although some signs of evolution may be observed, such as the differentiation of a few tree spots (about 10 % of the fallow area) and the disappearance of *C. odorata* under these spots, *C. odorata* is still largely dominant, accounting for 84 % of the phytomass (Table 3).

The comparison of the previous examples of *C. odorata* thickets shows that once settled they stay almost unchanged for years, and probably because of their extremely dense canopy but perhaps also because of the allelopathic properties of *C. odorata* (Ambika and Jayachandra 1980), they do not allow the growth of other successional species, therefore making up a kind of successional locking. This locking is obviously long lasting, but one may foresee a slow evolution of thickets towards impoverished kinds of pioneer forest, with the support of the few surviving trees, which will after some years create many unsuitable spots for *C. odorata*. However, this foreseeable succession is not likely to occur in practice because fields are now reopened after fallow periods of only 5 to 6 years, not long enough to allow such an evolution.

C. ODORATA: CONSEQUENCES OF AN INVASION

The zoning of vegetation and land use around Les Saras as described above provides an account of the agricultural landscape and of the relative importance of *C. odorata* as it existed at the time of study in 1988-1989.

From the railway opening until the early 1970s, this landscape has undergone important but mainly quantitative transformations: expansion of the area under cultivation, and increase of pioneer forest fallow areas at the expense of the undisturbed forest.

From the arrival of *C. odorata* until now, huge qualitative transformations began to be superimposed on this trend: appearance of long lasting low thickets at an increasing rate and reduction of areas supporting a forest cover, whatever its composition.

Bearing in mind the present natural succession trends, it seems obvious that *C. odorata* thickets are bound to extend, and it may be assumed that, except for a narrow strip of pioneer forest and cassava fields along the undisturbed forest border, the whole agricultural landscape will be reduced within a few years to one large area of *C. odorata* thickets, only locally shared by banana plantations and cassava fields.

This completely new process of replacement of classical pioneer forest fallows by *C.*

odorata thicket fallows is clearly visible on the ground, and is perceived by rural people (who indeed have a ringside seat) as extremely frightening. The first attempts of cultivation, following the traditional slash and burn practices, ended in complete failure. Although they may fully be explained by the vigorous resprouting properties of *C. odorata*, many people attributed these failures to a substantial decrease in soil fertility, and these people now believe that soils under *C. odorata* thickets are lost for agriculture.

However, this bad reputation could slowly change. As reported above, *C. odorata* thickets next to the village, in the A and B belt, are now more and more used for cultivation of maize, groundnut and cassava in mixture. Such fields are often completely managed by women, but also sometimes by men who do not "own" any forest fallow or who are too old to have their field far from the village; they are usually very small, and only constitute secondary fields. Provided cultivation operations are correctly undertaken, such as the removing of *C. odorata* stumps and careful weeding, these fields can yield successful crops.

We had the opportunity of following one of these fields from its opening during the 1988 dry season to the cassava dominated stage, just before the abandonment to fallow. All crops (mainly maize, groundnut, eggplant, chilli and cassava) were vigorous and healthy, and, although it was not possible to undertake any quantitative study, their productivity could be judged as fairly high.

A comparative study of soil characteristics in fallows of various age, structure, floristic composition, and history, was carried out at Les Saras[3]. No significant differences in soil nutrient composition between undisturbed forest and pioneer forest fallows (HFDS 16, 10, 12, 11) were observed, but this study clearly shows an improvement of soil chemical fertility under *C. odorata* thickets (Table 4).

Two years after the abandonment of a field opened on pioneer forest fallow ("parcelle Likibi": HFDS 9), the soil fertility is still similar to undisturbed forest soil fertility, but after 7 years (HFDS 14) the nutrient enrichment appears clearly, mainly with an increase in calcium , which is well reflected by a tremendous improvement in pH (2 points!).

This global improvement of soil chemical fertility does not appear to be affected by further cycles of cultivation/fallow, as may be deduced from the soil analysis of a three years old fallow following cultivation of a field opened on *C. odorata* thicket (HFDS 13).

In addition, it should be noted that in the two *C. odorata* thickets (HFDS 13 and 14), contrary to the other vegetation types, the soil was characterized by intense biological activity, shown by the important humus horizon depth (15 cm compared to about 3 or 5 cm under undisturbed or pioneer forest) and by the abundance of earthworms.

[3] Surface soil samples (0-10cm depth) were taken in all vegetation types at half slope. Each sample was made up of 16 elementary samples taken within a $100m^2$ area (10m x 10m) according to a systematic sampling in which the first sample was chosen at random, and then mixed together for further analysis. In addition, soil profiles were studied in each vegetation type. In order to assess the evolution of soil characteristics under various treatments, each fallow type was associated with the nearby undisturbed forest where soil samples were taken using the same methodology.

The combination of these results with the above examples of successful cultivation shows that a shifting cultivation system using *C. odorata* fallows could lead to a global and stable improvement of soil fertility, and that *C. odorata* thickets in Mayombe are not unsuitable for agriculture, provided that peasants adapt their cultivation practices slightly to the new conditions: the thicket should be slashed, left to dry for some days, and burnt; the remaining *C. odorata* stumps should be uprooted. As it seems that most of the soil embedded seeds are not destroyed by the high temperatures associated with burning[4] (Table 5), an early weeding, followed or not, depending of the composition of crop mixture, by periodical ones are needed in order to prevent the growth of *C. odorata* seedlings.

CONCLUSION

From its arrival in Mayombe in the early 1970's until now, *C. odorata odorata* has drastically transformed the agricultural landscape, which will probably be completely invaded by *C. odorata* thickets within a few years. The analysis of natural succession after slash and 9cultivation shows that *C. odorata* invasion has led to a heavy disturbance of the "classical" cycle known by local people for generations, with the replacement of the various pioneer forest stages by stable *C. odorata* thickets. The incapacity of villagers to control this new process, associated with the speed as well as the intensity of the invasion, has led to an understandable anxiety among local people, expressed by the overall opinion that *C. odorata* thickets are unsuitable for agriculture.

It should be stressed that the shortening of fallow periods in shifting cultivation systems usually leads to an increasing soil degradation. Contrary to this very general trend, under *C. odorata* thickets soil fertility seems to be fairly well improved, although more studies are needed in order to confirm and to explain our data.

In the framework of slash and burn cultivation, the soil improvement exhibited by *C. odorata* fallows seems to be stable with time, a fact which could be of great value for the future of agriculture in humid tropical Africa, allowing, within the traditional systems and without any inputs, a process of agricultural intensification. Assuming that field yields are similar in a 15 years cycle based on pioneer forest fallow and in a 2 years cycle based on *C. odorata* fallow, the global production over time in the second system would be five times higher!

Indeed *C. odorata* should be recognized as a weed, but only for a few given crops and only under given cultivation systems. In Indonesia, for instance, *C. odorata* has been reported as a weed mainly for rubber, but although rubber estates seem often to be invaded, smallholders' "jungle-rubber" plantations are never hampered.

[4] Six distant surface soil samples, each made up of 10 elementary samples taken with a 3.2cm long and 8cm radius cylinder, from a 3 years old *C. odorata* fallow were brought to the laboratory. They were mixed together and divided in 6 equal parts to be subjected to various temperature conditions. Then, they were placed in germination trays and checked for new seedlings using the same method as in the seed bank assessment experiment.

Considering the present distribution of *C. odorata* as well as its foreseeable future extension (Cruttwell McFadyen 1988), it seems urgent not only to find better ways to eradicate and to control *C. odorata* where it appears effectively as a weed, but also to assess its promising agronomic potentialities in order to use *C. odorata* in its beneficial aspects for the benefit of rural people.

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REFERENCES

Ambika, S. R. & Jayachandra, 1980. Influence of light on seed germination in *Eupatorium odoratum* L. Indian Forester. 106: 637 - 640.

Boungou, G., J. Nguembo & J. Sénéchal, 1989. Peuplement et population du Mayombe. Revue des connaissances sur le Mayombe. DGRST-Congo, UNESCO et PNUD. UNESCO, Paris. 157 - 185.

Clairac, B., B. Cros & J. Sénéchal, 1989. Le climat du Mayombe. Revue des connaissances sur le Mayombe. DGRST-Congo, UNESCO et PNUD.UNESCO, Paris. 47 - 78.

Cruttwell McFayden, R.E. 1988. History and distribution of *Chromolaena odorata* (L.) R.M. King and H. Robinson. In: R. Muniappan (Ed.) Proc. First Intern. Workshop Biol. Control *Chromolaena odorata*. pp. 7-12, Agri. Expt. Sta., Univ. Guam, Mangilao, Guam.

Cusset, G. 1989. La flore et la végétation du Mayombe Congolais: état des connaissances. Revue des onnaissances sur le Mayombe. DGRST-Congo, UNESCO et PNUD. UNESCO, Paris. 103 - 136.

de Foresta, H. 1990. Origine et évolution des savanes intramayombiennes (R. P. du Congo). II. Apports de la botanique forestière. Paysages quaternaires de l'Afrique Centrale atlantique. R. Lanfranchi et D. Schwartz. ORSTOM, Paris. in press.

Duchaufour, P. 1983. Pédologie: classification et pédogenèse. Masson, Paris. 1: 1 - 493.

Epp, G. A. 1987. The seed bank of *Eupatorium odoratum* along a successional gradient in a tropical rain forest in Ghana. Journal of Tropical Ecology. 3: 139 - 149.

Erasmus, D. J. & J. van Staden, 1986. Germination of *Chromolaena odorata* (L.) K. & R. achenes: effect of temperature, imbibition and light. Weed Research. 26: 75 - 81.

Gibert, G. & J. Sénéchal, 1989. L'économie forestière. Revue des connaissances sur le Mayombe. DGRST-Congo, UNESCO et PNUD. UNESCO, Paris. 249 - 293.

Gras, F. 1970. Surfaces d'aplanissement et remaniement des sols sur la bordure orientale du Mayombe. Cahiers ORSTOM, série Pédologie. 8: 274 - 294.

Hallé, F., R. A. A. Oldeman & P.B. Tomlinson, 1978. Tropical Trees and Forests: an architectural analysis. Springer-Verlag, Berlin. 1 - 441.

Jamet, R. 1975 - 1978. Pédogenèse sur roches cristallophylliennes et argileuses en milieu équatorial congolais. ORSTOM, Rapport interne.

Kouba, B. 1987. Les problèmes de production et de commercialisation de la banane douce dans la région du Mayombe. Cas du district de Mvouti. Institut du développement rural. Université Marien Ngouabi. Rapport de fin d'études.

Lanfranchi, R. & D. Schwartz, 1991. Les remaniements des sols pendant le Quaternaire supérieur au Congo. II: Evolution des paysages dans la région du Mayombe. Cahiers ORSTOM, série Pédologie. in press.

Mapangui, A. & J. Sénéchal, 1989. L'agriculture. Revue des connaissances sur le Mayombe. DGRST-Congo, UNESCO et PNUD. UNESCO, Paris. 217 - 233.

Marks, M. K. & A. C. Nwachuku, 1986. Seed bank characteristics in a group of tropical weeds. Weed Research. 26: 151 - 157.

Misset, M. 1989. La pédologie du Mayombe. Revue des connaissances sur le Mayombe. DGRST-Congo, UNESCO et PNUD. UNESCO, Paris. 85 - 92.

Nguembo, J. & J. Sénéchal, 1989. Les transports. Revue des connaissances sur le Mayombe. DGRST-Congo, UNESCO et PNUD. UNESCO, Paris. 295 - 313.

Richards, P. W. 1952. The Tropical Rain Forest: an ecological study. Cambridge University Press, Cambridge. 1 - 450.

Schwartz, D., H. de Foresta, A. Mariotti, J. P. Massimba, & C. Girardin. 1991. Dynamique actuelle du contact forêt-savane dans le Mayombe Congolais. Approche pédologique, botanique et biochimique. in press.

Schwartz, D., R. Lanfranchi, & A. Mariotti, 1990. Origine et évolution des savanes intramayombiennes (R. P. du Congo). I: apports de la pédologie et de la biogéochimie isotopique. Paysages quaternaires de l'Afrique Centrale atlantique. R. Lanfranchi et D. Schwartz. ORSTOM, Paris. in press.

Vennetier, P. 1968. Pointe-Noire et la façade maritime du Congo. Mémoires ORSTOM. ORSTOM, 26: 1 - 458.

White, F. 1983. The vegetation of Africa. Maps & Memoirs. UNESCO AETFAT, UNESCO, 1 - 356.

Yadav, A. S. & R. S. Tripathi, 1982. A study on seed population dynamics of three weedy species of *Eupatorium*. Weed Research. 22: 69 - 76.

Fig.1 Les grands ensembles de relief du Congo
Simplified geomorphology of Congo

1. Plaine côtière - *Coastal plain*
2. Mayombe *(massif)*
3. Vallée du Niari - *Niari valley*
4. Chaillu *(massif)*
5. Plateau et colline - *Hill and plateau*
6. Cuvette congolaise - *Congo basin*

- 1, 3, 6
- 5
- 2, 4

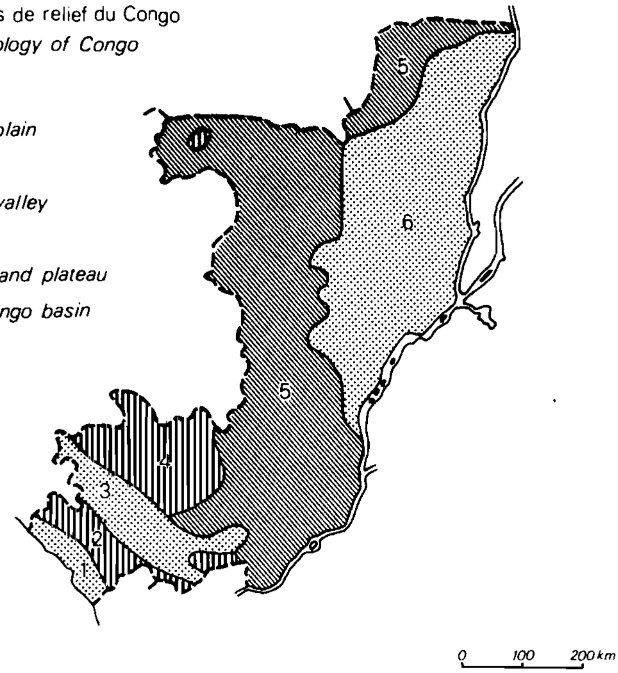
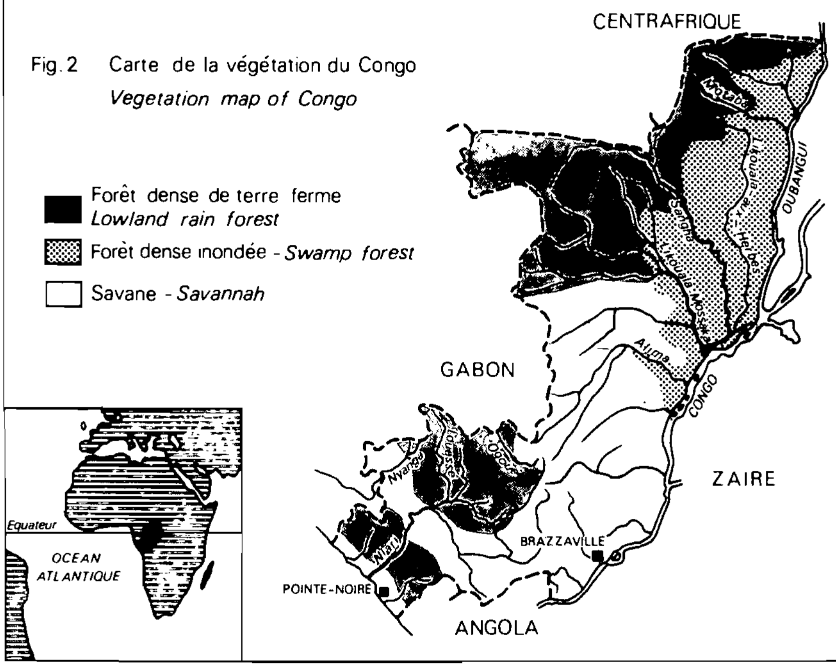
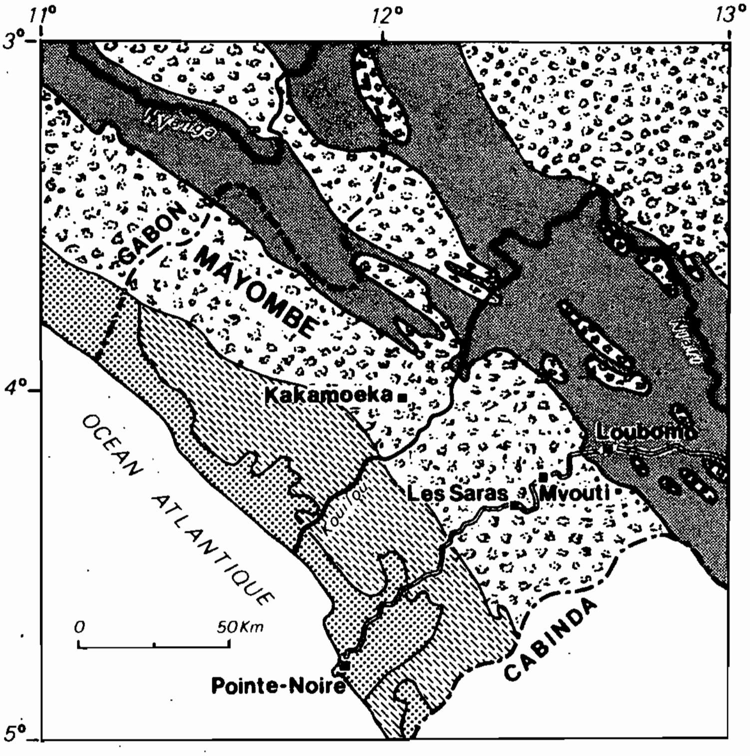


Fig.2 Carte de la végétation du Congo
Vegetation map of Congo

- Forêt dense de terre ferme *Lowland rain forest*
- Forêt dense inondée - *Swamp forest*
- Savane - *Savannah*



Source : Géographie de la République Populaire du Congo



savanes côtières - *coastal savannahs*

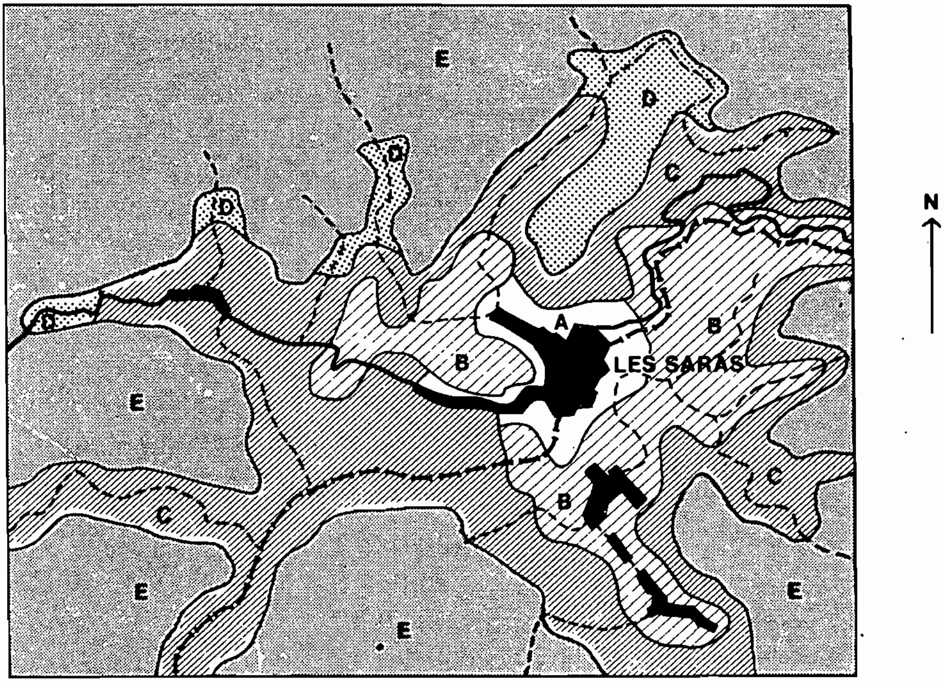
mosaïque forêt-savane de la façade maritime
occidental forest-savannah mosaic

forêts - *rainforests*

savanes du synclinorium Niari-Nyanga
Niari- Nyanga savannahs

railway Congo-Ocean

Fig.3 Le Mayombe congolais - *Congolese Mayombe*



Chemin de fer / *Rail way*

Route N1 / *N1 Road*

Anciennes Pistes Forestières / *Former logging Roads*

A. B.C.D.E: See text for detailed composition

0 5 10 Km

Legends for Figure 4:

Zone A: Mosaic of old banana plantations, oilpalm groves, small cassava fields and *C. odorata* thickets;

Zone B: mainly *C. odorata* thickets, with a few small oilpalm groves and cassava fields;

Zone C: mosaic of pioneer tree fallows and banana plantations, with a few cassava fields and *C. odorata* thickets;

Zone D: new cassava fields and banana plantations at the fringes of the still undisturbed forest;

Zone E: "primary" forest

Fig 4 : ZONATION CULTURES ET DE LA VEGETATION AUTOUR DE LES SARAS
LAND USE AND VEGETATION ZONING AROUND LES SARAS

Table 1: Soil seed bank under various vegetation types (mean number of seedlings per m2)

Vegetation types Species or species group	F1	F1(2)	FF	CF1	CF2
Chromolaena odorata	0	37	29	1119	2035
Ruderal Herbs (20 species)	0	112	702	485	5179
Pioneer Trees (16 species)	243	1039	900	506	112
Forest Herbs (4 species)	0	8	24	0	0
Unidentified (? species)	83	128	83	37	651
TOTAL	327	1376	1740	2147	7970

F1: undisturbed forest far from the village
F1(2): small patch of undisturbed surrounded by fields and fallows
FF: 16 year old pioneer forest fallow after cassava cultivation on undisturbed forest
CF1: 2 year old *C. odorata* fallow after cassava cultivation on pioneer forest fallows
CF2: 3 year old *C. odorata* fallow after cassava cultivation on *C. odorata* fallow

Table 2: Main floristic and structural characteristics of pioneer forest fallows after cassava cultivation (Les Saras, MAYOMBE)

Species or group of species	FF1				FF2				FF3			
	N	%	A.B. cm2	%	N	%	A.B. cm2	%	N	%	A.B. cm2	%
Musanga cecropioides	164	54	9611	96.9	174	53	21070	98.1	36	20	16345	85.1
Manihot esculenta	30	10	81	0.8	4	1	14	0.1	13	7	47	0.2
Bertiera racemosa	60	20	67	0.7	56	17	93	0.4	12	7	64	0.3
Porterandia cladantha	0	0	0	0.0	22	7	27	0.1	22	12	94	0.5
Macaranga spp.	0	3	69	0.7	5	2	50	0.2	7	4	153	0.8
Other species	34	11	77	0.8	39	12	138	0.6	46	26	538	2.8
Other species (resprouts)	9	3	13	0.1	30	9	88	0.4	43	24	1960	10.2
TOTAL (plot)	306		9918		330		21480		179		19201	
TOTAL (per Ha.)	7650		247950		8250		537000		2983		320016	

FF1 (400m2); 2 year old fallow ("parcelle Likibi")
FF2 (4oom2); 3 year old fallow
FF3 (600m2); 16 year old fallow ("parcelle Likibi")

N: number of trees with diameter at breast height higher than 1 cm
A.B.: basal area (trees with diameter at breast height higher than 1 cm)

Table 3: Above ground Phytomass of *C. odorata* fallows (Dry weight) of various *C. odorata* fallows

Species or group of species	CF1 Kg/Ha	%	CF3 Kg/Ha	%	CF2 Kg/Ha	%	CF4 Kg/Ha	%
	C. odorata Fallows							
Chromolaena	5876	36	8320	65	18052	64	13856	84
Cassava	1912	12	200	1	1968	7	508	3
Pioneer trees	5772	36	520	4	7248	26	604	4
Resprouts	604	4	0	0	0	0	0	0
Vines	1444	9	0	0	880	3	1480	9
Herbs	548	3	3840	30	20	0	120	0
TOTAL	16156		12880		28168		16568	

CF1: 2 years old, after cassava cultivation on pioneer forest
CF2: 3 years old, after cassava cultivation on *C. odorata* fallow
CF3: 1 year old, after cassava cultivation on *C. odorata* fallow
CF4: 7 years old, after cassava cultivation on pioneer forest

Table 4: Main chemical characteristics of surface soils under undisturbed forest, pioneer forest fallows and *C. odorata* fallows

No.HFDS	pH (H20)	C %	N %	C/N	Ca me/ 100g	Mg me/ 100g	K me/ 100g	Na me/ 100g	S me/ 100g	C.E.C. me/ 100g	S/CEC %
16.0	4	3.62	0.197	18.4	0.81	0.21	0.27	0.23	1.52	35.15	4.3
10.0	4.2	2.9	0.195	14.9	0.85	0.12	0.26	0.23	1.46	33.03	4.4
8.1	4.6	2.03	0.169	12.0	0.84	0.27	0.18	0.1	1.39	24.43	5.7
12.0	4.5	2.3	0.15	15.6	0.42	0.16	0.22	0.03	0.83	14.92	5.5
12.1	4.3	2.23	?	?	0.56	0.25	0.29	0.17	1.27	33.38	3.8
11.0	4.9	1.6	?	?	1.52	0.27	0.21	0.13	2.12	20.78	10.2
5.1	4.3	2.05	0.15	13.5	0.52	0.27	0.14	0.03	0.96	12.67	7.6
9.0	4.1	2.15	0.16	13.9	1.15	0.27	0.22	0.12	1.76	31.03	5.7
13.0	6.3	1.82	0.17	10.6	7.06	0.94	0.27	0.29	8.56	25.53	33.5
8.1	4.6	2.03	0.17	12.01	0.84	0.27	0.18	0.1	1.39	24.43	5.7
14.0	6	1.94	0.13	14.7	5.71	0.63	0.18	0.27	6.79	22.33	30.4
4.1	3.8	2.38	0.14	17.5	0.3	0.1	0.27	0.1	0.77	27.83	2.8

HFDS 8.1; 12.1; 5.1; 4.1; undisturbed forest
HFDS 16: 2 year old pioneer forest fallow
HFDS 10: 3 year old pioneer forest fallow
HFDS 12: 7 year old pioneer forest fallow
HFDS 11: 16 year old pioneer forest fallow
HFDS 9: 2 year old *C. odorata* fallow (CF1, "parcelle Likibi")
HFDS 13: 3 year old *C. odorata* fallow(CF2)
HFDS 14: 7 year old *C. odorata* fallow (CF4)

Table 5: Effect of high temperature on the soil seed bank under *C. odorata* fallow (number of seedlings per m2, two months after treatment)

Species or species group	80°c 5 minutes	80°c 1 hour	80°c 12 hours	130°c 5 minutes	130°c 1 hour	No Treatment
Chromolaena odorata	1412	497	60	1431	20	1352
Oldendia corymbosa	5149	5388	2266	5050	497	5189
Lindernia numuraliifolia	1869	1889	159	1431	0	2087
Ageratum conyzoides	417	755	0	596	0	596
Laportea aestuans	636	1491	40	517	20	457
Peperomia pellucida	119	80	20	60	0	119
Musunga cecropioides	0	298	0	0	0	60
Physalis angulata	179	517	99	139	20	278
Paspalum spp.	258	338	99	557	0	258
Cyperaceae spp.	338	437	179	179	0	239
Asteraceae sp. 1	60	60	20	60	0	0
Phyllanthus sp. 1	20	60	0	99	0	40
Phyllanthus sp. 2	0	60	0	0	0	0
unidentified spp.	139	40	0	99	0	40
TOTAL	10974	12565	3101	10636	557	11014

OBSERVATIONS ON CHROMOLAENA ODORATA (L.) R.M. KING AND H. ROBINSON IN INDONESIA

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INTRODUCTION

The occurrence of *Chromolaena* (=*Eupatorium*) in Indonesia which was probably *Chromolaena odorata* (L.) R. M. King & H. Robinson was mentioned as early as 1912 at Deli, on the east coast of North Sumatra. In 1862 the cultivation of the famous Deli tobacco was started in this area. The appearance of *Chromolaena* in North Sumatra therefore seems to coincide with the advent of the first large commercial tobacco, rubber and oil palm plantations at the turn of the century. The weed was either accidentally or deliberately introduced.

Further confirmation of its presence in Sumatra was reported by van der Laan (1914) and Biswas (1936). *C. odorata (=E. odoratum)* was considered to be a very dangerous alternate host of the vectors of tobacco pseudomosaic disease. In Java, *C. odorata* seems to have appeared later than in Sumatra.

C. odorata occurs in Sumatra, Java, Bali, Kalimantan and as far east as Lombok and Timor. (A bibliography of *Chromolaena odorata* (L.) R. M. King and H. Robinson in Indonesia is appended).

OBSERVATIONS IN AREAS WHERE C. *ODORATA* HAS ESTABLISHED

1. Sumatra

Although *C. odorata* is widespread in Sumatra, from Aceh to Lampung, there are areas where this plant does not exist due to higher altitude, isolated regions and in unsuitable soils.

a. Effect of the higher altitudes

During a survey in the mountains of Sumatra where observations were carried out every 20 km, in the "Bukit Barisan" from Pematang Siantar to Tarutung, Padang Sidempuan, Bukit Tinggi and Padang, *C. odorata* completely disappears above 1,100 m, after Balige as far as Sipahulan near Tarutung. Inside Bukit Barisan, the weed does not even occur at lower altitudes (800 to 900 m) beyond Padang Sidempuan as far as Bukit Tinggi, whereas it exists in Samosir with its special microclimate at 1,000 m.

Along the transverse road from the east coast (Kota Pinang) to the west coast (Sibolga), via Padang Sidempuan, *C. odorata* has invaded at least all the roadsides; the situation is the same along the transverse road from Pekanbaru to Bukit Tinggi - Padang, but only as far as Paya Kumbuh.

b. Isolated Places

There is no *C. odorata* in west coast areas isolated by the high altitude of Bukit Barisan and not linked by the lower transversal roads to the west coast; such is the case of the coastal area south of Padang.

c. Soil type

On sandy soils along the east coast, *Chromolaena* is well established north and south of Medan as far as Tanjung Balai and Bandar Aceh respectively. However, *C. odorata* seems unable to develop on peat soils, such as in Riau Province: Rengat, Tembilahan, Sungai Gantung, Pulau Burung, where other weeds such as *Mikania* totally invaded very quickly after deforestation for the new oil palm and coconut plantations.

The spread of *Chromolaena* in Sumatra is therefore limited by altitude of the Bukit Barisan, where the plant is unable to develop above 1,000 m or in isolated places below 1,000 m.

In addition, *C. odorata* has still not been noted on peat soils.

2. Kalimantan

During our visits to different estates in Kalimantan, *C. odorata* was seen in West, East and South Kalimantan, but it gradually disappears towards Central Kalimantan where road access is less.

3. Java

C. odorata is everywhere except at high altitudes. In drier areas such as East Java it covers extensive areas with dense growth.

A marked dry period during the year seems to favour *C. odorata* flowering and seed production. This is also the case in the South Sumatra (Lampung).

OBSERVATIONS IN AREAS WHERE *C. ODORATA* HAS NOT PREVIOUSLY BEEN REPORTED

1. Sulawesi

During our survey in Sulawesi, *Chromolaena* was found to be very dense in South Sulawesi Province: Ujung Pandang to the North, Parepare to Polewali on the west coast, Watampone to Palopo on the east coast. Beyond this on the border of Bone bay from Sabbang to Wotu, *C. odorata* was not noticed. On the otherhand, in the Jeneponto area, *C. odorata* growth is considerable, especially in the dry areas of South Sulawesi.

In the Torajaland, *C. odorata* does not exist at high altitudes. *C. odorata* was only seen on the road from Palopo to Rantepao for 20 km beyond Palopo, but to the South it exists from Makele to Kalosi - Enrekang - Rapang - Pangkajene. Near Enrekang, at lower altitude, where cattle farming has been developed, *C. odorata* has become established over a wide area. The weed is not eaten by the cattle and forms very dense *C. odorata* thickets, thereby very quickly reducing the acreage of pastureland.

In North Sulawesi, Manado and its surroundings, *C. odorata* has not been observed and probably does not exist.

2. Irian Jaya

In Irian Jaya *C. odorata* has not been reported earlier, but we found this plant particularly well developed in Jayapura, on the site of a former second world war military base.

From the airport to the town, a distance of 33 km, *C. odorata* grows in very dense bushes along the road and on the nearby hillsides. The spread of *C. odorata* can clearly be seen along the coastal roads and in the interior along the only road to the Papua New Guinea border as far as Arso, which is now the limit of the *C. odorata* invasion.

There is no *C. odorata* in the Doberai Peninsula on the western part of Irian Jaya: Manokwari and neighbouring areas.

IV. OBSERVATIONS ON THE FLOWERING TIME OF *C.ODORATA* IN INDONESIA

In Sumatra at Pematang Siantar - Prapat, *C. odorata* is really a "Christmas plant" flowering regularly every year at the end of December and in January. In Riau Province at Kota Pinang, Pekanbaru, this weed was flowering in March-April. In South Sulawesi this weed was flowering in June-July. In Irian Jaya *C. odorata* was without flowers at the end of January and it was said that flowering occurs in March - April.

It seems therefore that the flowering season of *C. odorata* is different according to the altitude and latitude from West to East in Indonesia.

CONCLUSION

Our survey results indicate the recent establishment of *C. odorata* in Sulawesi and Irian Jaya. The area occupied by this weed has been considerably extended to the East more than 1,500 km, about half of the Indonesian Archipelago where it was not reported before. The existence of *C. odorata* in Irian Jaya is a threat to Australia where this weed does not exist but where its introduction is greatly feared.

In recent years *C. odorata* has invaded Indonesia from the West to the East, and probably is already present in Maluku. Only isolated places and some islands, especially in Nusantara, are not yet invaded by this weed.

C. odorata is now one of the main weeds in Indonesia.

BIBLIOGRAPHY OF *CHROMOLAENA ODORATA* (L.) R.M. KING AND H. ROBINSON IN INDONESIA

Alif, A.F.B.M. 1982. Use of herbicides in small scale plantations in South East Asia. Biotrop Special Publication, 15: 83-89.

Amypaluppy, K., A. Sudiman & Siswanto. 1988. The effect of the turbidity of water solvent on the efficacy of Imazapyr on Alang-alang. Conf. Ke IX - Jilid III, 139-143.

Ardjasa, S.W., I. G. Ismail & S. Effendi. 1981. The application of Dowpon M on Alang-alang infested areas, in conjunction with the establishment of food crops. Prosiding Konperensi Ke-Enam, Himpunan Ilmu Gulma Indonesia, 15 - 23.

Aterrado, E.D. & R. L. Talatala-Sanico. 1988. Status of *Chromolaena odorata* research in the Philippines. Proc. First Intern. workshop Biological Control of *Chromolaena odorata*, pp. 53-55. Agri. Expt. Sta., Univ. of Guam, Mangilao, Guam.

Bennett, F.D. & V. P. Rao. 1968. Distribution of an introduced weed *Eupatorium odoratum* Linn. (Compositae) in Asia and Africa and possibility of its biological control. PANS (C), 14: 277 - 281.

Biswas, K. 1936. Some foreign weeds and their distribution in India and Burma. Indian Forester, 60: 861-865.

Budiman, A., M. Thamrin & S. Asikin. 1988. Some weed species growing on tidal land of different soil acidity. Prosiding Konperensi ke IX, Himpunan Ilmu Gulma Indonesia. Bogor, 22 - 24 Maret 1988. Jilid II, 81-92.

C.A.B. International Institute of Biological Control. 1988. Prospects for the Biological Control of *Chromolaena odorata* (L.) R.M. King and H. Robinson. In: R. Muniappan (Ed.) Proc. First International Workshop on Biol. Control of *Chromolaena odorata*, pp. 25-33. Univ. of Guam.

Cruttwell McFadyen, R.E. 1988. History and distribution of *Chromolaena odorata* (L.) R.M. King and H. Robinson. In: R. Muniappan (Ed.) Proc. First Intern. Workshop Biol. Control of *Chromolaena odorata*, pp. 7-12. Agri. Expt. Sta., Univ. of Guam, Mangilao, Guam.

Dalem, K.W.& A. Soedarsan. 1977. The effect of Buthidazole and new Diphenyl ether on*Chromolaena odorata* (L.) R.M. King and H. Robinson. Menara Perkebunan Bogor. 45(6), 287-289.

Daryono, H. 1985. Effect of age on the composition and development of teak, *Tectona grandis* undergrowth flora. Bul. Penelitian Hutan. 469: 67-93.

Desmier de Chenon, R. 1988. Observations on the presence of *Chromolaena odorata* in Indonesia. Paper presented at the First International Workshop on Biological Control of *Chromolaena odorata*, Bangkok, Thailand, Country Report 3 pp.

Dove, M.R., 1986. The practical reason of weeds in Indonesia: Peasant vs. State Views of*Imperata* and *Chromolaena*. Human Ecology 14:163-190.

Dove, M.R. & S. Martopo. 1987. Manusia dan Alang-alang di Indonesia. 286 p. Gadjah Mada University Press, 1987.

Eussen, J.H.H.& S. Wirjahardja. 1973. Pioneer plants in the secondary forest establishment. The Second Indonesian Weed Science Conference, Yogyakarta, April 2 - 5, 1973: 245-251.

Hamzah, Z. 1978. Forest weed problems in Indonesia. Biotrop Aniv. Publ: 75 - 83.

Holm, L.G., D. L. Plucknett, J. V. Pancho & J. P. Herberger. 1977. The World's Worst Weeds: Distribution and Biology. East West Center, University Press of Hawaii,USA. 609 p.

Johnstone, T. H. & H. Tryon. 1914. Report of the Prickly-Pear Travelling Commission, 1st November 1912 - 30th April 1914. Govt. Printer, Brisbane.

Karyono. 1980. Structure of homegarden in the rural area of Citarum watershed, West Java. Disertation Padjadjaran University. 232 p.

Mangoendihardjo, S. 1975. Prospects of biological control of weeds in Indonesia. 3rd Indonesian Weed Science Conf., Bandung: 33-41.

Mangoendihardjo, S.& M. Soerjani. 1978. Weed management through biological control in Indonesia. Proc. Plant Protection Conference, Malaysia: 323-337.

Muniappan, R.& M. Marutani. 1988. Ecology and distribution of *Chromolaena odorata* in Asia and the Pacific. In: R. Muniappan (Ed.) First InInternational Workshop on Biological Control of *Chromolaena odorata*. pp. 21-24. Agricultural Experiment Sta., Univ. Guam, Mangilao, Guam.

Naezer, H.W. & J.C. van der Meer Mohr. 1953. Insects and *Eupatorium odoratum*. Trop.Natur. Bogor, 33: 59-60.

Nasution, U. 1981. Inventory of weeds in rubber estate of North Sumatra and its relation with weed management. Prosiding Konp. ke-enam Himpunan Ilmu Gulma Indonesia, Medan 12-14 Februari 1981: 193-210.

Nasution, U. 1986. Gulma dan pengendaliannya di perkebunan karet Sumatra Utara dan Aceh. Pusat Penelitian dan Pengembangan Perkebunan Tanjung Morawa (P4TM). 269 p.

Pancho, J.V. & D.L. Plucknett. 1972. *Chromolaena odorata* (L.) R.M. King and H. Robinson. A new record of noxious weed in the Philippines. Phil. J. Ani. Sci. 8: 143-149.

Partomihadjo, T. & Suhardjono. 1988. Analysis of weed vegetation in the field after cassava cultivation at Cibinong - Bogor. Prosiding Konp. ke IX Himpunan Ilmu Gulma Indonesia, Bogor 22 - 24 Maret 1988, Jilid II: 140 - 153.

Ramlan, A. 1988. Weed species which were used as Traditional Medicinal Plants. Prosiding Konp. Ke IX HIGI, Jilid III, 1988: 276-283.

Ramlan, A.& Y. Dahyat. 1988. Weed species in the various types of vegetation in the inundated areas of the Saguling and Cirata Reservoirs. Prosiding Konp. Ke IX Himpunan Ilmu Gulma Indonesia, Bogor 22-24 Maret 1988, Jilid III: 234-241.

Risdiono, B. 1975. The inter-influence between *Chromolaena odorata* L. and *Brachiaria brizantha* Stapf. and the effect of Picloram on these plants. Proc. third Indonesian Weed Science Conf., Bandung, June 24 - 28: 367-376.

Sastroutomo, S. S. & E.T. Pandegirot. 1988. Ecological survey of weeds at Ciliwung tea plantation, West Java. Prosiding Konp. Ke IX HIGI, Jilid III: 233-253.

Setiadi, D. 1988. Notes on Weeds in Teak Forests. Pros. Konp. Ke IX HIGI, Jilid III: 74-77.

Siregar, H.H., T. L. Tobing & R. Sukarji. 1990. Dominasi gulma pada daerah pengembangan perkebunan kelapa sawit di Tapanuli Selatan (Sumatera Utara) dan Riau. Kongres I, Himpunan Perlindungan Tanaman Indonesia, Jakarta 8-10 Februari 1990. Makalah 320, 11 p.

Soedarsan, A., Noormandias & H. Santika. 1975. Glyphosate versus Dalapon for Alang-alang control. Proc. third Indonesian Weed Science Conference. Bandung, June 24-28: 428-436.

Soerjani, M., A. Soedarsan, S. Mangoensoekarjo, T. Kuntohartono & M. Sundaru. 1975. Weed problems and prospects for chemical control in Indonesia. 5th Conference of the Asian Weed Science Society: 18-22.

Soerjani, M., A.J.G.H. Kostemans & G. Tjitrosoepomo (eds.) 1987. Weeds of rice in Indonesia. Balai Pustaka Jakarta, 716 p.

Soerohaldoko, S. 1971. On the occurrence of `*Eupatorium odoratum* at the game reserve Penanjung, West Java, Indonesia. Weeds in Indonesia. Weed Science Society of Indonesia, Bogor. 2(2).: 9.

Soerohaldoko, S. 1973. Some remarks on the seed germination of *Chromolaena odorata* (L.) R.M. King and H. Robinson. The Second Indonesia Weed Science Conference Yogyakarta, April 2-5, 1973: 167-171.

Soerohaldoko, S. 1975. The after effect of filtered sunlight through green leaves on the seed germination of *Chromolaena odorata* (L.) R.M. King and H. Robinson compared with that of sunlight and darkness. Proceedings of the third Indonesian Weed Science Conference, Weed Science Society of Indonesia. Bandung, June 24 - 28, 1975: 12-17.

Sudiman, A. & K. Amypaluppy. 1988. The efficacy of Triclopyr against leguminous cover crops in the planting strips of young rubber. Prosiding Konp. Ke IX HIGI, Bogor 22 - 24 Maret 1988, Jilid III: 286-295.

Sumardja, E.A. & K. Kartawinata. 1977. Vegetation analysis of the habitat of banteng (*Bos javanicus*) at the Pananjung-Pangandaran Nature Reserve, West Java. Biotrop Bulletin, 13, 1977. 43 p.

Syed, R.A. 1973. Some aspects of biological control of weeds in South East Asia. The second Indonesian Weed Science Conference, Yogyakarta, April 2-5: 311-317.

Syed, R.A. 1977. An attempt on biological control of *Eupatorium odoratum* L. in Sabah, Malaysia. 6th Conf. Asian Pacific Weed Science Society, Jakarta: 457-466.

Tjitrosemito, S., S.S. Sastroutomo & I. H. Utomo. 1986. Weed management in a young rubber plantation in Indonesia. Weedwatcher. 1 (Supplement). 4 p.

Tobing, T.L. & C. Hutauruk. 1984. Identification of weeds found in oil palm plantations. Pedoman Teknis, Pusat Penelitian Marihat (No. 83): 10 p.

van der Laan, P.A. 1914. Motschildhuis en Eupatorium als oorjaken van pseudomozaiek. Vlugschr. Deli. Proefst. Medan, 67: 4 p.

Vayssiere, P. 1959. Agronomie Malaisie, Notes de mission. La culture et les parasites du Tabac a Sumatra. Journ. Agri. trop. Bot. appl. pp. 281-302.

Whitten, A.J., S. J. Damanik, J. Anwar & N. Hisyam. 1984. The ecology of Sumatra. Gadjah Mada University Press. 583 p.

Whitten, A.J., M. Mustafa & G. S. Henderson. 1988. The ecology of Sulawesi. Gadjah Mada University Press. 777 p.

Widyarmoko & H. Ryanto. 1986. Pengelolaan gulma pada lahan bukaan baru pengalaman di perkebunan tebu Gunung Madu plantations Lampung. Prosiding Konp. Ke VIII HIGI, Bandung 24 - 26 Maret 1986: 143-151.

Yusron, A. 1988. Weed Inventory in Corn Crop in the Transmigration Area of UPT A-1 Pangkalan Kersik, Regency of Musi Banyuasin, South Sumatra. Prosiding Konperensi Ke IX Himpunan Ilmu Gulma Indonesia. Bogor, 22 - 24 Maret 1988. Jilid III: 59-73.

PRELIMINARY RESULTS OF A SURVEY AND ASSESSMENT OF *CHROMOLAENA ODORATA* (SIAM WEED) IN AFRICA

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INTRODUCTION

Chromolaena odorata L. (R. M. King & H. Robinson) (*Eupatorium odoratum* L.) is an introduced herbaceous, annual or perennial woody herb or shrub which has become widespread in West and Central Africa. It has assumed various growth habits depending on the habitat in which it occurs. It does not take the plant long to become established once it finds an open, available niche. It grows and spreads very rapidly to cover the ground. In the process, it chokes and prevents other resident plant species from growing. It also prevents its own seedlings from becoming established.

The perennial and vegetative reproductive habits have made the plant become part of and integrated with the flora in most West African countries. In arable lands, it has become a nuisance during the crop growing season. It also disturbs seedlings of cash crops in young plantations. In this context, it has assumed a pest status because of its interference with food production and the economy in general.

Furthermore, the extent of its distribution and abundance is not fully known except perhaps in Ghana, Nigeria and Cote d'Ivoire. As a result of the threat posed by this weed to the economy and more especially to food production in the region, the Food and Agriculture Organisation of the United Nations (FAO) Regional Office for Africa is conducting a survey on *Chromolaena odorata* in Africa, to assess the extent and severity of its distribution, establish the state of knowledge on the biology and control of the weed and make an inventory of past and current research work. Surveys have been conducted in Ghana, Sierra Leone, Liberia, Cameroon and Nigeria. The following broad generalizations can be made out of the survey.

BACKGROUND INFORMATION AND DISTRIBUTION

C. odorata is an introduced perennial shrub common in the humid and semi-humid areas of the countries visited. Initial establishment is usually by seed which is an achene with a pappus of white bristles. Flowers occur in clusters of 10-20, in terminal cymes in axils of upper leaves. Colour of flowers can be either white, mauve or navy blue. After establishment the weed then achieves prodigious lateral spread by vegetative means. The origin of the weed in Africa is obscure but in most cases it was believed to have occurred as a contaminant in seed lots of *Gmelina arborea*, a forest tree species, which were imported from Malaya for use in reafforestation schemes in several West African countries during the sixties. Within two decades after it was noticed in most countries, except in Nigeria where it was recorded about four decades ago, the weed has spread from east to west and has replaced most of the other natural bush fallow species in the forest, transitional forest and parts of the wet Guinea Savannah vegetative zones.

Almost invariably, in all the countries visited the weed was found to occur within a belt between latitude 2° and 8° N stretching from east to west and in areas receiving more than 1000 mm rainfall per annum. The weed spreads and grows so fast that an impenetrable thicket is developed within about two seasons.

ECONOMIC IMPORTANCE

C. odorata has become the common weed of open spaces such as crop lands, roadsides and utility rights-of-way. It is also an important weed in young oil palm, cocoa, rubber plantations and other tree crops in the areas affected. As such, it interferes with both food and cash crops causing reduction of yields in the competition for light, moisture and nutrients and to some extent, by allelopathic effects. Extent of yield losses is yet to be determined.

Perhaps the most important effect of the weed on production is its high cost of control especially on small-holdings. A high input of labour is required for the initial clearing and subsequent frequent post-planting weedings necessary to reduce crop losses. The slash and burn method of land preparation is ineffective against this weed, but rather tends to aggravate the problem. This is because when the weed is slashed, regrowth can occur from buds on the above-ground portion of the stem and the root crown. Complete control can only be achieved by slashing, burning and uprooting the stumps manually.

C. odorata also constitutes a fire hazard in areas with a prolonged dry season (bimodal rainfall distribution). Large quantities of combustible plant debris are produced in the dry season and the dried vines serve as fire transmitting lines in the event of bush fire outbreaks causing the fire to spread far and wide. Large tree crop estates have been destroyed this way in Ghana and Nigeria.

Still on the negative side, the weed is known to harbour harmful insects under its dense canopy. Species of *Zonocerus* grasshopper breed freely under the canopy where they are protected from predators. From there they move on to neighbouring cassava farms, feeding on the leaves and thereby reducing crop yields.

On the positive side the weed may have some potential values, chief among which is the addition of organic matter to the soil through copious production of leaf litter. There are also indications, by way of 'farmer discovery notes', that *C. odorata* can reduce incidence of nematodes when used as a fallow crop.

Furthermore, the weed may have potential for soil erosion control on account of its vigour and rapid lateral spread. In some places, it is being used for curative and therapeutic purposes.

STATE OF KNOWLEDGE OF THE WEED

It is surprising that very little research work has been undertaken on such an important weed. Most of the research has been carried out in Nigeria and Ghana by individual researchers spread in universities and institutes responsible for cash crops such as rubber, cocoa and oil palm. There has been no attempt to prioritize and orchestrate these individual research efforts into one cohesive endeavour to find solutions to the problem of *C. odorata*. To date, research work carried out on the weed falls into two main categories, biology and control.

BIOLOGY

In Ghana, some aspects of reproductive biology, seed longevity, vegetative development and inherent germination inhibitors are being studied. In Nigeria, the effect of *C. odorata* on the performance of establishing Iroko trees (*Chlorophora excelsa* now *Milicise excelsa*) was studied. Attention was also focused on the possible use of the weed as a fallow crop for rapid nutrient regeneration of soils. Fields of maize were improved by 1-year *C. odorata* fallow in this context.

MANUAL CONTROL

In general, the control measure taken to check growth of the weed in arable land and prevent its spread is slashing and burning, and to a limited extent mechanical ploughing. Ploughing to a depth of 15 cm or more is known to destroy the weed completely and that perhaps accounts for its absence on mechanized holdings.

The manual method of control, involving the initial slashing and burning followed by frequent post-planting hoeings on small holdings, is very tedious and requires high labour input. This has led to the spate of research activities in the areas of chemical and biological control.

CHEMICAL CONTROL

Several pre-emergence and post-emergence herbicides have been evaluated and found useful for control of *C. odorata* in young cocoa and oil palm plantations. These include paraquat and paraquat-based mixtures with diuron (Paracol and Gramuron), 2,4-D, atrazine, glyphosate, terbuthylazine, triclopyr, ioxynil, fluorodifen, etc.

In most cases the herbicides failed to give season-long control and repeated, costly applications were often necessary in young cocoa and oil plantations. For a herbicide to be effective it must be phloem mobile so that enough of it is translocated basipetally to reach and kill the deeply seated buds on the underground portion of the stems of the weed. On this basis, only products such as glyphosate, triclopyr and to some extent, 2,4-D out of the long list of candidate herbicides deserve serious attention. Stage of growth of the weed at the time of application tends to influence the direction of movement of synthates along which these herbicides move and consequently is an important determinant of herbicide efficiency in perennial weeds.

BIOLOGICAL CONTROL

C. odorata appears to be a perfect target for biological control which is relatively cheap and environmentally safe. The weed is an introduced species and therefore there might exist insects or other natural enemies in its area of origin (South America) which are absent in West Africa. It is a perennial weed, widespread and abundant, ensuring constant food supply for any introduced enemies. Several natural enemies, mostly insects, have been introduced but apparently with little success in Africa. These include the arctiid moth *Pareuchaetes pseudoinsulata* (Rego Barros) (Syn: *Amalo insulata* (Walker)) introduced in Ghana and Nigeria and *Apion brunneonigrum* introduced in Ghana. In all cases the insects failed to establish.

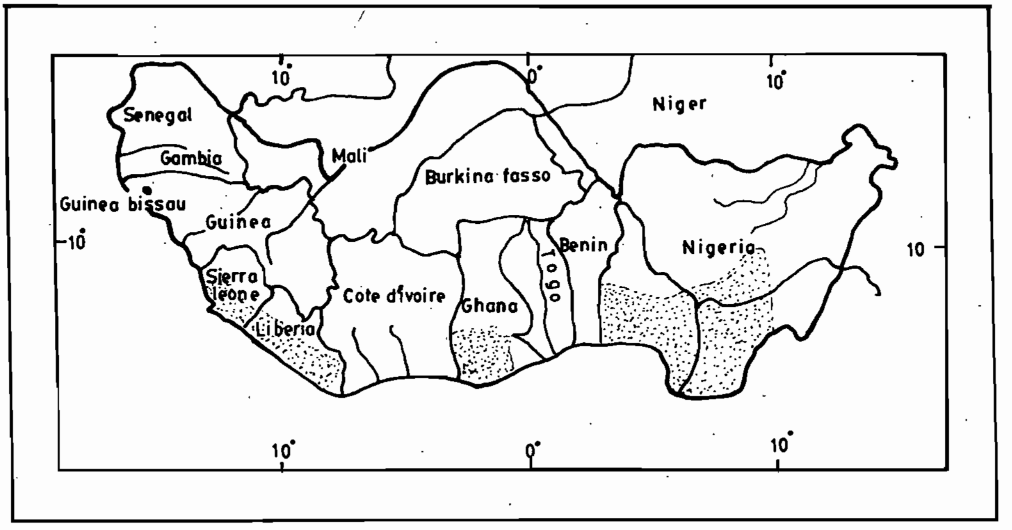

Fig. 1. Map of West Africa showing present distribution of *C. odorata* in countries visited.

THE STATUS OF *CHROMOLAENA ODORATA* (L.) R.M. KING AND H. ROBINSON IN INDONESIA

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ABSTRACT

Chromolaena odorata (L.) R.M. King & H. Robinson is known in Indonesia as kirinyu. It is a native of the neotropics. It was introduced to India in the 1840s as an ornamental plant, from where it spread to the Southeast Asian region. The first herbarium specimen identified later as *C. odorata* was collected in 1934 from Lubuk Pakam, North Sumatera. Since the Second World War it spread rapidly in Indonesia and received the name "independence shrub". It has become an important weed in forests, pastures and in plantation crops. Manual weeding is done commonly and chemical control is used only in the plantations. Biological control has not yet been taken up in Indonesia. Because of its rapid spread, it is imperative that its biology and ecology be studied and appropriate control measures be established.

INTRODUCTION

When Beumee (1922) made an inventory of undergrowth species in teak plantations in the island of Java he did not find kirinyu (*Chromolaena odorata* (L.) R.M. King and H. Robinson) at that time. However about 50 years later, foresters in central and east Java were startled by the heavy infestations of *C. odorata* that occurred. Subsequent investigation has indicated that infestation of *C. odorata* significantly reduced the growth of young teak plants (Daryono & Hamzah, 1979). Soerohaldoko (1971) also observed the occurrence of *C. odorata* at the game reserve of Penanjung, West Java, and blamed a reduction in the grazing area of banteng (*Bibos javanicus*) on this infestation of *C.odorata*. Other recent reports have given more information on the harmful effects of *C. odorata* (Nasution 1986, Tjitrosoedirdjo et al. 1984, Soerjani 1977).

TAXONOMIC ASPECTS

Kirinyu belongs to the family Asteraceae. For a long time the Asteraceae was divided into 12 tribes. However, with recent findings in biochemistry, pollen analysis, anatomy and cytology, the family Asteraceae has undergone considerable modification (Heywood 1979). Currently, this family is divided into two sub-families Lactucoideae and Asteroideae. Kirinyu is a member of the tribe Eupatoriae, within the sub-family Lactucoideae, which is characterized by white, reddish or bluish flowers lacking ray florets.

Kirinyu was previously included in the genus *Eupatorium* but is now under the genus *Chromolaena*. It is distinguished by the rather consistent pattern of many rows of phyllaries (bracts) that are progressively longer and give a markedly cylindrical appearance to the head, by the three prominent veins in the leaves and by the pungent odor emitted by the crushed leaves.

The genus *Chromolaena* contains 129 species and all are found in the neotropics (King and Robinson 1970). Of these *C. ivaefolia* (L.) and *C. larvigata* (Lamarck) are widespread and occasionally weedy in the Americas, but only *C. odorata* has spread to the Old World (Cruttwell McFadyen 1989).

SPREAD OF *C. ODORATA*

Based on information from Voight (1845) who listed *C. odorata* as a garden plant in Calcutta, India, from Hooker (1882) who reported that *C. odorata* was cultivated although very rarely, and from Prain (1903, 1906) who stated that it was cultivated sparingly in gardens of Central and East Bengal and around Calcutta, Cruttwell McFadyen (1989) concluded that *C. odorata* was introduced into Calcutta as an ornamental in the 1840s from where it gradually spread south into lower Burma and eventually reached Malaya by 1918. It was recorded as a serious and rapidly spreading weed in Burma, Assam and Bengal in 1920 (Ramachandra Rao 1920) and as a dangerous weed in Sri Lanka in 1944 (Grierson 1980). Once established in the Bengal-Lower Burma-Malaya area, *C. odorata* spread rapidly throughout southeast Asia. Its spread to new areas was assisted by the extensive movement of people, machinery and materials during the World War II (Cruttwell McFadyen 1989). In Sumatera this weed is sometimes called as "semak merdeka" or "independence shrub" because it became abundant after the independence war. In Indonesia the first herbarium specimen of *C. odorata* was collected in 1934 from Lubuk Pakam, North Sumatra by van Meer Mohr and kept at the Herbarium Bogoriense (4004). This specimen was identified as *Eupatorium repandum*, but later was reidentified by van Steenis as *Eupatorium odoratum* (Tjitrosoedirdjo 1990).

The exact year of introduction of *C. odorata* to Indonesia is not known. It is probable that it was introduced a few years before 1934, when the first herbarium specimen was collected.

It is now spread all over the islands of Indonesia from Aceh to West Irian.

ECOLOGICAL STATUS

C. odorata is a perennial shrub forming dense tangled bushes up to 3 m in height. Although it burns readily, it resprouts from its stump immediately after the rains. This ability coupled with its fast growth rate enables it to compete well with alang-alang (*Imperata cylindrica* (L.) Raeuschel) and shade it out. This condition will facilitate further vegetational succession toward secondary forest.

Eussen & Wirjahardja (1979) observed 4 stages of successional development from grass-type alang-alang vegetation (a sign of critically degraded environment) to an early secondary forest stage (a more desirable ecological condition), i.e. (1) *Imperata* formation, where the vegetation is still dominated by alang-alang, an indication of a critical, degraded environment. (2) The *Imperata - Chromolaena* formation, in which the area is dominated by alang-alang and *C. odorata.* (3) The *Chromolaena* formation where *C. odorata* dominates the vegetation. (4) The early young stage of secondary forest, where with the disappearance of grassy vegetation trees will establish: this is preceded by the domination of shrubs, such as *C. odorata* , *Melastoma malabathricum, Trema orientalis* and *Bridelia monoica.*

A similar observation was reported by Tanimoto (1981) in South Sumatera. In its role in vegetational succession from the alang-alang community, a sign of degraded environment, to a secondary forest community, *C. odorata* performs a useful function. However, pastoral land infestation of *C. odorata* is undesirable.

WEED STATUS

Forest plantations

The existence of this weed, *C. odorata* , is a concern for foresters in teak plantations. It reduces the growth of teak seedlings and results in reduced stem diameter. The fresh biomass of *C. odorata* in a teak plantation per hectare was reported to be a total of 18.7 tons, consisting of leaf 6.8 tons, stems 10.2 tons and underground parts 1.7 tons. This constitutes approximately a total of 3.7 tons of dry matter/ha. The elemental content of the biomass is listed in Table 1.

Table 1. Mean percentage of some constituent elements of *C. odorata* (modified from Daryono & Hamzah 1979)

Plant part	Elemental content (%)					
	N	P	K	Ca	Mg	Na
Leaf	5.89	0.74	3.13	3.30	0.83	0.01
Stem	1.00	0.23	1.73	0.37	0.18	0.01
Root	0.87	0.13	0.93	3.30	0.15	0.01

When the biomass is converted to its elemental constituents, in each hectare *C. odorata* will accumulate approximately 103.4 kg of N, 15.2 kg P, 80.9 kg K and 63.9 kg Ca. These nutritional elements are thus not available for the growing young teak as they are stored in *C.odorata.*

It was also reported that *C. odorata* transpired about 1908 mm of water per year. This amount of loss may not be much of a concern in wetter regions, but in areas where teak plantations are established (especially in Central and East Java) such water loss is certainly damaging to young teak. In such situations it seems that the occurrence of *C. odorata* should be controlled.

Pastoral land

In natural pasture land, as exemplified by the reserve at Penanjung, West Java, the infestation of *C. odorata* can be detrimental when left uncontrolled. Infested pastures are changed into secondary forest succession and this reduces herbage for banteng. As a result banteng migrated out of the reserve and disturbed the adjacent agricultural areas.

Prawiradiputra et al. (1986) investigated the effect of *C. odorata* on the production of grass herbage in a natural pasture land, and found that it reduced the grass herbage considerably as described by this equation:

$y = 178.09 - 3.51\ x_1$, where

y = herbage yield, and
x_1 = summed dominance ratio of *C. odorata*

When *C. odorata* is associated with *I. cylindrica*, the pasture quality is reduced. However, suppression of *C. odorata* in such situations may result in *I. cylindrica* becoming the dominant vegetation.

Perennial crop plantations

The importance of *C. odorata* as a weed in plantation crops such as in rubber, oilpalm, coconut, cocoa and others has been well documented (Soerjani et al. 1976, Wargadalam & Soedarsan 1977, Nasution 1981, Tjitrosoedirdjo et al. 1984).

Nasution (1981) showed that it is second only to alang-alang in terms of its harmfulness in plantation crops (Table 2). The effect of *C. odorata* on the growth of rubber trees is shown in Table 3.

Table 2. Classification of vegetation under rubber plantation for management purposes (modified from Nasution 1981)

Vegetation Group	Botanical name	Management option
A. Useful vegetation	1. *Calopogonium caeruleum* (Benth.) Hemal 2. *C. mucunoides* Desv. 3. *Centrosema pubescens* Benth. 4. *Pueraria phaseoloides* Benth.	Desired cover crops; when climbing the crop is controlled
B. Harmless vegetation	1. *Ageratum conyzoides* L. 2. *Cyrtococcum* spp. 3. *Digitaria* spp. 4. *Erechtites valerianifolia* (Wolf.) D.C. 5. *Phyllanthus niruri* L.	
C. Harmful when excessive	1. *Axonopus compressus* (Swartz.) Beauv. 2. *Borreria latifolia* (Aubl.) K Sch. 3. *Cyclosorus aridus* (Dor.) Ching 4. *Cynodon dactylon* (L.) Pers. 5. *Cyperus* spp. 6. *Echinochloa colonum* (L.) Link 7. *Eleusine indica* (L.) Gaertn. 8. *Nephrolepis biserrata* Schott. 9. *Ottochloa nodosa* (Kunth.) Dandy 10. *Paspalum* spp.	In sloping areas, they may act as soil binders to prevent soil erosion, however when excessive should be controlled
D. Harmful	1. *Brachiaria nutica* (Forsk.) Staft. 2. *Chromolaena odorata* (L.) R.M. King & H. Robinson 3. *Gleichenia linearis* Clarke. 4. *Lantana camara* L. 5. *Melastoma affine* D. Don. 6. *Scleria sumatrensis* Retz. 7. *Stachytarpheta indica* (L.) Vahl. 8. *Trema* sp. 9. *Grewia eriocarpa* Juss.	In young plantations should be controlled
E. Very harmful	1. *Imperata cylindrica* (L.) Raeuschel 2. *Mikania* sp. 3. *Mimosa* sp.	Must be controlled under most conditions

Table 3. The girth of rubber trees under various treatments of vegetational covers (modified from Wycherley & Chandapillai 1969).

No.	Treatment	Girth at 60 inch height (in inches)
1.	*Ottochloa*	20.02
2.	Creeping legume	19.81
3.	*Axonopus*	19.55
4.	*Moghania*	19.55
5.	*Melastoma*	18.74
6.	*Brachiaria*	18.64
7.	*Chromolaena*	18.54
8.	*Ficus*	18.51
9.	*Mikania*	18.40

NB : Treatments No. 4, 5, 7 and 8 were controlled by periodic slashing.

C. odorata reduces the girth of rubber trees when compared to those under creeping legume or *Ottochloa*. Other vegetational covers which reduced the growth were *Brachiaria mutica, M. malabathricum* (*affine*), and *Mikania* sp. In most conditions the infestation of *C.odorata* will be accompanied by other associated vegetation. When the infestation is very severe and control measures are inadequate, the growth of the crop will be retarded. In some instances the resulting trees become extremely variable in size. Such crops become worthless to continue maintaining and the field has to be replanted again, with huge financial loss.

CONTROL AND MANAGEMENT

Once an area has become infested, the weed is difficult to control. This is because it produces a great number of seeds, i.e. 93,000 seeds/ plant(Weerakoon 1972). Soerohaldoko (1979) kept *C. odorata* seeds up to 15 weeks in about 12 hours dark and 12 under daylight and found these seeds to be viable.

Manual control

Manual control is the most commonly used method in plantation crops especially in the island of Java where the availability of labor is still reasonably high. Manual control is done by slashing the stem above the ground, but the plant soon resprouts from its base. A more tedious form of control is uprooting *C. odorata*, with almost double the cost of slashing.

A typical program of weed control in young rubber plantation when infested with *C. odorata* is given in Table 4. (Tjitrosemito et al. 1986).

Table 4. Weed control program in young rubber plantations.

No. Activity	Frequency of control per year	Man days
1. Manual weeding between rows against shrubs	once in 2 months (6 x)	48
2. Manual weeding in rows	once in 3 months (4 x)	27
3. Weed control in rows prior to fertilizer application	once in 6 months (2 x)	6

Chemical control

Chemical control is the practice usually used in estate plantations. *C. odorata* is controlled by herbicides such as triclopyr (3;5,5 - trichloropyridinyl-oxyacetic acid), 2,4-D (2,4-dichlorophenoxyacetic acid), picloram (4-amino-3,5,6-trichloropicolinic acid). The rates given in table 5 have been tested and found to be reasonably effective.

In an integrated system, *C. odorata* can be controlled successfully in sugarcane plantations after 5-6 years. This integrated control system, which incorporates appropriate soil cultivation combined with correct timing of pre-emergence herbicide using diuron + 2,4-D amine at (1.6-2.5) + (1.0 + 2.5) kg ai/ha, is able to control *C. odorata* and other common weeds. When isolated specimens escape they can be treated by post emergence spraying using 2,4-D amine + ametryn together with diuron (Widyatmoko & Riyanto 1986).

Table 5. Herbicides used to control *C. odorata*.

No. Herbicides	Rate (kg ai/ha)	References
1. Triclopyr	0.8-1.6	Tjitrosoedirdjo et al. 1984
2. 2,4-D	2.5	Tjitrosoedirdjo et al. 1984
3. Picloram	2.0	Prawiradiputra et al. 1986
4. 2,4,5-T	1.0	Risdiono 1975

Biological control

Work on biological control of *C. odorata* in Indonesia is yet to be initiated. Preliminary surveys indicated absence of any significant local natural enemies. An aphid has been observed to attack young shoots and causes leaf curl.

FUTURE ACTIVITIES

C. odorata is rapidly spreading and covering new areas in Indonesia. It is necessary to understand its ecology to develop appropriate control methods. Research on its biology, ecology, influence of the environment on growth, productivity, population dynamics, and interaction with other species need to be carried out.

C. odorata accumulates considerable amounts of mineral nutrients, resulting in both useful and harmful effects depending upon the point of view. Its ability to shade out alang-alang is considered a desirable property. However in plantation crops and in young cassava fields, the infestation is detrimental.

Its possible uses as a source of green manure, active substances and for nematode control need to be investigated. However, as a weed its population should be suppressed adopting environmentally safe, economical and effective methods such as biological control.

REFERENCES

Beumee, J.G.B. 1922. Floristic-analytische onderzoekingen van de korte flora in kunstmating aangelegde djati plansoenen op Java in verband met de ontwikeling van de djati opstand. Dissertasie Landbouw Hoge School, Wageningen.

Cruttwell McFadyen, R.E. 1989. Siam Weed: a new threat to Australia's north. Plant Protection Quarterly 4: 3-7.

Daryono, H. & Z. Hamzah. 1979. A study of *Eupatorium odoratum* L. weed found in teak plantation. Lembaga Penelitian Hutan, Bogor, Laporan no. 312: 26p. (Forest Reseach Institute, Bogor, Report no. 312: 26p.).

Eussen, J.H.H. & S. Wirjahardja. 1979. Pioneer plants in the secondary forest establishment. Proc. 2nd Indon. Weed. Sci. Conf.: 245-251.

Grierson, A.J.G. 1980. Compositae. In Flora of Ceylon Vol. I. Smithsonian Institute, USA.

Heywood, V.H. 1979. Flowering plants of the world. Oxford Univ. Press. Oxford, London.

Hooker, J.D. 1882. Flora of British India, Vol. III. Spottiswoode, London.

King, R.M. & H. Robinson. 1970. Studies in the Eupatoriae (Compositae), 24: The genus *Chromolaena*. Phytologia 20: 196-209.

Nasution, U. 1981. Inventory of Weeds in Rubber Plantations in North Sumatra and its Relation with Weed Management. Proc. 6th Indonesian Weed Sci. Conf. 193-210.

Nasution, U. 1986. Weed and its Management in Rubber Plantation in North Sumatra and Aceh(in Indonesia). 1st Ed. Pusat Penelitian & Pengembangan Perkebunan Tanjung (P4TM), Medan, Indonesia.

Prain, D. 1903. Bengal plants, Vol I. Botanical Survey of India, Calcutta.

Prain, D. 1906. Contributions to Indian Botany. West Newman & Co., London.

Prawiradiputra, B.R., S. Hardjosoewignjo & S. Tjitrosoedirdjo. 1986. The effect of weed control on the vegetational composition of natural pasture land in Jonggol, West Java. Proc. 8th Indonesian Sci. Conf. : 103-108.

Ramachandra Rao, Y. 1920. Lantana insects in India. Memoirs, Dept. of Agric. in India. Entomol. Series, Calcutta 5: 239-314.

Risdiono, B. 1975. The interinfluence between *Chromolaena odorata* and *Brachiaria brizantha* and the effect of picloram on these plants. Proc. 3rd. Indon. Weed Sci. Conf. 1975, Bandung, Indonesia.

Soerjani, M. 1977. Weed management and weed science development in Indonesia. Proc. 6th. Conf. I: 31-41. Asian-Pacific Weed Science Society Conf. 1:31-41.

Soerjani, M., A. Soedarsan, S. Mangoensoekardjo, T. Kuntohartono & M. Sundaru. 1976. Weed problems and prospects for chemical control in Indonesia. Proc. 5th. Asian-Pacific Weed Science Society Conf. 1975, Tokyo, Japan.

Soerohaldoko, S. 1971. On the occurrence of *Eupatorium odoratum* at the game reserve, Pananjung, West Java. Weed in Indonesia. 2: 9.

Soerohaldoko, S. 1979. Changes in response to light by seed of *Chromolaena odorata* (L.) R.M. King and H. Robinson during storage. Proc. 5th. Indonesian Sci.Conf. 11/8-11/12.

Tanimoto, T. 1981. Vegetation of alang-alang grassland and its succession in the Benakat District of South Sumatra, Indonesia. Bull. For. and For. Product. 314: 11-18.

Tjitrosemito, S., S.S. Sastroutomo & I. H. Utomo. 1986. Weed management in a young rubber plantation. SEAWIC Weed Leaflet 1.

Tjitrosoedirdjo, S., I.H. Utomo & S.S. Sastroutomo. 1984. Tryclopyr for the control of woody weeds in young rubber plantation. Proc. 7th. Indonesian Weed Sci. Conf. 71-77.

Tjitrosoedirdjo, Sri S., 1990. Some notes on *Chromolaena odorata*. Proc. 10th. Indonesian Sci. Conf. 40-46.

Voigt. 1845. Hortus suburbanus Calcuttensis.

Warga Dalem, K. & A. Soedarsan. 1977. The effect of buthidazole and new diphenyl ether on *Chromolaena odorata* (L.) R.M. King and H. Robinsosn. Proc. 6th. Asian-Pacific Weed Sciences Society Conf. : 506-509.

Weerakoon, L. 1972. Studies on biology and control of *Eupatorium odoratum* L. M.Sc. Thesis, Vidyodaya Campus, Univ. of Ceylon.

Widyatmoko & H. Riyanto, 1986. Weed management in newly opened land. (An experience of Gunung Madu Sugarcane Plantation, Lampung). Proc. 8th. Indonesian Weed Sci. Conf. 143-151.

Wycherley, P.R. & M. M. Chandapillai. 1969. Effect of cover plants. J. Rubber Res. Inst. Malaya. 21: 140-157.

DISTRIBUTION AND IMPORTANCE OF *CHROMOLAENA ODORATA* IN COTE D'IVOIRE

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INTRODUCTION

Chromolaena odorata is native to South and Central America. It was introduced into West Africa in 1936-1937 as seeds mixed with seeds of *Gmelina arborea* in Enugu (Nigeria) from Sri Lanka (Odukwe 1965). In Cote d'Ivoire *C. odorata* was first reported in 1972 (Ivens 1972). Two sources of information exist about this introduction: firstly coffee farmers from Cameroon and Central African Republic in 1946 came with the weed to Eloka where they used it as a cover plant (Carlier - Gance - Snoeck - pers. comm.). Secondly *C. odorata* was introduced as seeds mixed with rubber seeds. According to Delabarre (1977) two written references also exist: that of Dr. Miege who reported the introduction of the weed in 1953, and that of Dr. Ake who found the weed in a rubber nursery in Anguededou in 1960.

DISTRIBUTION

According to Dr. Delabarre in 1977 *C. odorata* occupied only a small part of the south east of Cote d'Ivoire from Abengourou to Abidjan passing through Agboville (Fig. 1). Last December (1990) I made a survey and now only a small part of the North East is free of the weed (Fig. 1).

DAMAGE

Generally this weed is a problem for the cash and food crops (maize, cassava, etc.). In Cote d'Ivoire our economy is based on agriculture and we have two important crops:coffee and cacao. Many coffee plantations have been abandoned because they have been invaded by *C. odorata* in Aboisso and Abengourou (Durandeau 1976). In the dry season *C. odorata* becomes a fire hazard and many coffee plantations were lost due to this. *C. odorata* is also a problem among young palm trees, and in banana plantations resulting in poor production. *C. odorata* is also the host of the pest grasshopper *Zonocerus variegatus* (Atayi & Knipscheer 1980) and enhances its development.

CONTROL METHODS

Chemical treatment by herbicides is very expensive even for large plantations, so smaller farmers cannot be expected to use it. Slashing which is usually used to eliminate *C. odorata* is not efficient because the weed regrows rapidly, and when one shoot is cut a further 8 shoots develop. Burning is also used but is not efficient either.

So the last solution is biological control. So far we have tried to find natural enemies without any success. *Aphis gossypii* which curls up the leaves but causes the weed grow faster, and *Anoplocnemis curvipes* which cuts the young branches of *C. odorata*, do not have a significant impact on the weed. *A. curvipes* is also a pest of cotton. We plan to introduce the proven biological control agent *Pareuchaetes pseudoinsulata* from Guam.

REFERENCES

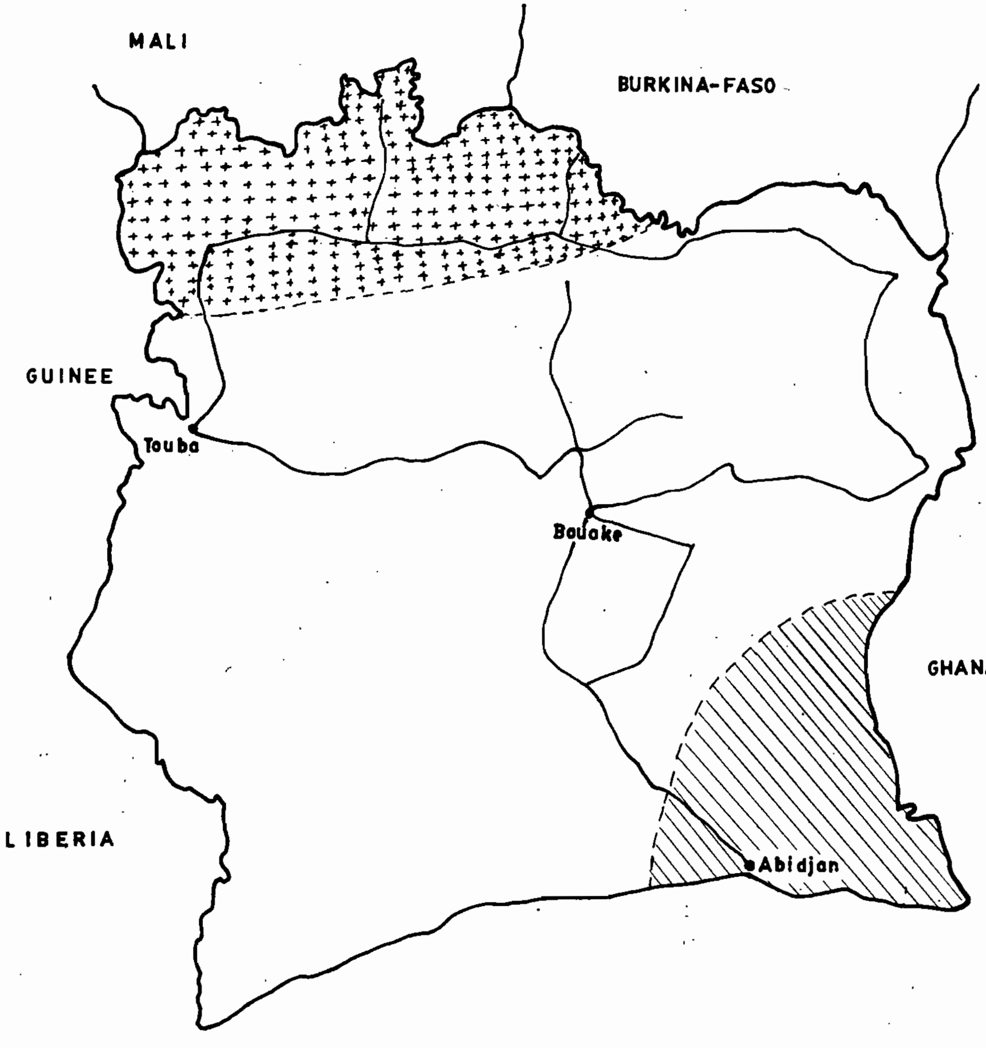
Atayi, E. A. & H.C. Knipscheer. 1980. Survey of Food Crop Farming systems in the "Zapi-Est". East Cameroon International Institute for Tropical Agriculture. ONAREST. p. 94

Delabarre, M. 1977. Incidence Agronomique du Developpement de *Eupatorium odoratum* (Composees) en Cote d'Ivoire (These).

Durandeau, B. 1976. I.F.C.C. Communication Personnelle.

Ivens, D. O. 1972. Weed Research Project at the University of Ibadan, Nigeria. PANS. 18: 210.

Odukwe, D. O. 1965. *Eupatorium odoratum* (Siam Weed). Bull. Nigerian Forest Dept.



LEGEND

Itinerary followed during the survey

Zone occupied by the weed *C. odorata* in 1977

Zone free of *C. odorata* in 1990

Figure 1. Distribution of *Chromolaena odorata* in Cote d'Ivoire

PRELIMINARY RESULTS ON THE ENZYMATIC DIVERSITY IN *CHROMOLAENA ODORATA* (L.) R. M. KING AND H. ROBINSON (ASTERACEAE)

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ABSTRACT

C. odorata was introduced to tropical Africa about fifty years ago and has become extremely invasive. It has colonised the whole of the forest zone in west and central Africa and is progressively spreading into the savanna zones to a minimum isohyet of 1250 mm and a maximum altitude of 1200 m.

A study was undertaken on the organisation of genetic diversity in order to obtain better knowledge of the plant with a view to optimising control methods. The principles of descriptive taxonomy were used to compare American, Asian and African samples but gave no differentiation. Chemotaxonomy studies were therefore carried out using enzymatic markers. Electrophoresis techniques designed for young leaves enabled the identification of seven clearly visible enzymatic systems, five of which were polymorphic. Preliminary research showed that the enzyme profiles of plants from America (French Guiana) were different from those of material of Asian or Africa origin, in which four enzymatic systems out of five were found to be monomorphic.

More detailed and more complete results are needed. The work is therefore continuing on a larger number of plants of more varied geographical origin.

INTRODUCTION

The genus *Chromolaena* D.C. is one of the most important genera of the Eupatorieae with 165 species described to date (King & Robinson, 1987). *Chromolaena odorata* (L.) R.M. King and H. Robinson is the best known species because it is now very widespread in the tropics and because it is important as a weed in the regions where it has been introduced. It is often known by its former name, *Eupatorium odoratum* L., or by the common names Siam Weed or Herbe du Laos.

C. odorata originated in America, where it is found from the southern United States to Argentina. Seeds were introduced in Asia in the 19th century, probably with the earth used as ballast in shipping from the Caribbean. Bennett & Rao (1968) reported that Singapore was one of the main entry sites. Introductions also occurred in other Asian countries, and then the species was spread widely by man and animals and became a major weed in annual and perennial crops. The earliest known introduction to Africa was in 1937 in eastern Nigeria (Ivens 1974). *C. odorata* seeds were introduced accidentally in a batch of *Gmelina arborea* Roxb. seeds from Sri Lanka. Other accidental introductions occurred in the English-speaking African countries such as Ghana. At the same period, it is thought that planters from Indochina introduced the plant in Cameroon and Central African Republic - either involuntarily or intentionally for use as a cover plant in coffee and pepper plantations (Delabarre 1977). After the Second World War, Siam Weed was brought from these areas to Cote d'Ivoire, where it was observed for the first time in 1952 (Miege 1955). It then spread as in Asia and is continuing to do so today. The whole of the west African forest zone and the Congolese basin has been infested. *C. odorata* is now becoming established in the savanna regions. It so far does not seem to have colonised areas where the annual precipitation is less than 1250 mm, but is nevertheless found in areas where precipitation is concentrated in 4 or 5 months. It is found up to an altitude of 1200 m under these conditions. It can spread rapidly, for example it is moving at 40 km per year in the sparse savanna in the Central African Republic.

This colonising ability led us to consider that the African type may be particularly aggressive, and we undertook a comparison, using the principles of descriptive taxonomy, of about a hundred samples from South America, the Caribbean, Asia and Africa. Differentiation was not possible by this means, and the work was continued by chemotaxonomic research using enzymatic markers.

MATERIALS AND METHODS

Plant material

Chromolaena odorata seeds from America, Asia and Africa were collected and sent to the laboratory for the investigation. Some were germinated in a greenhouse and a varying number of plants studied according to the germination percentage of the different batches (Table 1).

Table 1: Origins of the seeds and plants investigated

Origin of the seeds	Year collected	Number of plants studied
Indonesia - West Kalimantan (Borneo)	1988	2
Indonesia - Sumatra - Gunung Batin	1988	7
French Guiana	1989	2
" "	"	3
" "	"	2
" "	"	2
" "	"	5
" "	"	2
French Guiana - Petit Saut	1988	8
Gabon - Alovung	1988	3
Togo - Eto	1989	4
Cote d'Ivoire - Angedougou	1988	12
Benin - Sekou	1988	3
Central African Republic - Bohong	1988	10
Central African Republic - M'Baiki	1988	3
Montpellier - AMATROP (origin: Beheke 1988)	1989	6

METHOD

The techniques used at all stages from the collection and treatment of the plant material to the visualisation of the enzymatic systems were selected and refined.

Collection and treatment of the plant material

The material was extracted from germinated or ungerminated seeds and from young and old leaves from plants grown in the greenhouse. The leaves were used fresh or freeze-dried.

Techniques of analysis

Four extraction buffers were tested and the extracts obtained were used fresh or frozen in liquid nitrogen:

2 phosphate buffers:
A. Potassium phosphate (0.1 M), pH 7.2 + dithiothreitol (0.005 M)
B. Sodium phosphate (0.1 M), pH 7.0 + cysteine (0.005 M)

2 Tris HCl buffers:
C. Tris HCl (0.1 M), pH 7.2 + cysteine (0.005 M)
D. Tris HCl (0.1 M), pH 7.2 + cysteine (0.005 M) + EDTA (0.01 M) + ascorbic acid (0.3 M) + mercapto-ethanol (2%) + Triton (10%).

Six migration systems were then used on 13% starch gels or 11% polyacrylamide gels (Table 2).

Table 2: Different types of electrophoretic migration used for the visualisation of the enzymatic systems

Gels	Migration systems	Gel buffers	Electrode buffers
Starch gel	Hist 6	Histidine, pH 6	Tris, citric acid, pH 6
	Hist 8	Histidine, pH 8	Tris, citric acid, pH 8
	TC 7	Tris, citric acid, pH 7	Tris, citric acid, pH 7
	LiOH-borate	Tris, citric acid, pH 8.3	LiOH, boric acid, pH 8.3
Acrylamide gel	TBE	Tris, boric acid, EDTA, pH 8.1	Tris, boric acid, EDTA, pH 8.1
	AOD	According to Ornstein-Davis (1964)	

Finally, 17 enzymatic systems were studied:

-Malate dehydrogenase (MDH)
-Alcohol dehydrogenase (ADH)
-Isocitrate dehydrogenase (ICD)
-6 phospho-gluconate dehydrogenase (PGD)
-Shikinate dehydrogenase (SKD)

-Phosphoglucose isomerase (PGI)
-Leucine aminopeptidase (LAP)
-Phosphoglutomutase (PGM)
-Esterases (EST)
-Peroxidases (PEROX)
-Acid phosphatases (PA)
-Diaphorases (DIA)
-Catalases (CAT)
-Glutamate oxaloacetate transaminase (GOT)
-Endopeptidases (ENDO)
-Amylases (AMYL)
-Hexokinase (HEXO)

RESULTS

The choice of plant material analysed

Using extractions from germinated or ungerminated seeds is very long and the enzymatic activity detected is very small. The technique was thus not used. The legibility of the zymograms prepared from freeze-dried leaves was poor.

Old fresh leaves displayed less enzymatic activity than young leaves collected from beneath the tip of the plant, that gave clearer zymograms. This technique was therefore chosen in spite of the problem of the duration of the procedure, as sampling, extraction, migration and visualisation of the enzymatic systems had to be carried out in a single day.

The extracts were also used fresh since this gave much more distinct zymograms than those from the extracts frozen in liquid nitrogen.

Choice of extraction buffers

Buffer D (Tris HCl, pH 7.2) was chosen from the four buffers tested as it gave the clearest zymograms.

Choice of gels, enzymatic systems for analysis and migration systems

Some of the enzymatic systems displayed little or no activity. The zymograms of others were not clear and hence could not be interpreted. Only seven enzymatic systems and three migration systems were chosen (Table 3) for their high level of enzymatic activity and good band resolution. The results were all obtained by carrying out migration on starch gels at 40 mA/gel for 6 to 7 hours.

Table 3: Enzymatic systems and migration systems used

Migration systems	Enzyme systems						
	MDH	ICD	LAP	PEROX	PGM	PGI	DIA
TC7	X	X					
LiOH B			X	X			
H 6					X	X	X

Study of enzymatic diversity

Two of the seven enzymatic systems, MDH and DIA, were still monomorphic for the 87 individuals studied. Among the other systems, LAP, PGM, PGI and ICD displayed enzymatic polymorphism. They differentiate firstly the specimens from Guiana, which are all homogeneous for the four systems, and secondly the specimens from Africa and their progeny obtained at the AMATROP laboratory, from Borneo and Sumatra which are also similar to each other with regard to the four systems (Figs. 1, 2 & 3).

The PEROX system is also polymorphic and made it possible to visualise 3 genotypes (Fig. 4);

1 genotype specific to the individuals from Guiana, which were all similar to each other,

2 genotypes found both in all the samples from African countries and in those from Borneo and Sumatra.

DISCUSSION AND CONCLUSION

This preliminary study shows that enzymatic polymorphism exists in *C. odorata* and that five of the seven enzymatic systems tested were polymorphic in all the samples analysed.

The Guiana clones stand out clearly from the African and Asian clones in theses five systems. The second two geographical groups are similar in four of the five enzyme systems and heterogeneous in the fifth. These results support the theory that *C. odorata* was introduced to Africa from Asia.

The only American plants available were from French Guiana. These displayed a different enzymatic profile to that of the plants of other origins. However, *C. odorata* is widely distributed in tropical America, and in the light of its varied reproductive faculties - sexual reproduction with a high rate of polyploidy or apomixis (Ghosh 1961; Powell & King 1969) - there is probably enzymatic polymorphism within the American populations. The preliminary approach reported here tends to show simply that *C. odorata* was not introduced to Asia from

French Guiana. This research will therefore be continued with a larger number of plants of more varied origins to complete and refine these results.

REFERENCES

Bennett, F.D. & V.P. Rao. 1968. Distribution of introduced weed *Eupatorium odoratum* Linn. (Compositae) in Asia and Africa and possibilities of its biological control. PANS. 14 : 227-281.

Delabarre, M. 1977. Incidence agronomique du developpement de *Eupatorium odoratum* (composee) en Cote d'Ivoire. Thesis #38. Univ. Cote d'Ivoire, 108 p.

Ghosh, R.B. 1961. Chromosome number of some flowering plants. Curr. Sci. 30: 73.

Ivens G.W. 1974. The problem of *Eupatorium odoratum* L. in Nigeria. PANS. 20: 76-82.

King, R. M. & H. Robinson. 1970. Studies in the Eupatorieae (Compositae) 20. The Genus *Chromolaena*. Phytologia 20: 196-209.

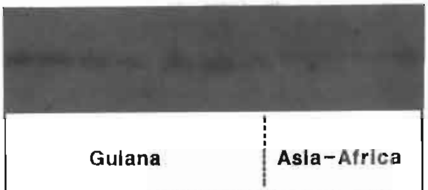
King, R. M. & H. Robinson. 1987. The Genera of the Eupatorieae (Asteraceae). Monographs in Systematic Botany, vol. 22. Missouri Botanical Garden, 581 p.

Miege, J. 1955. Les savanes et forets claires de Cote d'Ivoire. IV: Etudes Eburneennes. INFAN. Dakar. 67 p.

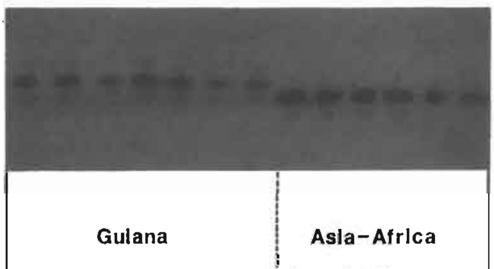
Ornstein, I. & B.J. Davis. 1964. Disc electrophoresis I : Background and theory. Ann. N.Y. Acad. Sc. 121: 321-349, 404.

Powell, A.M. & R.M. King. 1969. Chromosome number in the Compositae : West Indian Species. SIDA 3: 319-320.

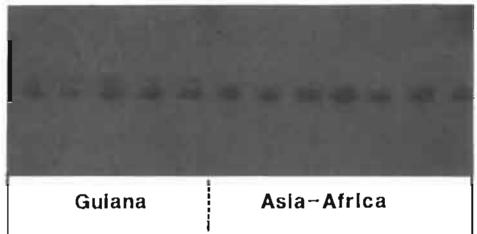
TYPES OF ZYMOGRAM OBSERVED IN THE SAMPLES FROM FRENCH GUIANA, ASIA AND AFRICA



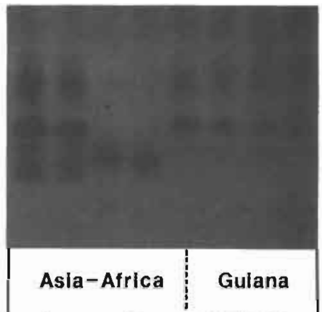
1-Leucine aminopeptidase (LAP)



2-Phosphoglucomutase (PGM)



3-Phosphoglucose isomerase (PGI)



4-Peroxidases (PEROX)

MECHANICAL, CULTURAL AND CHEMICAL CONTROL OF *CHROMOLAENA ODORATA*

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ABSTRACT

Mechanical control is one of the common methods used for control of *Chromolaena odorata* in many countries. It is labor intensive and provides only short term control. Cultural method in plantations using mulch is effective however, it is also labor intensive. Availability of mulch can be a problem. Cultural control utilizing various legume ground covers in plantations have been recommended in many countries. Signal grass in pastures has been reported to be effective in reducing the incidence of *C. odorata* in China. Triclopyr is an effective herbicide against *C. odorata*. Other herbicides used are 2,4-D amine, glyphosate and picloram.

C. odorata is a perennial, bushy and scrambling weed. It is neotropical in origin and introduced to rest of the humid tropical regions of the world except some countries in the Pacific and Australia. It is more of a menace in plantations of perennial crops such as oil palm, coconut, rubber, fruit trees and forest trees. Pastures, vacant lands and roadsides are also infested by this weed. Different kinds of control programs have been adopted depending upon the resources available.

MECHANICAL CONTROL

Hand weeding is a common practice in many countries. Hoes, machetes and bush knives are used for this purpose. Are and Folarin (1970) recommended slashing four times a year in cocoa plantations. Komolafe (1976) suggested a combination of slashing, ring weeding and mulching in Nigeria. Ojuederie et al. (1983) found slashing regimes in oil palm plantations increased bunch yield. Liggitt (1983) and Erasmus (1988) reviewed mechanical control methods in South Africa. Mechanical methods include labor intensive hand weeding, digging and uprooting and use of machinery such as brush cutters, mowers, tillers, plows and other tractor drawn equipments. Mechanical control provides short term control. A combination of other methods such as cultural and chemical weed control programs have been found to be economical and effective.

CULTURAL CONTROL

Mulching: Mulching is done mostly in plantation crops around the bases of trees. Although this method effectively suppresses *C. odorata*, high labor cost and problems with availability of mulching materials limit its use.

Cover crops: Salgado (1972) found *Tephrosia purpurea* planted as a cover crop in coconut plantations in Sri Lanka prevented the establishment of *C. odorata*. Rai (1976) recommended *Pueraria phaseoloides* as a cover crop in rubber plantations in India. Castillo et al. (1977) mentioned that planting *Leucaena leucocephala* in pastures reduced *C. odorata* population in the Philippines. *Pueraria phaseoloides, Calopogonium mucunoides, Centrosema pubescens and Vigna unguiculata* were recommended cover crops in West African plantations (Komolafe 1978). Torres and Paller (1989) suggested planting legumes like *Calopogonium mucunoides* and *Centrosema pubescens* and the grass, *Setaria* sp. immediately after burning the infested area. Wu and Xu (1991) stated that signal grass (*Brachiaria decumbens)* in pastures successfully competes and reduces the incidence of *C. odorata* in China.

CHEMICAL CONTROL

Most chemical control experiments on *C. odorata* were conducted in the Philippines, Indonesia, India, West Africa and South Africa. In the Philippines, Madrid (1974) found 2,4-D to be effective on seedlings, but for mature stands, 2,4-D had to be combined with either 2,4,5-T, picloram or Dicamba. Tumaliuan and Halos (1979) found Gramoxone (Paraquat 20%) gave a fair control of *C. odorata* for a short period. According to Castillo et al. (1980) brushing or spraying the herbicide, Tordon 101 mixture reduced the incidence of *C. odorata* in pastures.

In Indonesia, Risdiono (1975) determined picloram 1kg/ha to be effective. Soerjani et al. (1975) stated that picloram is used for *C. odorata* control in rubber and coconut plantations and MCPA and 2,4-D (amine salt) in lowland rice fields in Java. Tjitrosemito et al. (1986) found 2,4-D, triclopyr or picloram are effective against *C. odorata* in rubber plantations.

In India, George (1968) mentioned that Gramoxone at 0.5 Kg/acre provided satisfactory results, whereas Nair (1973) stated that Gramoxone at 0.3% concentration was not effective against *C. odorata* in open fields. Rai (1976) suggested Gramoxone 2.5 liters plus 2,4-D sodium salt at 2.5 Kg sprayed 3 to 4 times a year was effective in rubber plantations. Mathew et al. (1977) recommended Paraquat and Fennoxone, and Borthakur (1977) suggested 2,4-D for control of *C. odorata*.

In West Africa, 2,4-D was recommended by Sheldrick (1968), Ivens (1974), Martin (1977), Parker (1978) and Delorme (1979). Other chemicals found to be effective against *C. odorata* were glyphosate (Ivens 1974, Parker 1978), Dowco 290 (3-6-dichloropicolinic acid) (Parker 1978), Tordon 101 and Roundup (Dufour et al. 1979), 2,4-D plus 2,4,5-T in ester (Ivens 1974, Delorme 1979) and 2,4,5-T, glyphosate, picloram or 3,6-DCP (Quencez and Dufour 1982).

Liggitt (1983) and Erasmus (1988) reviewed chemical control in South Africa. Erasmus and van Staden (1986, 1987) recommended triclopyr for control of *C. odorata*.

In conclusion, mechanical control is labor intensive and it is not long lasting. Cultural control is long lasting; however, either a mechanical or chemical control program has to be carried out initially to implement the cultural control. Chemical control is effective but expensive and poses some environmental problems.

REFERENCES CITED

Are, L. A. & J. O. Folarin. 1970. Cultural weed control experiment. Ann. Rep. Cocoa Res. Inst. Nigeria 1968-69.

Borthakur, D. N. 1977. *Mikania* and *Eupatorium*, two noxious weeds of N.E Region. Indian Farming 26:48-49.

Castillo, A. C., F. A. Moog & C. Pineda. 1977. Introduction of ipil-ipil in "gonoy" infested pastures. Philippines J. Animal Industry 32:1-10.

Castillo, A. C., E. M. Sena & F. A. Moog. 1980. Prevalence of *Chromolaena odorata* (L.) R. M. King and Robinson under different grazing intensities and methods of weed control. 17th PSAS Annual Convention and Scientific Meeting, PICC, Manila, Nov. 21-22.

Delorme, M. 1979. Weeding of perennial oil crops. Particular cases of young crops and control of harmful weeds. Oleagineux 34:4-6.

Dufour, F., P. Quencez & D. Boutin. 1979. Techniques for the chemical control of *Eupatorium odoratum* in oil palm plantation. Oleagineux 34: 223-227.

Erasmus, D.J. 1988. A review of mechnical and chemical control of *Chromolaena odorata* in South Africa. Proc. First International Workshop on Biological Control of *Chromolaena odorata*, Bangkok. 34-40.

Erasmus, D. J. & J. van Staden. 1986. Screening of candidate herbicides in field for chemical control of *Chromolaena odorata*. S. Afr. J. Plant Soil 3:66-70.

Erasmus, D. J. & J. van Staden. 1987. Chemical control of *Chromolaena odorata*: efficacy of triclopyr and glyphosate applied to regrowth. Applied Plant Science 1:39-42.

George, K. 1968. Herbicidal control of *Eupatorium odoratum*. Indian Forester 94:817-818.

Ivens, G. W. 1974. The problem of *Eupatorium odoratum*. L. in Nigeria. PANS. 20:76-82.

Komolafe, D. A. 1976. Weed problems in tree crops in Nigeria. PANS. 22:250-256.

Komolafe, D. A. 1978. Weeds and their control in the humid and subhumid tropics. Proc. Conf. Inter. Inst. Tropical Agric. 344-349.

Liggitt, B. 1983. The invasive alien plant *Chromolaena odorata*, with regard to its status and control in Natal. Mono. 2, Inst. Nat. Res., Univ. of Natal, Pietermaritzburg, Rep. South Africa.

Madrid, M. T. Jr. 1974. Evaluation of herbicides for the control of *Chromolaena odorata* (L.) R.M. King and H. Robinson. Philippines Weed Sci. Bull. 1:25-29.

Martin, M. 1977. The use of herbicide products in oil palm growing. Oleagineux 32: 479-482.

Mathew, M., K. I. Punnoose & S. N. Potty. 1977. Report on the results of chemical weed control experiments, the rubber plantations in South India. J. Rubber Res. Inst. Sri Lanka 54:478-488.

Nair, P.N. 1973. The effect of gramoxone application on *Eupatorium odoratum*. Indian Forester 99:43-48.

Ojuederie, B. M., G. O. Iremiren & S. N. Utulu. 1983. Effects of various inter-row slashing regimes and size of weeded rings on the early growth, flowering and bunch yield of the oil palm. J. Nigerian Inst. Oil Palm Res. 6:322-334.

Parker, C. 1978. Pot experiment with some new herbicides on tropical perennial weeds. Soluma Troisieme Symposium Sur le Deserbage des Cultures Tropicales 288-296.

Quencez, P. & F. Dufour. 1982. Chemical weed control in palm plantations. II. Usual herbicidal active ingredients for oil palm culture and treatment techniques. Oleagineux 37:107-113.

Rai, S. N. 1976. *Eupatorium* and weedicides. Indian Forester 102: 449-454.

Risdiono, B. 1975. The inter-influence between *Chromolaena odorata* L. and *Brachiaria brizantha* Stapf and the effect of Picloram on these plants. Proc. 3rd Indonesian Weed Sci. Conf., Bandung, June 24-28, 367-376.

Salgado, M. L. M. 1972. *Tephrosia purpurea* (Pila) for the control of *Eupatorium* and as a green manure on coconut estates. Ceylon Cocon. Plrs. Rev. 6:160-174.

Sheldrick, R. D. 1968. The control of Siam weed in Nigeria. J. Nigerian Inst. Oil Palm Res. 5:7-19.

Soerjani, M., A. Soedarsan, S. Mangoensoekarja, T. Kuntohartono & M. Sundaru. 1975. Weed problems and prospects for chemical control in Indonesia. 5th Conf. of the Asian Weed Sci. Soc. pp. 18-22.

Tjitrosemito, S., S. Sastroutomo & I. H. Utomo. 1986. Weed management in a young rubber plantation in Indonesia. Weedwatcher 1(supplement), 4pp.

Torres, D.O. & E.C. Paller, Jr. 1989. The devil weed (*Chromolaena odorata* R.M. King and H. Robinson) and its management. SEAWIC Weed Leaflet. 4:1-5.

Tumaliuan, B. T. & S. C. Halos. 1979. Screening herbicidal preparations and mixtures for clearing reforestation areas. Sylvatrop Philippines Forest Res. J. 4:151-159.

Wu, R. & X. Xu. 1991. Effect of planting signal grass (*Brachiaria decumbens* Stapf) on feijicao (*Chromolaena odorata* King and Robinson) in Southern Yunnan, PRC. Second International Workshop on Biological Control of *Chromolaena odorata*, Bogor, Indonesia, Feb. 4-8, 1991.

CULTURAL CONTROL OF FEIJICAO (*CHROMOLAENA ODORATA* (L.) R. M. KING AND H. ROBINSON) BY PLANTING SIGNALGRASS (*BRACHIARIA DECUMBENS* STAPF) IN SOUTHERN YUNNAN, PEOPLE'S REPUBLIC OF CHINA

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ABSTRACT

The noxious weed, *Chromolaena odorata* (L.) R. M. King & H. Robinson (known as feijicao in China), was introduced to Yunnan Province of China via Southeast Asian countries from the Neotropics. It has seriously affected the native vegetation of the southwest, west and central parts of this province for the past twenty years. It has caused loss of productivity of rangelands and hindrance to the development of animal industry. In 1985, signalgrass (*Brachiaria decumbens* Stapf cv. Basilisk), was planted in pastures and effectively suppressed feijicao. Signalgrass has a better dry matter yield, high coverage, and forms a condensed tuft layer. Feijicao infested fields are burned, uprooted and allowed to dry in the sun. Signalgrass seeds are broadcasted and fertilized for effective establishment. Sampling of 10 one square meter quadrats within the signalgrass fields and one outside area was done to compare the incidence of feijicao. Incidence of feijicao gradually declined in the first three years after establishment of signalgrass. After three years there was no incidence of feijicao in the signalgrass pastures.

INTRODUCTION

Chromolaena odorata (L.) King and H. Robinson is known as feijicao in Chinese, meaning airplane weed. It occupies large areas in southwest, west and central parts of Yunnan Province and severely infests local rangelands and farmlands. It spread from the neotropics via Southeast Asian countries to southern China. A large part of this southern area invaded by feijicao is situated south of the Tropic of Cancer. Yunnan has different topographies and climatic regions. The altitude ranges from 100 to 1000 m above sea level. The weed infested areas are located up and down the hillsides from 500 to 1000 m. Generally, the rate of occurrence of feijicao gradually decreases as the elevation increases.

Feijicao is a perennial plant which produces thick foliage when young. Mature plants have many sturdy and overgrown stems. The young stems are somewhat soft, pithy in the center and the upright main stem sometimes reaches a height of 2 to 3 m. Leaves are opposite, rhomboid in shape and serrated. The inflorescence head is umbelled, and the flowers crowded and yellow colored when mature. They produce some thousands of pentagonous achenes (seeds) with windborne pappi. Seeds are very light and small, weighing 0.05 gm /1000.

Feijicao thrives best on fertile and soft soils and grows well on acid soils. If grown on alkaline soils, the leaves will turn yellow and wilt. When the temperature falls to to 1-2 C, chilly spots appear on the leaves and when it drops to 0 C, all the above-ground parts of the plant will be frozen.

Signalgrass (*Brachiaria decumbens* Stapf) is indigenous to the rangelands of the Great Lake Plateau in Uganda. It was introduced from Kampala, Uganda to Queensland, Australia in 1930. Commercial seeds of the cv. Basilisk are derived from the accession number CPI 1694. It was multiplied by CSIRO and approved for commercial release by Queensland DAS (Oram 1990).

This cultivar is well adapted to humid tropical areas with a dry season not exceeding 4-5 months. It is more drought tolerant than paragrass (*B. mutica*). It grows well on steep hillsides of southern Yunnan where paragrass can not establish. It forms an aggressive, high-yielding sward, which responds markedly to N fertilization. Its dry matter yield is high and it has a low crude protein content. It is palatable except when the stems are mature. It stands up fairly well to heavy stocking and trampling. Seed production is good during the first twelve months from planting provided the grass is not cut frequently. Germination of the seeds can be improved by treating with sulphuric acid for 10 to 15 minutes. This cultivar may be planted mixed with the legume, *Centrosema pubescens* Benth. (Oram 1990).

In 1983, our Center introduced this cultivar from Australia. It is a tetraploid (chromosome number 4n = 36; x = 9) and an obligate aposporous apomict (Pritchard 1967).

In 1985, we started an experiment in the southern part of Yunnan Province at the Manzhongtian Ranch of Simao County (geographical location: 22 47' N and 101 17' E; altitude 1030 m above sea level). The yearly average precipitation is above 2200 mm and the annual mean temperature is 20.6 C. Soil type is red and brown lateritic, pH 5.6 in the upper layer of 0-10 cm. We established improved pastures with the aim of developing and increasing animal production. However, the main problem encountered was the invasion of all the local grasslands by feijicao. During the evaluation trials of introduced grasses, we discovered that this cultivar of signalgrass is very adaptive and produced a dry matter yield of 11.12 ton/ha with 4 harvests per year in 1987 (Xu Xuejun et al. 1989). It is able to form a more aggressive sod-layer, with good coverage and high density, and with a criss-crossed underground root system. In this paper, we present the cultural method of control of feijicao by planting signalgrass.

MATERIALS AND METHODS

In February to March 1985, when feijicao was dispersing seeds, we burned infested waste lands, dug out the roots manually and let them dry for a period of two to three weeks in the sun. Before the advent of the rainy season, seeds of the signalgrass cv. Basilisk were broadcasted manually at the rate of 7 kg/ha. At the same time, fertilizer was applied at a rate equivalent to 20 kg P/ha, 9 kg S/ha, 22 kg K/ha and 92 kg N/ha. No fertilizer was applied afterwards. The grazing of livestock on these newly established pastures was controlled in order to develop a healthy sward.

Ten quadrats of 1 square meter each were used at random in the signalgrass-established pastures for estimating feijicao infestation. The same method was used for estimating feijicao infestation in non-signalgrass pastures in the neighboring areas.

Soil samples were taken at a depth of 0-10 cm and analysed for N, P and K. Kjeldahl method was used for N-determination. P and K were separately determined using spectrophotometric means with 0.5 N $NaHCO_3$ and an atomic absorption spectrometer.

RESULTS AND DISCUSSION

The mean values of number of plants of feijicao per square meter on signalgrass stands for successive years in different dates of sowing (August, 1985; July, 1986; August, 1987; each June from 1988 to 1990) were determined (Table 1). The results of samples taken on November 10, 1990 in different fields and in feijicao-infested rangeland are given in Table 2. The P and K status in the signalgrass pastures and feijicao-infested area were the same, however, N was a little higher in the former pastures.

Farmers in Yunnan Province spend a lot of manpower on burning and digging out feijicao without much success. Feijicao invasion of pastures has caused heavy losses to farmers. Establishment of signalgrass in pastures has effectively prevented germination of the seeds and growth of the seedlings of feijicao. A few seedlings of feijicao may grow in the first two years after establishment of the signalgrass; however, in the third year virtually no feijicao is noted in these fields (Table 1). Planting of signalgrass to control feijicao not only helps to get rid of this noxious weed, but has produced the added benefit of improved pastures for feeding livestock at Manzhongtian (MZT) in southern Yunnan. Xu Xuejun et al. (1989) reported that "Signalgrass showed great adaptability at MZT where its aggressive competitive ability allowed it to control the weed *Eupatorium odoratum* (=*C. odorata*). It has the additional advantage of being easy to establish on steep hills."

In Yunnan, four species of *Brachiaria* were introduced from Australia: *B. humidicola* (Rendle) Schweick cv. Tully, paragrass, *B. mutica* (Forsk.) Stapf and *B. ruzizensis* R. Germ. et Evrad. Our evaluation trials at MZT showed that *Br. decumbens* is the best, having not only the ability to suppress feijicao but also possessing good seeding ability and disease resistance (Xu Xuejun et al. 1989). According to Wu Renrun et al. (1986), there are 4 spp. of wild *Brachiaria* in Yunnan: *B. ramosa* Stapf, *B. eruciformis* Griseb., *B. subquadripara* Hitchc. and *B. villosa* A. Camus.

The N content showed an increase in the fifth year after establishment of the signalgrass; P and K contents were the same in signalgrass and feijicao soils. The increasing N content in signalgrass soil is probably due to the application of N fertilizers during the first year of establishment and additional N cycling from livestock manure. The increase in N content is an added advantage for cultivating signalgrass. The crude protein content of feijicao was 27.65%, while the crude protein content of signalgrass was 3.13% (Kui Jiaxiang et al. 1990a). To maintain and increase the crude protein content of signalgrass at MZT, we have recommended applications of N fertilizer after cultivation (Kui Jiaxiang et al. 1990b) (which, however, is not very economical owing to higher cost of fertilizer application) and mixed planting of legumes with signalgrass. The signalgrass cultivated sites at MZT are all steep slopes on hillsides. Hence, we recommend contour parallel planting of alternate rows of grass and a legume. This proved better than planting mixed seeds of grass and a legume. This alternate planting increased the crude protein content of signalgrass from 3.13 to 5.65% (Kui Jiaxiang et al. 1990b). According to Walsh (1959) Basilisk has performed well with the legume *Centrosema pubescens* in Queensland, Australia. Such a mixture is also utilized in China (Xu Xuejun et al. 1989); however, at MZT Ranch we use a native legume, *Flemingia macrophylla*, with the signalgrass (Wu Renrun et al. 1989).

Initial results using various herbicides for control of feijicao indicated that glyphosate and Paraquat were not effective. 2,4-DA was effective in controlling this noxious weed and it did little damage to grasses. We have recommended spot application of 2, 4-DA to control feijicao in signalgrass fields, as an effective and economical method. Wider use of herbicides is not recommended as it is not economical for forage production at MZT.

Table 1. Average Number of Feijicao Plants in Signalgrass Pasture Established for Six Years and a Neighboring Wasteland (Nov. 10, 1990).

	Years of Establishment of Signalgrass pastures						Wasteland infested by Feijicao
	1	2	3	4	5	6	
	1990	1989	1988	1987	1986	1985	
Number of plants of Feijicao /sq.m	41.3	38.2	10.3	nil	nil	nil	64.6*
Percentage of Feijicao	63.9	59.1	15.9	—	—	—	100

*Plants/1sq. m. quadrat. Average of 10 quadrats.

Table 2. The Status of N, P and K in Soils of Feijicao Waste Land and Signalgrass Improved Pastures after Six Successive Years of Establishment

	Years of Establishment						Wasteland*
	1	2	3	4	5	6	
	1990	1989	1988	1987	1986	1985	
N(%)	0.19	0.17	0.19	0.20	0.13	0.20	0.15
P (ppm)	2.4	0.5	—	1.7	—	1.7	1.7
K (ppm)	28	14	24	12	13	18	18

* Soil samples taken on November 10, 1990 from the neighboring waste lands.

Figure 1. Signal grass pasture and the neighboring feijicao infested wasteland.

Figure 2. Signal grass field along the riverside in the MZT ranch.

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REFERENCES

Kui Jiaxiang, Deng Jufen & Zhou Ziwei. 1990a. On the application of various herbicides to control Feijicao (*Chromolaena odoratq*) in the humid-warm subtropical climate regions of Yunnan Province, China, Yunnan Provincial Livestock & Pasture Research Center (YPLPRC), (in press).

Kui Jiaxiang, Deng Jufen & Zhou Ziwei. 1990b. The preliminary report on mixed planting of legumes and swordgrass *(Brachiaria decumbens* Stapf) in pastures.

Oram, R.N. 1990. Register of Australian herbage plant cultivars, 3rd Edition, CSIRO, Australia, p. 89-90.

Pritchard, A.J. 1967. Apomixis in *Brachiaria decumbens* Stapf. J. Aust. Inst. Agric. Sci. 33: 264-265.

Vaughan, A. M. 1988. Weed problems in tropical pasture management. Training Manual for Tropical Pasture Production in Yunnan, China. 95-98.

Walsh, S.R. 1959. Improved pastures will fatten cattle in far North. Queensland Agric. J. 85: 576-592.

Wu Renrun, Zhang Deyin & Lu Xinshi. 1986. A preliminary report on germplasm resources of grasses, legumes and other forage plants in Yunnan Province of China (1) Crop Pt. Germ. Res., (1): p. 1-8: (2) Sichuan Grassland, 1987 (2): 1-17, With List in Germplasm Resources in Yunnan, Grasses and Legumes, p. 1-24.

Wu Renrun, Zhang Deyin & Lu Xinshi. 1988. On the pattern of distribution of two pernicious weeds, *Ageratina adenophora* and *Chromolaena odorata* and biological control measures taken in Yunnan Province, China. (Abstract). In: R. Muniappan (ed) Proc. First Intern. Workshop Biol Control *Chromolaena odorata,* p. 82 ., Agri. Expt. Sta., Univ. of Guam, Mangilao, Guam.

Wu Renrun, Zhang Deyin & Lu Xinshi. 1989. The study of grasses, legumes and other forage plants germplasm resources in Xishuangbanna of Yunnan Province, China. XVI International Grassland Congress, Nice, France, 1989, p. 1541-1542.

Xu Xuejun, Wang Tu & Guo Zhenyun. 1989. Preliminary results of field trial evaluation of some tropical pasture species performance in the humid and sub-humid tropical zones of Yunnan Province, Southern China (1), XVI International Grassland Congress, Nice, France, 1989, p. 1511-1512.

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

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ABSTRACT

Both augmentative and classical biological control of Siam weed, *Chromolaena odorata*, were attempted in Thailand. Of the native arthropod fauna only an aphid complex consisting of *Aphis gossypii* Glover, *Aphis craccivora* Koch and *Aphis spiraecola* Patch, the amaranth weevil *Hypolixus truncatulus* F., and an eriophyid mite, *Acalitus adoratus* Keifer, were of some importance. The top shoot miner, *Melanagromyza eupatoriella* Spencer, introduced from Trinidad in 1978, failed to survive in the quarantine. During 1986-1988, an arctiid moth, *Pareuchaetes pseudoinsulata* Rego Barros, was introduced from Guam. The moth could not be recovered after repeated field releases. In laboratory mass-rearing, *P. pseudoinsulata* lost its egg hatchability after the fourth generation necessitating reintroductions. This preliminary result was discouraging and there is an urgent need to formulate a new strategy on biological control of *C. odorata* in Thailand.

INTRODUCTION

The Siam weed, *Chromolaena odorata* (L.) R.M. King and H. Robinson (Asteraceae), is one of the target weeds of exotic origin subjected to biological control attempts in Thailand. In contrast to other exotic weeds with satisfactory achievement and success witnessed, e.g., alligator weed, waterhyacinth and the giant sensitive plant, biological control of *C. odorata* has not yet been very encouraging. So far an arctiid moth, *Pareuchaetes pseudoinsulata* Rego Barros (Lepidoptera: Arctiidae), has been introduced and released but its establishment is yet to be confirmed. A failure to obtain reasonably high egg hatchability after four generations of laboratory mass-rearing has prevented moth-rearing on a large scale for additional and continuing field releases. There exists a need to search and screen native natural enemies showing biological control potential for augmentative use as well as to introduce additional exotic natural enemies to the country for further utilization.

Earlier attempts at biological control of *C. odorata* carried out in Thailand from 1975 to 1988 were described by Napompeth (1982) and Napompeth et al. (1988). No native natural enemies were found having adequate potential as biological control agents. The top shoot miner, *Melanagromyza eupatoriella* Spencer (Diptera: Agromyzidae), and an arctiid moth, *Pareuchaetes pseudoinsulata* Rego Barros (Lepidoptera: Arctiidae), were introduced from Trinidad and Guam in 1978 and during 1986-1987, respectively.

The present paper attempts to review further progress, although negligible, on biological control of *C.odorata* in Thailand.

NATIVE NATURAL ENEMIES OF *C. ODORATA*

Being an exotic weed species *C. odorata* contains a small number of associated insect and other arthropod species outside of its native range of Central and South America. It is also less likely that these euryphagous species would be of any potential for further utilization in biological control of this weed. In Thailand *C. odorata* was found to harbor a number of known insect pest species and several polyphagous insects and plant pathogens. Of all the arthropod species found associated with *C. odorata*, those that could cause some noticeable damage were:

1.An Aphid complex consisting of Aphis gosspii Glover, aphis craccivor Koch and Aphis spiraecola Patch (Homoptera: Aphididae).

2.Amaranth weevil, *Hypolixus truncatulus* F. (Coleoptera: Curculionidae).

3.Eriophyid mite, *Acalitus adoratus* Keifer (Acarina: Eriophyidae).

The current impact of these native natural enemies as natural biological control agents of *C. odorata* in Thailand is as follows.

Aphid complex, *Aphis* spp.

Either alone or collectively *A. gossypii*, *A. craccivora* and A. *spiraecola* can induce considerable damage to the growing top shoots of *C. odorata*. Curly, stunted and malformed top shoots of *C. odorata*, sometimes called "phyllodies", are very common and widespread in all *C. odorata* infested areas of the country. Such deformation is probably due to the toxin secreted by aphids in their feeding similar to the symptom of phytotoxemia. To a very large extent this type of damage to the plant obviously obstructs flower bud formation and thus normal flowering. These aphids are widespread all over the country and have significantly reduced the spread and density of *C. odorata* in Thailand.

Amaranth weevil, *Hypolixus truncatulus* F.

H. truncatulus has been a major biological control agent for the spiny amaranth, *Amaranthus spinosus* L., in Thailand (Napompeth, 1982, 1989, 1990b). While the adult weevils cause no obvious damage, it is the grubs that form galls in the stem of *A. spinosus* which are damaging. Only as recently as 1988 adults of *H. truncatulus* have been observed to feed on young branches and stems of *C. odorata* (Napompeth 1990a). When they occur in large numbers the weevils can cause substantial damage to the weed. The distribution of *H. truncatulus* is, however, confined to the central plain areas of the country.

Eriophyid mite, *Acalitus adoratus* Keifer.

A. adoratus has been reported on *C. odorata* in Trinidad, Brazil and Bolivia since 1974 by Cruttwell McFadyen (1988). It was detected in Thailand in the mid-1980s in the southern peninsular area of the country and its identity confirmed by Napompeth et al. (1988). *A. adoratus* since then has spread northwards and can be found in all *C. odorata* infested areas. The infested leaves, both young and mature, are not as deformed as those damaged by aphids, and flowering of the plant is apparently normal. Although widespread all over the country on *C. odorata*, the impact of *A. adoratus* as a biological control agent is relatively inadequate. It is also not known how *A. adoratus* reached Thailand.

EXOTIC OR INTRODUCED NATURAL ENEMIES OF *C. ODORATA*

Only two exotic natural enemies of *C. odorata* have been introduced to Thailand. The top shoot miner, *Melanagromyza eupatoriella* Spencer (Diptera: Agromyzidae), was introduced from Trinidad in 1978. Unfortunately the culture perished under quarantine and thus no field release could be made (Napompeth et al. 1988). The arctiid moth, *Pareuchaetes pseudoinsulata* Rego Barros (Lepidoptera: Arctiidae), was introduced on several occasions from Guam during 1986-1988 (Table 1). The first two shipments received in 1986 were used in quarantine screening and host specificity tests covering 48 species of plants in 25 families. Of all these plants, *P. pseudoinsulata* could feed and survive on only two other asteraceous weeds, namely, *Ageratum conyzoides* L. and *Ageratina adenophora* Sprengel. Biological studies and mass-rearing of *P. pseudoinsulata* were made using the subsequent shipments received from Guam in 1986-1987.

Field releases were carried out at six locations in the northern highland areas of Chiang Mai and Chiang Rai provinces and at four locations at Khao Yai National Park in the central area adjoining the rim of the northeastern plateau areas. Commencing in 1987 field releases were carried out in.1988 (Table 2) but terminated at the end of 1988 due to failure to obtain more larvae from the laboratory mass rearing program.

Laboratory rearing of *P. pseudoinsulata* was observed to deteriorate after every four generations when all the eggs laid failed to hatch. With no field population to help rejuvenate laboratory cultures, two additional shipments of *P. pseudoinsulata* were made from Guam in May and June 1988. It was suspected that sodium could play an important role in plant nutrition and subsequently egg hatchability (I.W. Forno, pers. comm.). As a result, 0.05% sodium chloride solution was added to the soil for the potted *C. odorata* plants and leaves from these plants were used for rearing the moth. Again after four generations of laboratory rearing all the eggs did not hatch (Napompeth 1990a).

Table 1. Introduction of natural enemies of Chromolaena odorata for biological control in Thailand, 1978-1988.

Natural Enemy	Source	Date	Remarks
Melanagromyza eupatoriella Spencer (Diptera: Agromyzidae)	Trinidad	October 1978	No release
Pareuchaetes pseudoinsulata Rego Barros (Lepidoptera: Arctiidae)	Guam	March 1986	No release
		May 1986	Quarantined
		November 1986	Quarantined & released
		July 1987	Mass-reared & released
		November 1987	Mass-reared & released
		May 1988	No release
		July 1988	Mass-reared & released

Table 2. Field releases of *Pareuchaetes pseudoinsulata* in Thailand during 1987-1988.

Date	Location	NumberReleased
February 1987	Khao Yai National Park	2,000 larvae
January 1988	Km #1 Chiang Mai-Phrao Road Muang District, Chiang Mai	600 larvae
February 1988	Km #50 Chiang Mai-Phrao Road Phrao District, Chiang Mai	200 larvae
	Km #86 Chiang Mai-Phrao Road Phrao District, Chiang Mai	200 larvae
	Mae Kok River Bridge, Tha Ton, Mae Ai District, Chiang Mai	200 larvae
	Pong Tam, Ban Tha, Chaiprakarn Subdistrict, Chiang Mai	200 larvae
	Near Chiang Dao Cave, Chiang Dao District, Chiang Mai	200 larvae
	Khao Yai National Park	600 pupae
	Km #7 Prachinburi-Khao Yai Road Muang District, Prachinburi	200 pupae
March 1988	Khao Yai National Park	3,000 larvae
August 1988	Khao Yai National Park	200 larvae
September 1988	Khao Yai National Park	500 larvae
October 1988	Khao Yai National Park	1,000 larvae

"NATIVE" *P. PSEUDOINSULATA* - LIKE ARCTIID MOTH

During a field survey in 1989, an egg mass of an arctiid moth resembling *P. pseudoinsulata* was discovered on *C. odorata* in the central plain area. The adult moth resembles an arctiid, *Amsacta (Estigmene) lactinea* Cramer, which is a known phytophagous pest species of several economic crops. This arctiid moth was able to complete its life cycle on *C. odorata*. Additional field survey did not warrant any further investigation. However, when the adult moth is observed on *C. odorata* plants, it can easily be mistaken for *P. pseudoinsulata*. The larvae are more hairy and can easily be differentiated from those of *P. pseudoinsulata*.

DISCUSSION AND CONCLUSION

Preliminary work on biological control of *C. odorata* in Thailand carried out during 1986-1988 by introducing *P. pseudoinsulata* from Guam did not yield encouraging results. Of all the arthropods surveyed and evaluated in Thailand none of them could be cost-effectively utilized for augmentative purposes. Being an exotic invading weed species, *C. odorata* should be amenable to classical biological control utilizing introduced natural enemies from its native range of origin. In spite of a wealth of information on phytophagous insects recorded from *C. odorata* in its native range and elsewhere by Cruttwell McFadyen (1988), relatively little information on their potential as biological control agents is known except those few species elucidated by Cock (1984). There exists an urgent need to explore further if the biological control program of *C. odorata* is to be realized and reasonably achieved on a world-wide basis, not merely in a few locations as now witnessed.

As in the case of Thailand, a new biological control strategy for *C. odorata* must be formulated. However, considering other *C. odorata* affected areas such a strategy should be equally applicable and should be devised in such a way that a more intensive regional and international effort is given a high priority together with adequate support provided to a program such as the Biological Control of *Chromolaena odorata* Working Group under SEARS/IOBC.

REFERENCES

Cock, M.J.W. 1984. Possibilities for biological control of *Chromolaena odorata*. Tropical Pest Management 30(1): 7-13.

Cruttwell McFadyen, R.E. 1988. Phytophagous insects recorded from *C. odorata*. *Chromolaena odorata* Newsletter No. 2. p. 5-23.

Napompeth, B. 1982. Biological control research and development in Thailand. Proc. Intl. Conf. Plant Prot. in Tropics. p. 301-323.

Napompeth, B. 1989. Biological control of insect pests and weeds in Thailand. BIOTROP Spec. Publ. No. 36. p. 51-68.

Napompeth, B. 1990a. Contributions from Thailand. *Chromolaena odorata* Newsletter No. 3. p. 6.

Napompeth, B. 1990b. Country report: Thailand. Biological control of weeds in Thailand. BIOTROP Spec. Publ. No. 38. p. 23-36.

Napompeth, B., Nguyen Thi Hai & A. Winotai. 1988. Attempts on biological control of Siam weed, *Chromolaena odorata*, in Thailand. In: R. Muniappan (ed.)Proc. First Intl. Workshop on Biol. Control of *Chromolaena odorata*. pp.57-62. Agri. Expt. Sta., Univ. of Guam.

STATUS OF BIOLOGICAL CONTROL OF THE SIAM WEED, *CHROMOLAENA ODORATA* (L.) R.M. KING AND H. ROBINSON ON POHNPEI, FEDERATED STATES OF MICRONESIA

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ABSTRACT

Biological control of the Siam weed on Pohnpei, Federated States of Micronesia involved mass rearing the biological control agent, *Pareuchaetes pseudoinsulata* Rego Barros, in the laboratory and mass releasing either larvae or adults in field infestations of the weed.

Almost two years of field release did not result in establishment. It was observed that predators such as ground lizards, spiders, birds, red and black ants preyed heavily on the adults, larvae and eggs of *P. pseudoinsulata*.. On October 24, 1990, feeding injury and the presence of a number of caterpillars were noticed in one of the release areas. It is planned that after further confirmation of the firm establishment, field adapted larvae will be collected for release in other areas. About 500 adults will be released on each site to facilitate the establishment in other areas.

Problems in mass rearing and mass releasing *P. pseudoinsulata* and techniques used to overcome the problems both in the field and in the laboratory are discussed.

INTRODUCTION

The Siam weed has become a serious weed pest in the States of Pohnpei, Kosrae and Yap in the Federated States of Micronesia(FSM). The weed is spreading rapidly and is now abundant in Madolenihmw and Kitti municipalities of the southern part of Pohnpei. It is spreading slowly toward Sokehs and isolated patches of the weed are appearing on Kolonia and Nett.

In the two municipalities where they are present, *Chromolaena odorata* is usually abundant on vacant lands, pastures, roadsides, and cultivated lands. The weed seems to grow well on Pohnpei, with an annual rainfall of about 500 cm and temperature range from 70° - 92° F. Once established, the weed forms a dense mass of green cover over land, impeding access to roads and pathways. It becomes a fire hazard in dry seasons.

Because of the seriousness of this weed in FSM, the College of Micronesia Land Grant Program decided to include *C. odorata* as a target for biological control under the Agricultural Development in the American Pacific (ADAP) Biological Control Agent Exchange Project. In February 1989, through the help of the University of Guam, larvae of *Pareuchaetes pseudoinsulata* Rego Barros (Lepidoptera: Arctiidae) were brought to Pohnpei.

This paper discusses the procedures and activities that were carried on and will be implemented on Pohnpei aimed at controlling the Siam weed with the arctiid moth, *P. pseudoinsulata*.

MATERIALS AND METHODS

Laboratory rearing of *P. pseudoinsulata*

Rearing the caterpillars of *P. pseudoinsulata* to produce large numbers in the laboratory followed the techniques used by Muniappan et al. (1989) and Seibert (1985) with some modifications. The technique used was as follows:

Eggs of *P. pseudoinsulata* were laid in groups on *Chromolaena* leaves. Leaves with eggs were detached from the stems and placed in ice cream cups with covers. Eggs laid on screens in rearing cages were allowed to hatch and newly hatched larvae were collected and placed in cups with covers and fresh detached leaves of *Chromolaena* as food. Ventilation was provided for the rearing cups by glueing muslin cloth on the cut portion of the lid. The first and second larval instars were maintained in these cups and fresh leaves were provided daily. The cups were cleaned every 2 days and larvae feeding on detached leaves were transferred to clean cups, thus avoiding accumulation of frass that could be toxic to the insect. Upon reaching the third instar, the larvae were transferred to 25 gallon-plastic containers. *Chromolaena* stems with leaves were kept in small bottles with water to prevent wilting of leaves and assuring larvae ample supply of fresh leaves for two days. The 25 gallon containers were cleaned of frass and dried leaves every two days and caterpillars transferred to clean containers with fresh leaves. When the caterpillars were mature and about to pupate, fresh detached leaves were placed on the bottom of the containers for pupation. Three days after, the pupae were collected and placed inside the 30.4 x 30.4 cm organdie nylon cloth and 30.4 x 30.4 x 60.9 cm fine meshed wire rearing cages. Cut shoots of *Chromolaena* kept in small bottles with water were placed inside the rearing cages to provide as oviposition sites for female moths. Pieces of cotton soaked in sugar solution were kept hanging inside the cages and replaced every two days. Cotton soaked in salt solution was also hung inside the cages. These served as food for the moths.

Population Density of *Chromolaena* at the release site

A 5 x 5 meter wooden quadrat was thrown in the designated release site and the number of *Chromolaena* plants were counted. Ten weeds were randomly selected inside the quadrat. The size of stems and height of these ten weeds were measured using a meterstick.

Field Release and Monitoring of *P. pseudoinsulata*

Larvae:

Laboratory reared third instar larvae of *P. pseudoinsulata* were placed in cups with covers and brought to the release sites. Each release site was heavily infested with luxuriantly growing *Chromolaena*. The larvae were individually picked from cups using a camel-hair brush and released on *Chromolaena*. Signs of feeding and presence of larvae were monitored two days and one week after their release.

Adults:

Newly emerged adults of *P. pseudoinsulata* from laboratory cultures were released in the release site. One week after their release, observations were made for the presence of eggs and newly hatched larvae on *Chromolaena*.

Adult moths were also released in a 1.17 x 1.17 x1.22 m field cage with naturally growing *Chromolaena* inside for oviposition. Since earlier attempts at facilitating the establishment of adult moths inside the cage were a failure due to predators, the cage and *Chromolaena* including about 1.2 m around the cages were sprayed with diazinon at 1 kg ai/ha to kill predaceous insects and other organisms.

RESULTS AND DISCUSSION

Other Insects Feeding on *Chromolaena* in the field

In the course of surveying the extent of *Chromolaena* infestation on the southern part of the island, some insects were observed feeding on the weed although it is very unlikely that they could be utilized for a biological control program for this weed. These insects were observed to feed also on other plants and economic crops on Pohnpei.

Melon aphid, *Aphis gossypii*, infested the shoots and tender leaves causing curling and cupping of affected leaves. Negligible damage also occurred due to feeding by the Philippine katydid, *Phaneroptera furcifera* Stal. An unidentified mealybug also infested the tender shoots of Siam weed.

Population And Growth of *Chromolaena*

Prior to releasing the larvae of *P. pseudoinsulata*, the release site at Kitti was sampled for *Chromolaena* density in a 5 x 5 m quadrat. The total number of weeds was 116 and most of them were in the actively growing stage. On the release site, the weed formed tangled bushes 2-3 m high ($\overline{x}$ = 2.35) with stem sizes ranging from 4 to 6 cm ($\overline{x}$ = 5.45). The site was chosen primarily because the surrounding areas were also infested with the Siam weed and therefore assured the biocontrol agent ample food to support several generations when established.

Flowering of *Chromolaena* usually occurs in December through February each year on Pohnpei. Since the seeds of *Chromolaena* are wind-borne and can easily be carried by wind to new areas, it is expected that in 2 to 3 years, if left uncontrolled, it will be distributed throughout the island.

Rearing Problems in the Laboratory and Solutions

Rearing of larvae of *P. pseudoinsulata* started from 60 larvae received from Guam. Development of larvae, pupae, adults and eggs were normal and cultures were successfully completed up to 7 generations, and during that time periodic releases of the larvae were made in the field. Unfortunately, in the 8th generation many mature larvae began to die from an unknown cause, and this almost eliminated the cultures despite cleaning of rearing cups and 25 gallon rearing containers every other day. Only a few larvae survived the 8th generation. To prevent further mass mortality of larvae in 25 gallon containers, the cloth covers were removed from 8:00 a.m. to 4:30 p.m. to assure oxygen in containers for the larvae. The containers were covered in the evening to prevent the escape of larvae.

It was also observed in the process of culturing that a few eggs from the majority of egg masses laid on the leaves of *Chromolaena* and on the screen of the rearing cages failed to hatch for unknown reasons, despite providing cotton balls soaked in sugar solution as food for the adults. Napompeth (1990) mentioned a similar problem in his laboratory cultures of *P. pseudoinsulata* and felt that trace amounts of sodium (Na) played a role in the hatchability of eggs. He recommended adding NaCl to the diets of both adults and larvae. Hence, in addition to sugar solution, cotton balls soaked in salt solution were hung in rearing cages to supplement the adult nutrition.

Ants were observed to interfere with laboratory cultures by preying on eggs and larvae of *P. pseudoinsulata* in rearing cups and 25 gallon containers. Pupae were collected, placed in rearing cups and brought to another room for 2 days. The rearing room was sprayed with diazinon at 1 kg ai/100 gallons of water to kill ants. Legs of chairs and tables where rearing was being done were placed in cans with water to prevent ants from interfering with the culture.

Field Releases of *P. pseudoinsulata*: Problems Encountered and Solutions

Larvae:

Table I shows the number of larvae that were released in the field. However, field released larvae could not be recovered from the release site one week after. It was observed that spiders, red ants and black ants, birds and ground lizards were attracted readily to the release sites. Spiders were seen preying on the larvae.

Since larvae could not get established despite many releases made, possibly due to predation, releases of larvae were made inside a 1.17 x 1.17 x 1.22 m field cage with *Chromolaena* growing naturally inside the cage. Again, the larvae released inside the cage could not be recovered after the release.

Adults:

Field releases of adult moths of *P. pseudoinsulata* were made in July and August 1989. More than 300 adults were liberated at the release site. Again one week after, no eggs or young larvae could be recovered from *Chromolaena*. In March and April 1990 adults were again released, but after a week neither egg masses nor young larvae were evident at the release site. In May 1990 it was decided to release adults in field cages with *Chromolaena* inside. A week before releasing the adults, the cages were sprayed with diazinon at 1 kg ai/Ha, including the *Chromolaena* inside the cages and the surrounding areas about 1.2 m around the cages, to get rid of the existing predators and to prevent them being attracted to the cages with adult moths inside. Again, lizards and spiders were able to enter the cages and killed those adults inside.

The arctiid moth, *P. pseudoinsulata*, so far is the only biocontrol agent that has been reared and released on Pohnpei for the control of Siam weed. About 15 months of field release of larvae and adults since February 1989 did not result in establishment. However, in one release site feeding injury on leaves of the Siam weed and few caterpillars were noticed. This field population is now being monitored to observe its buildup in the release site as well as its natural spread.

In some parts of the world, like India and West Africa, the arctiid moths failed to establish because these areas have a very pronounced dry season. But in Sri Lanka where the dry season is less severe, as in Trinidad, the insect sucessfully established. CAB International Institute for Biological Control (1988) suggested that collections of *P. pseudoinsulata* should be made from climatic conditions similar to the proposed released zone: in our case, similar to the wetter conditions of Pohnpei should be the most promising approach.

Seibert (1985), based on his work in Guam, mentioned that in an effort to maximize the number of *P. pseudoinsulata* individuals in one location, adult moths were released. He found that approximately 500 adults if released in the same location would increase the chances of establishment. This is desirable because the high resulting density of larvae are believed necessary to overcome predatory pressure and to create an epidemic population.

Attempts are also being made to produce more adults in the laboratory. Five hundred adults will be released each time and releases will be made two or three times in the same release site to find out whether *P. pseudoinsulata* will become established in other areas of Pohnpei infested with *Chromolaena*. It is also planned that the larvae from the established site be transferred to new sites to assist in spreading and to cover the island within a short period.

Table 1. Number of laboratory-reared *P. pseudoinsulata* released on Siam weed infested area.

Date	Location	Stage	number released
2/28/89	Wenik Elem. Sch. (Kitti)	larvae	219
4/27/89	Wenik Elem. Sch. (Kitti)	larvae	1010
5/3/89	Wenik Elem. Sch. (Kitti)	larvae	210
6/15/89	Wenik Elem. Sch. (Kitti)	larvae	502
7/14/89	Wenik Elem. Sch. (Kitti)	adults	128
8/23/89	Nan Mal (Palikir)	adults	202
9/25/89	Nan Mal (Palikir)	larvae	350
10/15/90	Nan Mal (Palikir)	larvae	751
11/21/89	Nan Mal (Palikir)	larvae	462
1/18/90	Nan Mal (Palikir)	larvae	1503
3/8/90	Palikir (Sokehs)	adults	216
4/12/90	Palikir (Sokehs)	adults(Field Cage)	300
5/2/90	Palikir (Sokehs)	adults(Field Cage)	225

REFERENCES

CAB International Institute for Biocontrol Control. 1988. Prospects for the biocontrol of *Chromolaena odorata* (L.) R.M. King and H. Robinson. In: R. Muniappan (ed.) First Intern.Workshop on Biol. Control *Chromolaena odorata*. pp.25-33. Agr. Expt. Sta., Univ. of Guam.

Muniappan, R., V.T. Sundaramurthy & C.A. Viraktamath. 1989. Distribution of *Chromolaena odorata* (Asteraceae) and bionomics, consumption and utilization of food by *Pareuchaetes pseudoinsulata*(Lepidoptera: Arctiidae) in India. Proc. VII Int. Sym. Biol. Contr. Weeds, 6-11 March1988, Rome,Italy. Delfosse, E.S. (ed.). Ist.Sper.Pathol.Veg. (MAF), pp. 401-409

Napompeth, B. 1990. Infertility of *Pareuchaetes pseudoinsulata*. In: Contributions from Thailand. *Chromolaena odorata* Newsletter. No. 3.p.6.

Seibert, T.F. 1985. Biological Control of *Chromolaena odorata*. Guam Agric. Expt. Station. Annual Report. 12-13.

HIGHLIGHTS OF WORK ON *CHROMOLAENA ODORATA* IN GHANA

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ABSTRACT

The introduction and spread of the Siam weed, *Chromolaena odorata*, in Ghana is reviewed, and its weed status, adverse effects and potential benefits are described. Recent efforts at ascertaining the distribution of *C. odorata* in Ghana are highlighted, and studies on the biology of *Pareuchaetes pseudoinsulata* in the laboratory are reported.

Out of 44 plant species of 25 families tested for host specificity of *P. pseudoinsulata*, none was found to be eaten. Fauna associated with *C. odorata* were found to include Coleoptera, Orthoptera, Dictyoptera, Hymenoptera and Acarina. No bacterial or fungal pathogens were collected. The possibilities of using biological agents to suppress *C. odorata* while maintaining its benefits are discussed.

INTRODUCTION

Chromolaena odorata (L.) King and Robinson (*Eupatorium odoratum* L.) belongs to the plant family Asteraceae. *C. odorata* occurs naturally over a wide area in tropical and subtropical Americas, from southern Florida to the northern border of Argentina (Cruttwell McFadyen 1988). It was accidentally introduced into most of the other regions where it is currently found (Biswas 1934, Simmonds 1965). By the late 1960s, *C. odorata* had become a weed in Nigeria (since its introduction in the 1940s), and has since spread to Ghana, Ivory Coast and Cameroon (Cruttwell McFadyen 1988). In Ghana, the weed was first discovered in February 1969 infesting abandoned experimental plots in the Legon Botanical Gardens, and by 1972 it had been observed in the Greater Accra, Central and Western Regions (Hall et al. 1972). There are two schools of thought about the introduction of *C. odorata* to Ghana. One holds the view that it was introduced by Ghanaian residents in Nigeria for its medicinal properties; the other claims the weed was intentionally introduced during the construction of the Akosombo Dam between 1962 and 1966 to suppress other weeds along the grid. It was probably a coincidence that the Legon and Central/Western Region outbreaks occurred almost simultaneously, as *C. odorata* appears to be absent from the intervening country (Hall et al. 1972), and it is more likely that the Western outbreak may be the result of spread from the Ivory Coast. Although *C. odorata* is not recorded from Cote d'Ivoire by Hutchinson & Dalziel (1963), there is in fact in the Ghana Herbarium a specimen collected near Abidjan in 1962.

Locally, the weed is named after two former heads of state, who ruled around the time of its introduction and spread, as "Busia" in the Western region and "Acheampong" elsewhere. This is probably further testimony to the different origins of the Legon and western region colonies. This paper reports on surveys made in Ghana on the distribution of *C. odorata* and the fauna associated with it. Biological studies made on *Pareuchaetes pseudoinsulata*, a defoliator of *C. odorata* , since its arrival from Guam in November, 1989, are also reported.

DISTRIBUTION AND WEED STATUS OF *CHROMOLAENA ODORATA* IN GHANA

The geographical distribution of *C. odorata* is known to be limited to about 30° N and S latitudes and about 1000m in altitude near the equator (Muniappan & Marutani 1988). Further, its distribution is limited to areas with a rainfall of 200cm and above and where temperature ranges from 20° to 37° C.

In Ghana, *C. odorata* is a weed in both arable and plantation crops. Particularly affected are cocoa, oilpalm, coffee, rubber, maize and cassava fields. Other areas include abandoned fields, roadsides, riverbanks, cleared lands and forest margins. It is usually controlled by uprooting, slashing and burning, brushing or by use of herbicides such as Gramoxone, Atrazine and Glyphosate. *C. odorata* is also known to suppress other weeds, and serves as an alternate host of nymphs of the variegated grasshopper, *Zonocerus variegatus*, and a breeding ground for the adults. *C. odorata* is suspected to be the source of the characteristic foul smell of *Z. variegatus* which is important in deterring predators. Its potential as a fire hazard has been reported in Asia and the Pacific (Muniappan & Marutani, 1988), Thailand (Napompeth et al. 1988) and in India (Ambika & Jayachandra 1990). Recent extensive bush fires in Ghana are also probably attributable to the spread of *C. odorata.*

On the other hand, many people claim that *C. odorata* has medicinal properties and could be used in treating wounds and abdominal disorders (pers. obs.). It is also claimed to enrich soils by recycling minerals and by litter fall. In spite of this apparent "conflict of interest", farmers welcome any effective control program because of the cost involved in its control by either chemical or mechanical means. Secondly, the potential environmental hazards of the usage of weedicides, their unavailability at the right time and harm to operators makes their use even if affordable unwelcome. Thus alternative less costly and safer methods are required.

Though biological control of *C. odorata* has been attempted in Ghana without success, lack of sustained effort (Greathead 1989) may have been the cause. Success in control of *C. odorata* has been achieved in Asia and the Pacific (Greathead 1989) and chances are that insect control agents when used in a sustained effort could bring about suppression of *C. odorata.* Biological control of *C. odorata* by introduced agents will not only reduce its density to a level where its benefits can be enjoyed without it being a pest, but will also reduce the possibility of environmental pollution that could follow the extensive use of inorganic weedicides.

An informal survey conducted in March and April, 1990 (Haruna & Timbilla, unpublished data) revealed that *C. odorata* has spread over the whole of the southern part of

Ghana and as far north as latitude 8° 15' N. (Fig. 1). Its spread further north appears to be limited by the amount of rainfall.

BIOLOGY OF *PAREUCHAETES PSEUDOINSULATA* IN GHANA

The biology of *P. pseudoinsulata* was studied in the laboratory to confirm reports already available from the Philippines (Aterrado & Talatala-Sanico 1988) and elsewhere.

MATERIALS AND METHODS

Larvae were reared in Kilner jars for the first two instars and later transferred into wooden cages covered with grey baft (30 x 30 x 30cm). Fourth to Sixth instar larvae were finally reared in 45 x 45 x 75cm cages. In all cases, the larvae were fed on fresh *C. odorata* leaves. The adults were fed on a sucrose solution and allowed to mate in 30 x 30 x 30cm grey baft covered cages.

RESULTS

Eggs were laid in batches on leaves and on the walls of the cages. Egg batch size varied from 2-68 (Table 1). Incubation period lasted about 4.9 days. Larval size ranged between 2mm-22mm. The larval stage lasted 21.4 days while pupation took 9.3 days. Adults lived for an average of 5 days. Thus the total life cycle of *P. pseudoinsulata* from egg to adult emergence lasted for 35.6 days.

Egg hatchability decreased with generation until zero hatchability was obtained after the 4th generation.

HOST RANGE AND SPECIFICITY TESTS

Second instar larvae of *P. pseudoinsulata* were tested for their host range and specificity. Larvae were supplied with fresh samples of the test plants until they died. So far 44 plant species from 25 different families have been tested (Table 2). None of the plants tested was found to be eaten by *P. pseudoinsulata*. Larvae tested died from starvation within 5 days.

FAUNA ASSOCIATED WITH *CHROMOLAENA ODORATA* IN GHANA

A limited survey was carried out during July, 1989 and April, 1990 to determine the fauna associated with *C. odorata* and potential control agents. Specimens collected have not yet been fully identified; however, among them are arthropods belonging to the orders Hymenoptera, Diptera, Orthoptera, Coleoptera, Dictyoptera, Homoptera and Acarina. The hymenopteran insects were specifically found to be stem borers while the others were generally found on leaves and/or flowers. No collections of fungal and bacterial agents were made.

DISCUSSION

C. odorata has been a serious pest since its introduction in Ghana both in arable and plantation crops. Its control has been specific to local needs.

There is an urgent need to control the weed. However, physical control is expensive while chemical control is both expensive and potentially hazardous. The need for biological control as a better control alternative is very much evident.

The studies on *P. pseudoinsulata* indicate that though it could be efficient and specific as a defoliator, its ability to control *C. odorata* is presently limited by the inability to rear it in the laboratory beyond the third generation. Although the moths appeared healthy they were inactive, and adult size decreased from generation to generation. Given the profuse growth of *C. odorata* it may be that it will require more than just a defoliator to achieve effective suppression.

The fauna associated with *C. odorata* suggests that other associated organisms may also be quite varied, and other natural enemies including insects, fungi and bacterial pathogens should be investigated.

It is probable that extensive surveys in the center of origin of *C. odorata* will lead to the discovery of other natural enemies in the categories of stem, root and flower borers/feeders that could be used to supplement *P. pseudoinsulata*. It is also possible that pathogenic fungi and other micro-organisms could be found.

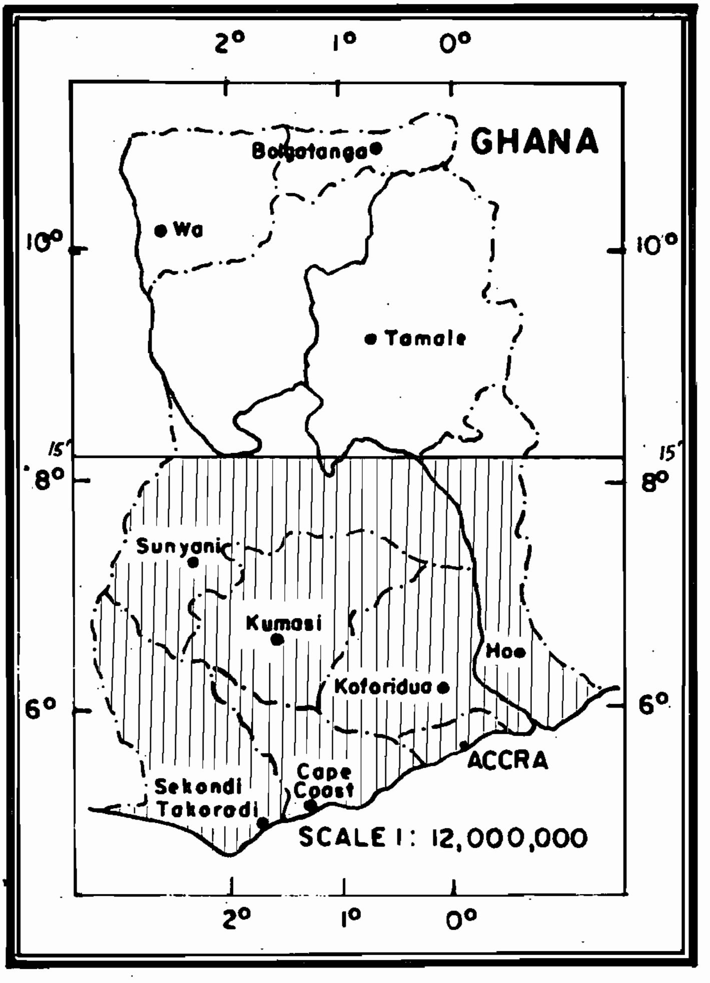
It is evident from the above that the biological control of *C. odorata* in Ghana, following its extensive spread and establishment, will require a special effort.

Table 1. Sizes of Egg Batches laid by 25 Females of *Pareuchaetes pseudoinsulata*

Sample No.	No. of Eggs/Batch	Sample No.	No. of Eggs/Batch
1	63	14	16
2	23	15	11
3	34	16	29
4	2	17	13
5	13	18	18
6	10	19	9
7	35	20	14
8	50	21	7
9	53	22	2
10	42	23	11
11	10	24	68
12	10	25	19
13	13		

Table 2. Plants Tested for Host Range and Specificity of *Pareuchaetes pseudoinsulata*

SER. NO.	TEST PLANT	BOTANIC NAME	FAMILY
1.	Mango	*Mangifera indica*	Anacardiaceae
2.	Papaya	*Carica papaya*	Caricaceae
3.	Lettuce	*Lactuca sativa*	Asteraceae
4.	Sweet Potato	*Ipomaea batatas*	Convolvulaceae
5.	Watermelon	*Citrullus lanatus*	Cucurbitaceae
6.	Cassava	*Manihot esculenta*	Euphorbiaceae
7.	Avocado	*Persea americana*	Lauraceae
8.	Groundnut	*Arachis hypogaea*	Leguminosae
9.	Pigeon pea	*Cajanus cajan*	"
10.	Soybean	*Glycine max*	"
11.	Cocoa	*Theobroma cacao*	Sterculiaceae
12.	Cola	*Cola mitida*	"
13.	Jute	*Corchorus spp.*	Tiliaceae
14.	Onion	*Allium cepa*	Amaryllidaceae
15.	Cabbage	*Brassica oleracea*	Cruciferae
16.	Cocoyam	*Colocasia esculenta*	Araceae
17.	Pineapple	*Ananas comosus*	Bromeliaceae
18.	Cowpea	*Vigna unguiculata*	Leguminosae
19.	Cotton	*Gossypium spp.*	Malvaceae
20.	Kenaf	*Hibiscus cannabinus*	"
21.	Okra/Okro	*H. esculentus*	"
22.	Roselle	*H. sabdariffa*	"
23.	Aramina	*Urena lobata*	"
24.	Guava	*Psidium guajava*	Myrtaceae
25.	Yams	*Dioscorea alata*	Dioscoreaceae
26.	Sugar cane	*Saccharum officinale*	Gramineae
27.	Rice	*Oryza sativa*	"
28.	Maize	*Zea mays*	"
29.	Common millet	*Panicum muliaceum*	"
30.	Banana	*Musa sapientum*	Musaceae
31.	Plantain	*Musa paradisiaca*	"
32.	Coconut	*Cocos nucifera*	Palmae
33.	Oil palm	*Elaeis guineensis*	"
34.	Arabica coffee	*Coffea arabica*	Rubiaceae
35.	Lemon	*Citrus limon*	Rutaceae
36.	Grape fruit	*Citrus paradisi*	"
37.	Tangerine	*Citrus reticulata*	"
38.	Sweet orange	*Citrus sinensis*	"
39.	Lime	*Citrus aurantifolia*	"
40.	Hot pepper	*Capsicum annuum*	Solanaceae
41.	Tomato	*Lycopersicon esculentum*	"
42.	Tobacco	*Nicotiana tabacum*	"
43.	Egg plant	*Solanum melongena*	"
44.	Ginger	*Zingiber officinalis*	Zingiberaceae



✱ AREA INFESTED BY C. ODORATA

Figure 1. Distribution of *Chromolaena odorata* in Ghana

REFERENCES

Ambika, S.R. & Jayachandra. 1990. The problem of *Chromolaena* weed. *Chromolaena odorata* Newsletter 3:1-6.

Aterrado, E.D. & R.L. Talatala-Sanico. 1988. Status of *Chromolaena odorata*. Research in the Philippines. In: R. Muniappan (ed.). Proc. First International Workshop on Biol. Control of *Chromolaena odorata*. pp. 53-55. Agri. Expt. Sta., Univ. Guam.

Biswas, K. 1934. Some Foreign Weeds and their distribution in India and Burmah. Indian Forester 60:861-865.

Cruttwell McFadyen, R.E. 1988. History and Distribution of *Chromolaena odorata*. In: R. Muniappan (ed.). First International workshop on Biol. Control of *C. odorata*.. pp 7.-12. Agr. Expt. Sta., Univ. Guam.

Greathead, D.J. 1989. Present Possibilities for Biological Control of Insect Pests and Weeds in Tropical Africa. Biological Control. A Sustainable Solution to Crop Pest Problems in Africa. 190 pp.

Hall, J.B., R. Kumar & A.A. Enti. 1972. The obnoxious weed *Eupatorium odoratum* (Compositae) in Ghana. Ghana J. Agric. Sci. 5:75-78.

Hutchinson & J.M. Dalziel. 1963. Flora of west tropical Africa 2, 2nd ed. (F.N. Hepper, ed). pp. 544.

Muniappan, R. & M. Marutani. 1988. Ecology and Distribution of *C. odorata* in Asia and the Pacific. In: R. Muniappan (ed.) Proc. First Intern. Workshop on Biol. Control of *Chromolaena odorata*. pp. 21-24. Agri. Expt. Sta., Univ. of Guam.

Napompeth, B., N. Thi Hai, & A. Winotai. 1988. Attempts on Biological Control of Siam Weed, *Chromolaena odorata* in Thailand. Proceedings of the First International Workshop on Biological Control of *Chromolaena odorata*. pp.57-62. Agri. Expt. Sta., Univ. Guam.

Simmonds, F. J. 1965. Report on a visit to Sierra Leone, Ghana, Nigeria, Mauritius and East Africa. November 1964 - March 1965. Commonw. Agric. Bureaux. 42 pp.

STUDIES ON CAUSES OF INFERTILITY OF EGGS OF *PAREUCHAETES PSEUDOINSULATA* REGO BARROS

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The insect *Pareuchaetes pseudoinsulata* Regò Barros, is an important and promising biotic agent against the Siam weed *Chromolaena odorata* (L.) R.M. King and H. Robinson. *P. pseudoinsulata* larvae feed voraciously on leaves and young shoots of the Siam weed. The species is specific to Siam weed and a few other related weed species.

One of the major problems encountered in the utilization of this biotic agent is laboratory rearing. There were instances when most, and sometimes all, of the egg masses laid by the moth were infertile, resulting in complete loss of a stock. This paper reports the results of some observations carried out at College, Laguna, Philippines regarding the probable causes of this problem.

MATERIALS AND METHODS

P. pseudoinsulata used in this study was obtained from Puerto Princesa, Palawan. Larvae were collected in August, 1989 and reared under laboratory conditions. Rearing was done using screen cages and screen covered plastic trays and with fresh Siam weed leaves as diet. The observations made were on the insect mating behavior, the effect of light and inbreeding.

Observation on Mating Behavior

The mating behavior of the insect was observed in 0.5 m x 0.5 m x 0.5 m screen cages. The top and one side of each cage were made of glass whereas the bottom was made of galvanized iron sheet. Pupae were sexed by means of the location of the genital opening. In the female the genital opening is near the anterior margin of the eighth abdominal segment while in the male it is located on the ninth abdominal segment. Five male and five female pupae ready for eclosion were placed inside the cage at about 5:00 p.m. Observations were made continuously for 24 hours, taking note of the behavior of the male and female moths. Five such observations were made in different days in an undisturbed room. The lighting condition of the room is described in the results and discussion part of the paper.

Effect of Light

An experiment was conducted to determine if the amount of light could affect the production of infertile eggs. This inquiry was based on the observation that adults remained inactive both when fully lighted and under complete darkness.

Cages were covered with carbon paper to create conditions of varying light intensities inside. One cage was completely covered while another was completely exposed to light. Two others were partly covered, one third and two thirds from the top. Ten pairs of male and female pupae that were due for eclosion were placed inside each cage. The cages were left inside the laboratory, lighted with fluorescent lamps from the ceiling, day and night for one week. The cages were laid out on one-meter high wooden stands in a randomized complete block design with four replications. The distance between the top of the cages and the light sources was two meters.

Effects of Inbreeding

Four pairs of adults were selected from those that developed from field-collected larvae. Each pair was reared separately and their respective eggs, representing the first generation (F1), were labeled as A, B, C and D. The eggs were reared to adults and various mating combinations were made as follows:

A x A	B x B	C x C	D x D
A x B	B x C	C x D	
A x C	B x D		
A x D			

The resulting eggs from these combinations (F2) were again reared and all possible mating combinations such as AA x AA, AA x AB, AA x AC, ..., and DD x DD were made. The process was repeated until the third generation when the culture had to be discontinued due to virus disease infection. The original plan had been to continue up to 10 generations using selected mating combinations.

In each generation and for each mating combination, the number of fertile and infertile egg masses was obtained and the number of male and female pupae produced was recorded.

RESULTS AND DISCUSSION

Observations on Mating

Eclosion of adults took place in general between 5:00 and 6:30 pm. This period was not dark at the time of this study.

Immediately after eclosion, adults walked on the base of the cage toward the sides. Most of them climbed on the sides of the cage and then settled in one place while a few stayed at the base. In some cases, the adults flew to the sides of the cage in the direction of the light source. Very seldom did the adults find the honey-impregnated cotton, provided as a source of food, hanging on the sides of the cage. In fact, about 50% of them did not feed on the honey within 24 hours.

Initial observation showed that the activity of the adults is affected by light. When the observation cage was exposed to light the moths remained motionless during the day and night and there was no mating within the 24 hour period. The eggs produced by the females were infertile. Succeeding observations therefore were made with the room lights off. To make the insects visible, a small flash light was directed to the wall of the room to provide indirect light to the observation cage. In later observations, similar lighting conditions were obtained by leaving the door about 30 cm open and letting light from a source outside enter indirectly.

When maintained under these lighting conditions, the adults also remained still but only until 1:45 am to 2:58 am. Within this range of time, mating activity started among the majority of adults, although some were observed to begin mating as late as 5:00 am. In general, a male moth would start running around inside the cage, creating noise as if its wings were flapping rapidly against the wall of the cage. Other males would follow, but these would walk fast with vibrating wings but without much noise. They would generally move from the floor then up on the sides of the cage. After reaching the top, they would drop themselves to the floor and then move up again, as if searching for a female.

Females normally remain still, but if a male comes within 3 to 4 cm they will partially raise their wings.

After several up and down movements within the cage, the male will come near a female and will make one, two or several journeys around her within about a 2 to 6 cm radius. He may then move away and find another female to chase in the same way, or may approach the same female and instantly copulate. The female raises her wings when the male approaches, the male positions himself under her wings, and then suddenly turns back with his organ already inserted. This happens in about two seconds.

Unless disturbed, most pairs of adults were observed to remain in copulation for about one and a half to three and a half hours. A few would exceed this, and several cases were also observed where the mating pair did not separate from each other even up to death.

Effect of Inbreeding

There was a wide range of percentage infertility of F2 egg masses among the different mating combinations made. The lowest was 18.82% and the highest was 100%. There was, however, no statistically significant difference obtained between crosses involving the same parent egg masses and those involving different parent egg masses.

Similarly, the percentage of infertile egg masses produced by F3 adults ranged widely, from 25% to 100%. When grouped according to the degree of inbreeding, there were significant differences in mean percentage infertility among the different groups (Table 1). Crosses involving two F2 inbreds (e.g., AA x AA or BB x CC) gave significantly lower incidence of infertile egg masses (58.65% and 58.05%) followed by those involving only one F2 inbred. More diverse crosses gave correspondingly higher percent infertility, such as those involving an inbred and its hybrid (82.44%), an inbred and an unrelated hybrid (65.46%) the same hybrid (or selfing a hybrid, 78.05%), and completely unrelated hybrids (100%).

Table 1. Percentage of infertile egg masses produced by F3 adults

Mating Combination	No. of Egg Masses	Percent (%) Infertile	Mean* of Mating Type
AA x AA	20	45.00	
BB x BB	28	64.28	
CC x CC	21	66.67	58.65 d
AA x AC	41	97.56	
AA x AC	25	28.00	
BB x BC	33	51.51	
BB x BD	21	100.00	
AB x BB	22	100.00	
AC x CC	9	100.00	
BC x CC	32	100.00	82.44 bc
AA x BB	13	69.23	
BB x CC	32	46.87	58.05 d
AA x BC	23	73.91	
AA x BD	20	25.00	
AB x CC	24	45.83	
AC x BB	10	100.00	
AD x BB	25	88.00	
BD x CC	25	60.00	65.46 cd
AB x AB	26	100.00	
AC x AC	19	47.00	
BC x BC	23	95.65	
BD x BD	23	69.56	78.05 bc
AB x AC	26	84.00	
AB x BC	24	54.00	
AB x BD	23	100.00	
AC x BC	44	97.73	
BC x BD	29	96.55	86.46 b
AC x BD	41	100.00	100.00 a

* Any two means followed by a common letter are not significantly different at 5% level (DMRT).

These results are surprising because most species of plants and animals behave otherwise. In addition, this cannot explain the development of infertility that is observed in the laboratory. Continuous culture of the insect from a single stock in the laboratory is inbreeding, and yet infertility develops. The authors have at present not found an explanation for this.

The proportion of male and female pupae produced in the F2 and F3 generations (Tables 2 and 3) were also greatly affected by the mating combinations used. A Chi-square test of the data revealed a significantly lower proportion of female pupae from F2 inbreds (e.g. A x A) than from crosses (e.g. A x B). The same was true in the F3 generation. There was a distinct decrease in the proportion of female pupae as the parents involved in the crosses became more related. It is worth emphasizing that one of the F2 inbreds (DD) had been lost due to infertility of eggs. In the F3, on the other hand, one inbred (AA x AA) produced only 29.63% females and two other inbreds (BB x BB and CC x CC) produced all male offsprings.

Table 2. Number of male and female pupae produced by F2 adults

Mating Combination	Number of Pupae Male	Female	Proportion of Females*
A x A	33	35	0.5147
B x B	119	133	0.5278
C x C	238	233	0.4947
A x B	66	75	0.5319
A x C	85	112	0.5685
A x C	4	12	0.7500
B x C	117	110	0.4846
B x D	82	79	0.4907

*Proportions not significantly different.

The observed infertility of eggs of the Siam weed moth appears to be a result of several interrelated factors. Lack of mating could be a major factor resulting from the influence of other factors like light and inbreeding. The effect of light may not be a very influential factor in actual rearing practice, since rearing laboratories are normally not lighted at night.

Table3. Number of male and female pupae produced by F3 adults

Mating Combination	No. of Pupae Male	Female	Proportion of Females Per Cross	Per Group
AA x AA	19	8	0.2963	
BB x BB	48	0	0	
CC x CC	5	0	0	0.1000 a
AA x AB	2	1	0.3333	
AA x AC	98	67	0.4061	
BB x BC	17	6	0.2609	0.3874 b
AA x BB	5	4	0.4444	
BB x CC	14	8	0.3636	0.3871 b
AA x BC	1	3	0.7500	
AA x BD	5	3	0.3750	
AB x CC	57	68	0.5440	
AD x BB	14	15	0.5172	
BD x CC	48	37	0.4343	0.5020 d
AC x AC	53	39	0.4239	
AC x BC	4	3	0.4286	
BD x BD	32	25	0.4386	0.4295 c
AB x AC	21	30	0.5882	
AB x BC	36	38	0.5135	
AC x BC	2	2	0.5000	
BC x BD	8	4	0.3333	0.5248 d

Any two means having a common letter are not significantly different at 5% levels (Chi square)

Imbalance in the proportion of males and females resulting from inbreeding is perhaps the most important factor that leads to the absence of mating. A small proportion of either sex among the pupae produced will not guarantee mating because eclosion from this small population may not necessarily coincide with that of the opposite sex. It would surely help if pupae could be subjected to sex determination. Those produced ahead of the opposite sex could be stored under refrigeration to delay eclosion.

SUMMARY

Mating in the moth *P. pseudoinsulata* moth was observed to take place from 1:45 a.m. to 5:00 a.m. Adults remained in copulation for about one and a half to three and a half hours. Under lighted conditions, the moths remained still inside the observation cage for the whole day and night and did not mate, resulting in the production of infertile eggs. Results of experiments involving variation in the amounts of light by covering the cages with carbon paper at different degrees, however, failed to show any effect of such treatments on egg fertility.

Experiments on inbreeding showed that F3 inbreds had a smaller percentage of infertile eggs compared to more diverse crosses even when reared with equal number of males and females. However, F3 inbreds gave very low proportions of females compared to other crosses; this female proportion increased to almost equal number of males and females as the members of the crosses made become more diverse.

Infertility of eggs of the Siam weed moth appeared to be largely due to lack of mating resulting from an unbalanced proportion of males and females. A major cause of this imbalance is the effect of inbreeding. The problem could be minimized, therefore, by renewing stocks after a number of generations, which is a recommended practice in laboratory rearing.

THE CHEMISTRY OF THE PUTATIVE FEMALE SEX-ATTRACTANT PHEROMONE OF *PAREUCHAETES PSEUDOINSULATA* REGO BARROS (LEP.: ARCTIIDAE)

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INTRODUCTION

The arctiid moth *Pareuchaetes pseudoinsulata* is a potential biological agent for controlling the tropical pest weed *Chromolaena odorata* King & Robinson (see Seibert 1989 and several papers in this Proceedings). However, so far there are no means available for monitoring the presence of these moths and their population dynamics, which should be a routine in the course of releasing control agents (*cf.* Boppré 1991). As a basis for developing pheromone traps, this paper reports on the chemistry of the putative female sex-attractant pheromone of *P. pseudoinsulata*.

MATERIALS AND METHODS

Pupae of *Pareuchaetes pseudoinsulata* Rego Barros were collected in the field in Sri Lanka and shipped to Germany. The pheromone glands from freshly emerged females were excised, immersed into 50 µl pentane (Uvasol, Merck), and stored at -78° C. Mass spectra (70 eV) were obtained with a Varian MAT 311A mass spectrometer coupled to a Carlo-Erba Fractovap 2101 gas chromatograph. For analytical gas chromatographic analyses a Carlo-Erba gas chromatograph of the same type equipped with a flame ionization detector and split injection was employed. Separations were performed using a 50 m SE-54 glass column (inner diameter 0.32 mm, film thickness 0.25 µm) and a 50 m WG 11 glass column (inner diameter 0.32 mm, film thickness 0.25 µm); helium served as carrier gas. For identification of compounds, mass spectra and retention times were compared with those of authentic reference samples.

RESULTS

Gas chromatograms of extracts of the female pheromone glands (*cf.* Fig. 1) show one main component accompanied by several minor components and some trace compounds. The main component exhibited a mass spectrum showing characteristic signals at m/z=79, m/z=108, m/z =234 and a molecular ion at m/z=290. This mass spectrum is identical with the spectrum of an authentic sample of (Z,Z,Z)-3,6,9-heneicosatriene; the retention times on different stationary phases proved to be identical, too. Thus, (Z,Z,Z)-3,6,9-heneicosatriene is the main volatile component of the pheromone gland.

In a similar way (Z,Z)-6,9-heneicosadiene and (Z,Z)-6,9-nonadecadiene as well as (Z)-9-nonadecene were identified as minor components. Small amounts of heptadecene and heneicosene were also present. In addition, the corresponding saturated hydrocarbons heptadecane and nonadecane could be identified. In contrast to these compounds two trace compounds show a branched carbon chain; they proved to be 2-methylheptadecane and 5-methylheptadecane. Figure 1 shows the relative amount to the compounds identified.

Electroantennogram (EAG) recordings demonstrated that male antennae respond strongly to excised female glands as well as to (Z,Z,Z)-3,6-9-heneicosatriene (for details see Schneider *et al.* 1991).

DISCUSSION

(Z,Z,Z)-3,6,9-Heneicosatriene, the main component of the putative female pheromone of *Pareuchaetes pseudoinsulata*, is quite widespread as a constituent of sex-attractants in arctiid moths. It has been found in *Halisidota leda* (Descoins *et al.* 1989), *Tyria jacobaeae* (Frérot *et al.* 1988), *Arctia villica* (Einhorn *et al.* 1984), *Phragmatobia fuliginosa* (Descoins & Frérot 1984), and *Pericallia ricini* (S. Schulz & D. Schneider unpubl.) and proved to be a component of the female sex pheromone of *Hyphantria cunea* (Tóth *et al.* 1989), *Creatonotos transiens* and *C. gangis* (Wunderer *et al.* 1986) and *Utetheisa ornatrix* (Conner *et al.* 1980). It also occurs in other lepidopteran families (*cf.* Arn *et al.* 1988/1990). The minor components which likely add to the specificity of the pheromonal signal are closely related to the main component but show different degrees of unsaturation along the chain, possibly produced from unbranched polyunsaturated fatty acids. Such acids have been identified in male pheromone glands of several species of milkweed butterflies (Danainae) (Schulz *et al.* 1988).

The branched hydrocarbon, 2-methylheptadecane, which appears to show a different biogenetic origin from the above mentioned compounds, is also known to act as a sex pheromone in some arctiid species: *Holomelina lamae* (Schal *et al.* 1987, Roelofs & Cardé 1971), *H. aurantiaca*, *H. immaculata*, *H. nigricans* (Roelofs & Cardé 1971), and *Pyrrharctia isabella* (Krasnoff & Roelofs 1988). So far, however, *Pareuchaetes pseudoinsulata* is the only species producing both types of compounds.

The chemical findings reported above provide a first step towards developing of techniques for monitoring *Pareuchaetes* where it has been and will be released as a leaf-defoliator to control *Chromolaena*. However, prior to a routine application of synthetic pheromones, studies on the sexual behaviour of *Pareuchaetes* are required (*cf.* McNeil 1991) as well as behavioural tests to elucidate the role(s) of the different compounds identified; very likely, males will not respond to the major component alone but to a specific blend of compounds.

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REFERENCES

Arn, H., M. Tóth & E. Priesner. 1988. addendum 1990. List of Sex Pheromones of Lepidoptera and Related Attractants. Intern. Organs. Biol. Contr. Work Group: Pheromones. Swiss Fed. Res. Station Wädenswil

Boppré, M. 1991. A non-nutritional relationship of *Zonocerus* (Orthoptera) to *Chromolaena* (Asteraceae) and general implications for weed management. In: R. Muniappan & P. Ferrer (eds.) Proc. 2nd Intern. Workshop on Biol. Control of *Chromolaena odorata*. pp. 143-147. Agri. Expt. Station, Univ. Guam, Mangilao, Guam.

Conner, W. E. T. Eisner, R. K. Vander Meer, A. Guerrero, D. Ghiringelli & J. Meinwald. 1980. Sex attractant of an arctiid moth (*Utetheisa ornatrix*): a pulsed chemical signal. Behav. Ecol. Sociobiol. 7: 55-63

Descoins, C. & B. Frérot. 1984. Taxonomic value of the chemical composition of the sex pheromone blends in arctiid moths and related families. Abstr. of the XVII Intern. Congr. Entomol., Hamburg: 467

Descoins, C., B. Lalanne-Cassou, B. Frérot, C. Malosse & M. Renou. 1989. Comparative study of pheromonal secretions produced by arctiid and ctenuchid moths (insects, Lepidoptera) from the neotropical area. C. R. Acad. Sci. Ser 3, 309: 577-581

Einhorn, J., B. Boniface, M. Renou & M-L. Milat. 1984. Etude de la phéromone sexuelle de *Arctia villica* L. (Lépidoptére, Arctiidae). C. R. Acad. Sci. Paris 298 III: 573-576

Frérot, B., M. Renou, C. Malosse & C. Descoins. 1988 Isolement et identification de composés à activité phéromonale chez les femelles de l'arctiide *Tyria jacobaeae*: détermination biologique de la configuration absolue du composé majoritaire. Entomol. Exp. Appl. 46: 281-289

Krasnoff, S. B. & W. L. Roelofs. 1988. Sex pheromone released as an aerosol by the moth *Pyrrharctia isabella*. Nature 333: 263-265

McNeil, J. N. 1991. Behavioral ecology of pheromone-mediated communication in moths and its importance in the use of pheromone traps. Annu. Rev. Entomol. 36: 407-430

Roelofs, W. L. & R. T. Cardé. 1971. Hydrocarbon sex pheromone in tiger moths (Arctiidae). Science 171: 684-686

Schal, C., R. E. Charlton & R. T. Cardé. 1987. The temporal patterns of sex pheromone titers and release rates in *Holomelina lamae* (Lepidoptera: Arctiidae). J. Chem. Ecol. 13: 1115-1129

Schneider,D., S. Schulz, R. Kittmann & P. Kanagaratnam. 1991. Pheromones of both sexes of the weed-defoliator moth *Pareuchaetes pseudoinsulata* (Lepidoptera: Arctiidae). J. Appl. Entomol: in press.

Schulz,S.,W. Francke & M. Boppré. 1988. Carboxylic acids from hairpencils of male *Amauris* butterflies (Lep.: Danainae). Biol Chem Hoppe-Seyler 369: 633-638

Seibert, T. F. 1989. Biological control of the weed, *Chromolaena odorata* (Asteraceae), by *Pareuchaetes pseudoinsulata* (Lepidoptera: Arctiidae) in Guam and the Northern Mariana islands. Entomophaga 34: 531-539

Tóth,M., H. R. Buser, A. Pena, H. Arn, K. Mori, T. Takeuchi, L. N. Nikolaeva & B. G. Kovalev. 1989. Identification of (3Z,6Z)-1,3,6,-9,10-epoxyheneicosatriene and (3Z,6Z)-1,3,6-9,10-epoxyeico satriene in the sex pheromone of *Hyphantria cunea*. Tetrahedron Lett. 30: 3405-3408

Wunderer, H., K. Hansen, T. W. Bell, D. Schneider & J. Meinwald. 1986. Male and female pheromones in the behaviour of two Asian moths, *Creatonotos* (Lepidoptera: Arctiidae). Exp Biol 46: 11-27

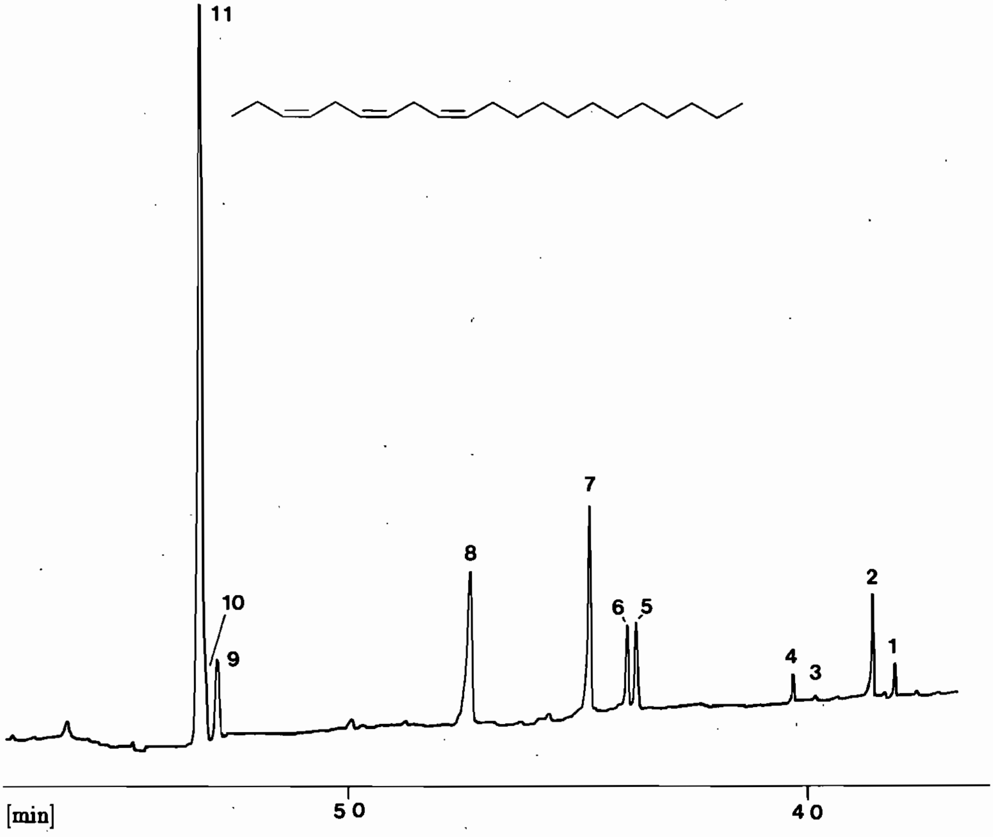

Fig. 1 Gas chromatogram of an extract of female pheromone glands of *Pareuchaetes pseudoinsulata* Rego Barros. 1 heptadecene; 2 heptadecane; 3 5-methylheptadecane; 4 2-methylheptadecane; 5 (Z,Z)-6,9-nonadecadiene; 6 (Z)-9-nonadecene; 7 nonadecane; 8 hexadecanoic acid (ubiquitously occurring fatty acid); 9 (Z,Z)-6,9-heneicosadiene; 10 heneicosene; 11 (Z,Z,Z)-3,6,9-heneicosatriene.

ARTHROPODS AND PATHOGENS FOR BIOLOGICAL CONTROL OF *CHROMOLAENA ODORATA*

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ABSTRACT

A study of the biological attributes of four arthropod candidates recommended for biological control of *Chromolaena odorata* was made using Goeden's (1983) criteria. The results suggested that these agents would provide only partial control on their own. The exception to this has been the biological control programme at Guam using *Pareuchaetes pseudoinsulata*. The suggestion for importation of several agents together merits serious consideration. Besides arthropods, five fungal pathogens of *C. odorata* are being investigated in Trinidad. These fungal pathogens may prove to be useful either as classical biological control agents or as mycoherbicides. Studies thus far indicate that *Ciononthrix praelonga* and *eptoria ekmaniana* are promising candidates.

INTRODUCTION

Chromolaena odorata (L.) R. M. King and H. Robinson is a serious weed in West Africa, South and South-east Asia (Cruttwell McFadyen 1988a). It has been the subject of a biological control programme since the 1970s. Two decades later, limited success has been achieved and there are more questions raised than answers obtained about the state of biological control of this weed. Its often innocuous position in the neotropics (Cruttwell McFadyen 1988b) has suggested that this weed could be similarly controlled in the Old World.

Hitherto, the only country that has reported complete success in the biological control of *C. odorata* is Guam (Muniappan & Marutani 1988, Seibert 1989). This event has provided both impetus and frustration to proponents of the programme to control C. *odorata* biologically. Part of the impetus is the renewed interest in other biological control agents of *C. odorata* in Central America and some results are reported. The biological attributes of four recommended agents are analysed and discussed. In addition, an update on the study of pathogens are given in this report.

ARTHROPODS FOR BIOLOGICAL CONTROL OF *C. ODORATA*

Cruttwell (1974) reported that some 225 arthropods were recorded on *C. odorata* in its native range. Of these, only four have been recommended for introduction into the Old World where the weed is a serious problem (Cock 1984). Recommendations were made following extensive studies in the native range of the weed. The agents recommended are: *Pareuchaetes pseudoinsulata* Rego Barros (Lepidoptera: Arctiidae) (reported by Bennett & Cruttwell 1973), *Apion brunneonigrum* Bequin-Billecoq (Coleoptera: Apionidae) (reported by Cruttwell 1973), *Mescinia parvula* (Zeller) (Lepidoptera: Pyralidae) (reported by Cruttwell 1977a) and *Acalitus adoratus* Keifer (Acari, Eriophyidae) (reported by Cruttwell 1977b). *P. pseudoinsulata* was introduced into seven countries but was reported to be successful only in Guam (Seibert 1989) (Table 1). No establishment was reported from Ghana and Nigeria. In Asia, the arctiid established in Malaysia, India and Sri Lanka but not in Thailand. In countries with successful establishment, *P. pseudoinsulata* did not impact significantly on the weed population. In the Philippines, the insect fortuitously arrived in the southern islands but did not appear to cause serious damage to *C. odorata* (Aterrado & Talatala-Sanico 1988).

In the case of *A. brunneonigrum*, the insect failed to establish in all the five countries to which it was introduced (Table 1). Long periods when no flowers occur could possibly be the reason for the failure to establish (Syed 1979).

Considering the limited success achieved thus far, an examination of the biological attributes of these agents was attempted using Goeden's (1983) criteria for selection of arthropod agents in biological control of weeds. The agent with the highest score of 50 is *P. pseudoinsulata* which confirms this insect as the agent of first choice in the biological control programme (Table 2). The next agent is *M. parvula* with a score of 40 while *A. brunneonigrum* and *A. adoratus* had a total score of only 29 each. Goeden (1983) suggested that species with scores of between 20 and 50 would indicate that the agent is only partially effective, reflecting the need for more than one agent to provide adequate control.

PATHOGENS OF *C. ODORATA* IN TRINIDAD

Five fungi attacking *C. odorata* were identified in Trinidad and Tobago (Table 3). Of these, only two were studied extensively, *viz. C. praelonga* and *S. ekmaniana*.

Infection of Caribbean *C. odorata* from one site in Trinidad by *C. praelonga*, collected at that site, has been achieved by inoculation at 15-22°C and 100% RH for 48 hours. Symptoms appeared after 10-14 days but only if the plants were protected from direct sunlight and high temperatures.

Infection studies are continuing to establish the rust's pathogenicity to *C. odorata* from other Caribbean locations. Other host range tests conducted to date have indicated that symptoms do not develop on *Ageratum conyzoides*, *Verononia cinerea*, *Rolandra fructicosa*, *Struchium spaganophora*, *Mikania micrantha* and *Pseudoelephantopus spicatus*.

These hosts have also been challenged with *S. ekmaniana* with all but *M. micrantha* and *P. spicatus* failing to show disease symptoms.

The host range studies are continuing during which it will be necessary to confirm resistance by microscopic examination of inoculated tissues.

BIOLOGICAL CONTROL POSSIBILITIES

Over a period of two decades, the initial question of whether *C. odorata* could be controlled by biological control agents has been replaced by questions pertaining to selection of types of biological control agents. That a biological control agent can control *C. odorata* has been demonstrated by Seibert (1989). However, failures in other countries (Table 1) suggest that other factors, such as bird predation (Cruttwell McFadyen pers. comm. 1990) could affect the effectiveness of *P. pseudoinsulata*. This is probably the case in Sri Lanka (Dharmadhikari et al. 1977) and in Sabah (Ooi et al. 1988). Cock & Holloway (1982) suggested that climate compatibility is important and further suggested that agents should be collected from areas matching that of the host country. The analysis of biological attributes of the agents, however, suggests that more than one agent should be introduced. So far only two species have been introduced into Asia and Africa. The eriophyid mite is believed to have arrived fortuitously into Asia and appeared to have little impact on the weed. The next candidate is *M. parvula*. However, studies in Trinidad have indicated that this moth is difficult to breed in the laboratory and attempts are being made to develop a suitable rearing technique. Countries pursuing biological control of *C. odorata* should attempt to introduce all four agents. In addition, the search for new arthropod biological control agents should not be abandoned.

Besides arthropods, there has been advancement in the study of potential fungal pathogens to control *C. odorata*. It appears that *C. praelonga* is a host specific and recent studies of its germination at 15-20°c may make it a likely biological control agent. Studies of *S. ekmaniana* show encouraging results. Hence, the future of biological control of *C. odorata* now appears brighter with a wider arsenal of biological control agents working together to reduce the weed to an innocuous plant.

Table 1: Summary of attempts at biological control of *Chromolaena odorata* (after Julien 1987; Napompeth et al. 1988; Seibert 1989)

	Ghana	Guam	India	Malaysia (Sabah)	Nigeria	Sri Lanka	Thailand
P. pseudoinsulata	Not Est.	S'cessful	Establ'ed	Establ'ed	Not Est.	Establ'ed	Not Est.
A. brunneonigrum	Not Est.	-	Not Est.	Not Est.	Not Est.	Not Est.	-

Not Est. = Not established
Establ'ed = Agents established without much impact
S'cessful = Very successful control of weed
- = Not introduced

Table 2: Comparative score of four arthropod biological control agents of *Chromolaena odorata* using Goeden's (1983) criteria.

Category	*Pareuchaetes pseudoinsulata*	*Mescinia parvula*	*Apion brunneonigrum*	*Acalitus adoratus*
I-1	4	6	1	2
I-2	2	2	2	0
I-3	4	4	2	4
I-4	3	3	3	3
I-5	0	0	0	0
I-6	0	0	0	0
I-7	3	3	3	0
I-8	2	2	2	6
Subtotal	18	20	13	15
II-1	6	6	6	6
II-2	2	0	2	2
II-3	6	2	2	6
II-4	6	6	6	6
Subtotal	20	14	16	20
III-1	6	0	-6	0
III-2	6	6	6	6
III-3	0	0	0	-12
Subtotal	12	6	0	-6
Total	50	40	29	29

Table 3: List of pathogens of *Chromolaena odorata* found in Trinidad and Tobago.

Cionothrix praelonga Wint.(Arthur)	Basidiomycotina, Uredinales
Septoria ekmaniana Petrak & Cif.	Deuteromycotina, Coelomycetes
Anhellia niger (Vingas) von Arx	Ascomycotina, Dothideales
Mycovellosiella perfoliati (Ell. & Everh.) Deighton	Deuteromycotina, Hymphomycetes
Phoma sp.	Deuteromycotina, Coelomycetes

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REFERENCES

Aterrado, E. D. & R. L. Talatala-Sanico. 1988. Status of *Chromolaena odorata* research in the Philippines. In: R. Muniappan (ed.) Proc. First Intern. Workshop on Biol. Control of *Chromolaena odorata* pp. 53-55, Agr. Expt. Sta., Unv. Guam, Mangilao, Guam

Bennett, F. D. & R. E. Cruttwell. 1973. Insects attacking *Eupatorium odoratum* in the Neotropics. 1. *Ammalo insulata* (Walk.) (Lep: Arctiidae), a potential biotic agent for the control of *Eupatorium odoratum* L. (Compositae). Tech. Bul. Commonwealth Institute Biol.Control 16: 105-115.

Cock, M. J. W. 1984. Possibilities for biological control of *Chromolaena odorata*. Tropical Pest Management 30: 7-13.

Cock, M. J. W. & J. D. Holloway. 1982. The history of, and prospects for, the biological control of *Chromolaena odorata* (Compositae) by *Pareuchaetes pseudoinsulata* Rego Barros and allies (Lepidoptera: Arctiidae). Bul. Entomol. Res. 72: 193-205.

Cruttwell, R. E. 1973. Insects attacking *Eupatorium odoratum* in the Neotropics. 2. Studies on the seed weevil *Apion brunneonigrum* B.B., and its potential use to control *Eupatorium odoratum* L. Tech. Bul. Commonw. Institute Biol. Control 16: 117-124.

Cruttwell, R. E. 1974. Insects and mites attacking *Eupatorium odoratum* in the Neotropics. 4. An annotated list of the insects and mites recorded from *Eupatorium odoratum* L., with a key to the types of damage found in Trinidad. Tech. Bul. Commonw. Institute Biol. Control 17: 87-125.

Cruttwell, R. E. 1977a. Insects and mites attacking *Eupatorium odoratum* L. in the Neotropics 5. *Mescinia* sp. nr. *parvula* (Zeller). Tech.Bul. Commonw. Institute Biol. Control 18: 49-58.

Cruttwell, R. E. 1977b. Insects and mites attacking *Eupatorium odoratum* L. in the Neotropics 6. Two eriophyid mites, *Acalitus adoratus* Keifer and *Phyllocoptes cruttwellae* Keifer. Tech. Bul. Commonw. Institute Biol. Control 18: 59-63.

Cruttwell McFadyen, R. E. 1988a. History and distribution of Chr*omolaena odorata* (L.) R.M. King and H. Robinson. In: R. Muniappan (ed.) Proc. First Intern. Workshop Biol. Control *Chromolaena odorata* pp. 7-12. Agr. Expt. Sta., Univ. Guam, Mangilao, Guam

Cruttwell McFadyen, R. E. 1988b. Ecology of *Chromolaena odorata* in the Neotropics. In: R. Muniappan (ed.) Proc. First Intern. Workshop Biol. Control *Chromoleana odorata* pp. 13-20. Agri. Expt, Sta., Univ. Guam, Mangilao, Guam.

Dharmadhikari, P. R., P. A. C. R. Perera, & T. M. F. Hassen. 1977. The introduction of *Ammalo insulata* for the control of *Eupatorium odoratum* in Sri Lanka. Tech. Bul. Commonw. Institute Biol. Control 18: 129-135.

Goeden, R. D. 1983. Critique and revision of Harris' scoring system for selection of insect agents in biological control of weeds. Protection Ecology 5: 287-301.

Julien, M. H. 1987. Biological Control of Weeds. A world catalogue of agents and their target weeds 2nd edition, CAB International Institute of Biological Control, U.K. p. 15.

Muniappan, R. & M Marutani. 1988. Rearing, release and monitoring of Pareuch*aetes pseudoinsulata*. In: R. Muniappan (ed.) Proc. First Intern. Workshop on Biol. Control of *Chromolaena odorat*a pp. 43-44. Agr. Expt. Sta., Univ. Guam., Mangilao, Guam.

Napompeth, B., N. Thi Hai, & A. Winotai. 1988. Attempts on biological control of Siam weed Chromo*laena odorata* in Thailand. In: R. Muniappan (ed.) Proc. First Intern. Workshop on Biol. Control of *Chromolaena odorata* pp. 57-62. Agri. Expt. Station,, Univ. Guam, Mangilao, Guam.

Ooi, P. A. C., C. H.Sim, & E. B.Tay. 1988. Status of the arctiid moth introduced to control Siam weed in Sabah, Malaysia. Planter, Kuala Lumpur 64: 298-304.

Seibert, T. F. 1989. Biological control of the weed *Chromolaena odorata* (Asteraceae), by *Pareuchaetes pseudoinsulata* (Lep.: Arctiidae) on Guam and the Northern Mariana Islands. Entomophaga 34: 531-539.

Syed, R. A. 1979. An attempt on biological control of *Eupatorium odoratum* L.f. in Sabah, Malaysia. *In:* Proceedings of the sixth Asian-Pacific Weed Science Society Conference, Jakarta, Indonesia. Vol. II pp. 459-466.

GUIDELINES FOR INTRODUCTION, REARING, FIELD RELEASE AND ESTABLISHMENT OF *PAREUCHAETES PSEUDOINSULATA*

The following guidelines were adopted following discussion at the 2nd International Workshop on Biological Control of *Chromolaena odorata*.

A. Pre-importation

1. Sources of *P. pseudoinsulata*
    1.1. Guam (Attention Dr. R. Muniappan)
    1.2. Sri Lanka or India
    1.3. Trinidad

2.Conduct nationwide survey to determine arthropods on *C. odorata*.

3.Secure permission from authorities to import *P. pseudoinsulata*.

4. Secure funding to support programme for at least 2 years.

5. Identify personnel to carry out the programme.
(Minimum: 1 scientist/entomologist + 2 assistants).

6. Ensure adequate supply of *C. odorata* (in pots or field patches).

7. Arrange for 1-2 weeks training for programme scientist to familiarize with rearing techniques and hand carry first consignment to initiate colony.

B. Collection and Despatch

1. 1000 insects in egg stage should be introduced.
2. Insects preferably laboratory reared.
3. Wherever possible, hand carry consignment to destination and avoid X-ray (airport security).
4. Ensure efficient communication link up between source and recipient countries.

C. Quarantine

P. pseudoinsulata has been extensively tested and found to be very host specific. While further host testing is unnecessary, it is prudent to adhere to national quarantine requirements and adopt measures to ensure that no arthropods other than *P. pseudoinsulata* arrive with the consignment.

1. A minimum quarantine room, which is insect proof, is required to examine the consignment. The consignment should be opened only in this room.

2. After confirming the content, each batch of eggs is transferred to a 500 ml cup with lid. A fresh *C. odorata* leaf is provided.

3.Upon eclosion, remove materials from source country and destroy in formalin/alcohol/freezer.

4.Record and report number of emergence.

D. Rearing

1. A minimum of one room with several cages is required to rear *P. pseudoinsulata*.

2. Rear no more than 30 newly hatched larvae in 500 ml cups together with 1-2 leaves/cup

3. Change leaves every 2 days but no more than 2 leaves/cup.

4. After 2nd moult (ca. 1 week after hatching) transfer larvae to 2 liter cups lined with gauze or 1/4 inch hardware cloth.

5. After 3rd moult (ca. 10 days after hatching) move 50 caterpillars into 100 liter trash cans (or something similar). Closethe can with fine nylon mesh cloth held by rope or rubber band. Stems of *C. odorata* are added into the can to feed the caterpillars. Clean the cans every 2-3 days.

6. Pupation occurs amongst the frass or in leaves. Collect pupae and place in oviposition cages (30 x 30 x 30 cm) for emergence and subsequent mating.

E. Field Release

1. Select 2 or 3 localities with healthy patches of *C. odorata*.

2. At each locality release 500 moths or 2000 larvae/release and continue to release over a period of time.

3. It is preferable to release the insect at night.

F. Monitoring

1. Following release, establishment of moth should be monitored monthly for a period of 2 years.

2. As the insect is nocturnal, such monitoring should be carried out at night or just before sunrise.

NEW APPROACHES TO THE BIOLOGICAL CONTROL OF *CHROMOLAENA ODORATA* IN SOUTH-EAST ASIA

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INTRODUCTION

Papers presented at the first International Workshop in Thailand highlighted both the seriousness of the weed problem caused by *Chromolaena* and the fact that it is still actively spreading. Successful biological control was reported from Guam and the Marianas but not elsewhere, and at that time there were few other biological control programmes active. Three years later, the situation is very different; reports have been presented here of renewed investigations in Trinidad and South America and of agent introductions imminent in West Africa and Indonesia. At the same time, there has been increasing interest in the weed in Australia, and proposals for active Australian participation in biological control programmes in the countries to our north.

THE THREAT TO NORTHERN AUSTRALIA

Despite the erroneous record in Holm et al (1977), *Chromolaena* does not occur in Australia, but there are areas of northern Australia which are climatically suitable (Fig. 1), and the risk to Australia is increasing. Concern over the increasing spread of *Chromolaena* in south-east Asia and the threat that this posed to Australia was first raised in 1984 to 1985, as a result of my visit to Manila in the Philippines, and discussions there regarding the problem of *Chromolaena* in the southern islands. The 1st International Workshop in 1988 stimulated further investigations, resulting in the production of a map showing how the weed has spread since 1940, which clearly demonstrated its continued inexorable spread south and east towards Australia and the Pacific (Fig. 2). Information from that Workshop was incorporated into an article designed to inform and warn Australian weed scientists (McFadyen 1989), and at the same time, a Quarantine leaflet on the weed was produced and circulated to possible northern entry points (Commonwealth of Australia 1988). An independent study of weed threats to northern Australia was commissioned by the Australian Quarantine and Inspection Service, and the 1989 report identified *Chromolaena odorata* as the worst weed threat, both on the grounds of the danger of accidental introduction and of the potential damage likely to be caused by its presence (P. Michael Unpublished Report 1989).

THE PROPOSED BIOLOGICAL CONTROL PROGRAMME

As early as 1986, suggestions had been made that Australia should act to promote the successful biological control of this weed in south-east Asia, thereby reducing the amount of seed and the speed of continued spread. ACIAR was asked for support, and sponsored three people to the 1st Workshop in Thailand, two scientists from the Philippines and myself. As a result of that Workshop, a definite proposal was submitted to ACIAR, for a co-operative biological control programme whereby Australia would supply the scientific expertise, and suitable insects would be tested and released in Indonesia and the Philippines.

The rationale for this approach is that Australia and particularly Queensland has a great fund of expertise and experience in the biological control of introduced weeds, particularly those of pasture and plantation crops. The Alan Fletcher Research Station in Brisbane is part of the Queensland Government Department of Lands, and has been actively involved in importing, host-specificity testing and field-releasing of insects and pathogens for the biological control of weeds ever since the 1920s. We currently have active programmes against 9 weeds, and import on average 3 new species of insect or disease every year. In particular, we have experience with the introduction and release of insects against two other *Eupatorium* species, crofton weed *Ageratina* (*Eupatorium*) *adenophora* and mistflower *Ageratina* (*Eupatorium*) *riparia*, and fortuitously we also have on the staff the entomologist (myself) who was responsible for the original investigations of the insects of *Chromolaena* in the West Indies in the late 1960s.

The AFRS also has considerable experience in the collection and shipment of insects from the Americas. We have imported insects from South America for the control of Harrisia cactus, from Mexico for the control of *Parthenium* weed, and currently have an entomologist based in northern Argentina testing and shipping insects for the control of *Parthenium* and lantana, as well as a second entomologist based in southern Texas. Both these are experienced field biocontrol entomologists, with considerable knowledge of the area and the plants, and either could collect the insects required from *Chromolaena* and arrange shipment to Indonesia or the Philippines.

PROPOSED PROGRAMME

Since the original investigations were made between 1967 and 1972, several papers have commented on the number of potentially useful biocontrol agents which exist in the Americas but which have never been tried (Cock 1984; McFadyen 1989). Only two agents have been deliberately released; the seed-feeding weevil *Apion brunneonigrum* which was released in Ghana, Nigeria, India, Sri Lanka and Malaysia but failed to establish, and the arctiid moth *Pareuchaetes pseudoinsulata* which has been released in Ghana and Nigeria in West Africa and India, Thailand, Sri Lanka, Malaysia and the Marianas in South-east Asia, but has only established in the last 3 (Julien 1987; Muniappan et al 1988). The eriophyid mite *Acalitus adoratus* was tested but never cleared for release, but has reached south-east Asia accidentally and is now widespread through much of the region. Partly as a result of the 1st Workshop, the European Common Market is financing a 4-year programme with IRHO and IIBC to introduce *Pareuchaetes* and the stem-tip moth *Mescinia parvula* into Cote d'Ivoire in west Africa and into Indonesia, and to investigate the possible use of pathogens as biological control agents. However, only these two insects are to be trialled at this stage.

Table 1. Potential Insect Biological Control Agents against *Chromolaena*

Name	Damage caused	Specificity	Problem	Country found
LEPID. *Mescinia parvula*	Shoot-borer: damaging	Tested: genus	Mating in cages	All Americas
Actinote anteas	Leaf-feeder damaging	untested: genus	Mating in cages	Trinidad, Costa Rica
Bucculatrix sp.	Leaf-miner; not very damaging	untested: genus		Mexico
DIPTERA *Perasphondylia reticulata*	Bud-galls: damaging	untested: genus	rearing in cages	All Americas
Clinodiplosis	Tip-galls: damaging	untested: genus	rearing	Trinidad
Procecidochares sp.	Stem-galls: mod. damaging	untested: genus	parasites	American mainland
Melanagromyza eupatoriella	Shoot-borer: damaging	untested: genus	mating in cages	WI, South America
COLEOPT. *Chlamisus insularis*	Stem feeder: not damaging	untested: genus		All Americas
Aulocochlamys	Stem-feeder: mod. damaging	untested: genus		Trinidad
Pentispa explanta	Leaf-miner: mod. damaging	untested: genus	prefers shade	Trinidad
Rhodobaenus cariniventris	Stem-borer: damaging	untested: genus	host range	Trinidad

The proposed ACIAR programme, therefore, would concentrate on the most promising of the agents present in South and Central America, excluding the 4 species already trialled or included in the IRHO programme. There are many potential agents (Table 1) and the priority assigned to these will vary according to the views of the scientists doing the selection as well as the country for which they are intended. However, for the proposed ACIAR programme the following three factors are of over-riding importance; 1) the insect must be highly host-specific, to the genus *Chromolaena* at least; 2) the insect must be easy to keep safely in quarantine without the need for a modern high-security building; 3) the insect must be easy to rear, with a known technique already established. These three factors mean that the Project Leaders would be able to assure the governments involved that on the one hand no risk whatever was involved in the quarantine rearing and host-testing of the insect selected, while on the other that a colony could be established and valuable experience in rearing and host-testing gained by the local entomologists involved.

In view of these factors, the first insect selected is the stem-galling tephritid fly Procecidochares sp. This fly was found in Vera Cruz, Mexico and in Belem, Brazil, and probably occurs over much of mainland South and Central America, through not in the West Indies. Two other flies in the same genus, *Procecidochares utilis* and *P. alani*, have been used for the biological control of their hosts *Ageratina adenophora* and *A. riparia* respectively, in Hawai'i and Australia. Both are highly host-specific, attacking as far as is known one plant species only, ie *P. utilis* from *A. adenophora* will not attack *A. riparia* and vice-versa. Both are easy to rear in cages and, because only the adult flies are mobile and these are quite large, 3-4mm long, are comparatively easy to maintain safely in quarantine. In Hawaii both species have given excellent control of their host weeds, which are no longer considered a problem. In Australia control of the weeds has not been adequate because the galls are heavily parasitised by native parasites. There is no way of determining what effect parasites might have on the species in the various islands of Indonesia or the Philippines.

The proposed programme, therefore, is for a permit for the introduction of this tephritid to be requested from the governments concerned. Once granted, stem galls of *Procecidochares* would be collected in South America and shipped directly to the quarantine insectary in Indonesia or the Philippines, where they would be received by an entomologist from the AFRS. The galls would be kept within a secure cage for adult emergence, all parasites would be destroyed and adult *Procecidochares* transferred to a rearing cage with plants of *Chromolaena*. Once a parasite-free colony was established, host-testing would be carried out by the local entomologists, with assistance from the AFRS entomologist as required. When host-testing had been completed to the satisfaction of the government, mass-rearing and field releases would begin, and releases would then be planned for all islands within the archipelago. Regular monitoring would be necessary to determine whether establishment was occurring and whether parasitism was developing as a problem.

CURRENT STATUS

As a result of discussions at this Workshop, it is clear that the prospects for this proposed programme have improved greatly over the last 12 months. The IRHO programme has received the necessary permit from the Indonesian government for the introduction of the moth *Pareuchaetes* from Guam, and the Marihat research station in Sumatra is well equipped to rear and host-test this or other potential biocontrol agents. Matters are less advanced in the Philippines, but the GTZ biological control of pests programme could serve as a base and liaison for the introduction of new agents, and there are entomologists here and at Los Banos interested in participating. As a result, ACIAR should now be able to draw up a firm budget and 3 year programme, and allocate funds to this, hopefully to start next year.

REFERENCES

Cock, M.J.W. 1984. Possibilities for biological control of *Chromolaena odorata*. Tropical Pest Management 30:7-13.

Commonwealth of Austraila. 1988. Christmas Bush. Plant Quarantine Leaflet No. 56, Department of Primary Industries and Energy, Canberra.

Holm, L.G., D.L. Plucknett, J.V. Pancho & J.P. Herberger. 1977. The World's Worst Weeds: Distribution and Biology. East-West Center, Univ. Press, Hawaii, U.S.A.

Julien, M. 1987. Biological control of weeds: A world catalogue of agents and their target weeds. 2nd ed. C.A.B. International, Wallingford.

McFadyen, R.E. Cruttwell. 1989. Siam weed: a new threat to Australia's north. Plant Protection Quarterly, 4, 3-7.

Muniappan, R., M. Marutani & G.R.W. Denton. 1988. Introduction and establishment of *Pareuchaetes pseudoinsulata* Rego Barros (Arctiidae) against *Chromolaena odorata* in the Western Caroline Islands. J. Biol. Control 2: 141-142.

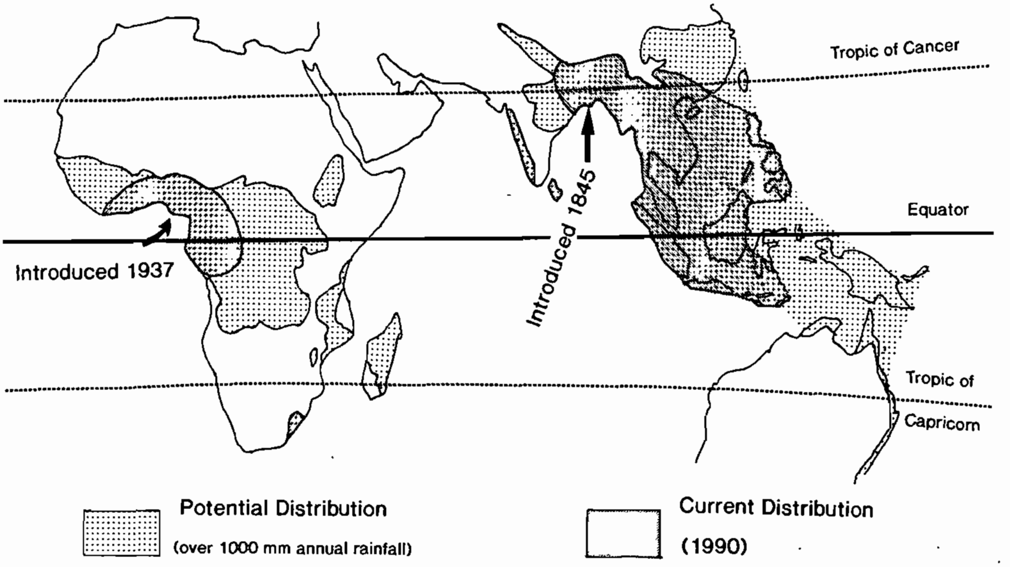

Fig.1. Current & Potential Distribution of *Chromolaena odorata* in Asia and Africa

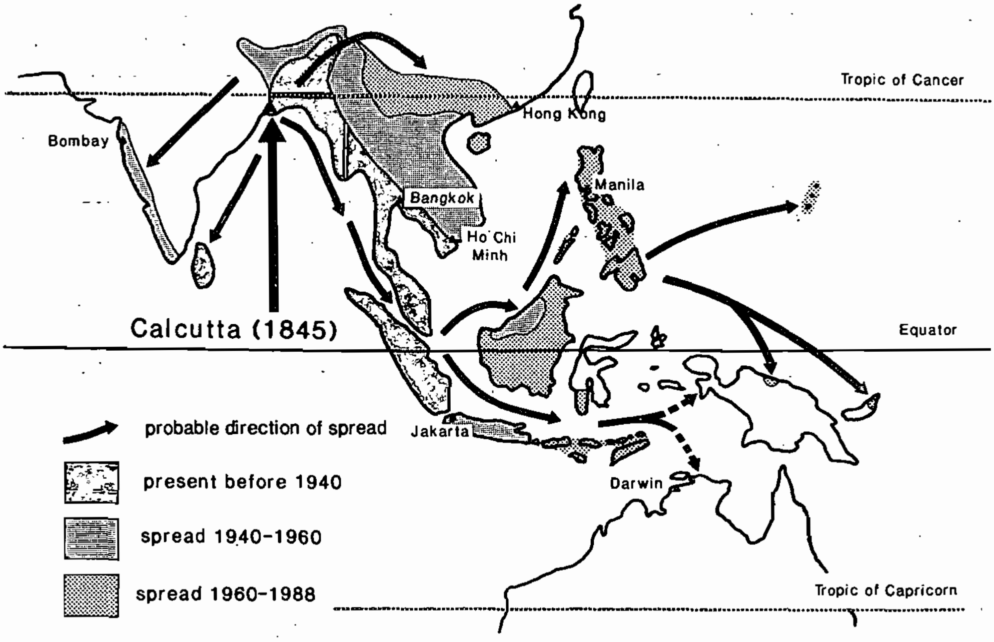

Fig. 2. Spread of *Chromolaean odorata* in South-east Asia.

SUCCESSION OF VEGETATION AFTER SUPPRESSION OF *CHROMOLAENA ODORATA* BY *PAREUCHAETES PSEUDOINSULATA* IN GUAM

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ABSTRACT

Chromolaena odorata (L.) King & Robinson had been one of the dominant weeds in open areas and along a roadside in the northern and central parts of Guam. In 1985, a biocontrol agent, *Pareuchaetes pseudoinsulata* Rego Barros (Lepidoptera:Arctiidae) was introduced and its establishment was confirmed in the north central part of Guam. Although 100 % of defoliation of *C. odorata* was recorded initially at release sites, the weed has recovered to some degree afterwards. Relative importance value of plant species in a five square meter quadrat at three sites were measured from July 1987 to May 1989 to estimate dominance of plant species and to study seasonal changes in plant competition in the field where *C. odorata* was dominant in 1984 and suppressed by *P. pseudoinsulata* in 1985-86. Three components were included to calculate relative importance value of a species: number of individual plants, plant height, and vegetation cover within the quadrat. The names of plant species found within three 5mx5m permanent quadrats and seasonal changes of plant distribution expressed by a species importance value are presented. *C. odorata* did not become a dominant species during this study.

INTRODUCTION

The first record of *Chromolaena odorata* (L.) King & Robinson (Asteraceae) in Guam was documented in 1963 as a herbarium specimen at the University of Guam. By early 1980, *C. odorata* had replaced many native and exotic plant species in fallow lands and along roadsides. Biological control of the weed was initiated at the Agricultural Experiment Station in 1984 supported by a grant from the Pacific Basin Tropical and Subtropical Research Program, Special grants, CSRS, United State Department of Agriculture. Seibert (1989) reported his work on introduction and establishment of *Pareuchaetes pseudoinsulata* Rego Barros (Lep.:Arctiidae) in Guam. Approximately 100 pupae of *P. pseudoinsulata* were obtained from the Commonwealth Institute of Biological Control (now named the CAB International Institute of Biological Control) Bangalore, India and 55 pupae and late instar larvae from Trinidad. Mass rearing in the laboratory and field releasing was carried out in early 1985, and the first recovery of field-reared

P. pseudoinsulata was observed in June 1985 in northcentral Guam. The initial spread of *P. pseudoinsulata* was very slow. Two months after establishment at the initial release point there were no signs of the insect presence beyond 30 m radius. Four months after establishment (by the 4th generation) defoliation was mostly complete at the initial release point. After 18 months, *P. pseudoinsulata* had defoliated over 25,000 hectares of the weed. The initial impact of *P. pseudoinsulata* in controlling *C. odorata* was great. Defoliation of the weed by the insect reached 100% in most areas. The shoot tips were eaten and virtually all buds were destroyed. The plant had no resources other than to produce new shoots from the base which were defoliated as they emerged from the ground. When growing tips and lateral buds were eaten prior to late November, no flowers were produced. As a result, the distribution of the weed has become patchy and the population of *P. pseudoinsulata* has become smaller and localized.

It is our concern to determine the effectiveness of *P. pseudoinsulata* as a biocontrol agent in the long period of time on Guam. For this reason, we started two types of ecological survey studies. One study was to examine plant species which had started to grow and replaced *C. odorata* after initial defoliation of the weed by *P. pseudoinsulata* at the initial release site. The second and long term study is periodical visitation to selected sites around the island where *C. odorata* is present with or without association of *P. pseudoinsulata*. In this paper, the result of the first study, succession of plant species replacing *C. odorata* after defoliation at or near the initial release sites using the permanent quadrats is presented.

MATERIALS AND METHODS

Three locations were selected to examine the plant species replacing *C. odorata* at or near the initial *P. pseudoinsulata* release site. A permanent quadrat (5mx5m) was placed at each location. Within a quadrat, number of individuals of a species, average height of plants of a species, and canopy cover were measured. For average height of the species, 10 individual plants of the species were randomly sampled and if less than 10 plants were found within the quadrat, the heights of all plants were measured. To measure the canopy cover of the species in the quadrat, one square meter grid which had 100 of 10cmx10cm units was used. The maximal area of the species in the quadrat was 25 m^2. Relative importance value (RIV) (%) of a species was calculated by

(Relative density + Relative height + Relative canopy cover)/3 where

Relative density (%) = (no. of individuals of a species/total no. of plants in a quadrat)x100

Relative height (%) = (average height of a species/sum of average heights of all species) x100

Relative canopy cover (%) = (canopy cover of a species/total canopy of all species present in a quadrat)x100.

Data were collected once a month in the first year and every other month during the second year. The three locations studied were NCS (Naval Communication Station), Hilaan (near Hilaan Point) and Two Lovers Point (near Two Lovers Point) (Figure 1). Climatological data during the survey were obtained from National Oceanic and Atmospheric Administration, Department of Commerce, USA.

RESULTS AND DISCUSSION

Monthly total rainfall and mean air temperature near the study sites during the experiment are presented in Figure 2. Total precipitation from July 1, 1987 to June 30, 1989 (24 months) was 4676 mm. During the first year (July, 1987-June 1988), September 1987 was the wettest month and February was the driest month. In the second year, the heavy rainfall occurred in July and October, 1988 and the driest month of 1989 was March. The months of February to May are usually considered as a dry period of the year on Guam; however, in 1989 there was fairly heavy rainfall in February and April. Mean air temperature was relatively consistent throughout a year with the range of 24.2-27.2 C. The amount of rainfall and daylength seem to be major factors to trigger seasonal changes of plant development of many species in Guam. The daylength falls in the range of 11.3 hours (December) and 12.9 hours (June).

Major species found at three study sites during the experiment are listed in Table 1. It is noticeable that the majority of these weeds are introduced from tropical America (Stone 1970, Moore & McMakin 1979, Moore & Krizman 1981, Whistler 1983).

In 1985, prior to introduction of *P. pseudoinsulata* and its establishment, all three study sites were basically covered with *C. odorata* (Muniappan, unpublished data). Soon after *P. pseudoinsulata* was established, nearly 100% of *C. odorata* at the release site was defoliated (Seibert 1989). The species relative importance value during the experiment from July 1987 to May 1989 indicated that at all three locations, *C. odorata* never became a single dominant weed (Figures 3, 4 and 5). Periodically *P. pseudoinsulata* and aphids were observed infesting *C. odorata* within the quadrats or near the quadrats in the field.

Many plant species including *C. odorata* produced flowers and seeds during the months of December to April in the field. The first flower bud initiation of *C. odorata* was noticed in November. Flowering occurred soon after the bud initiation. The flowering period could last or was delayed as late as April or May if there were any biotic factors involved such as partial defoliation of the weed by *P. pseudoinsulata*. Under normal circumstances, seed dispersal started in January and at that time sprouting of new shoots and development of new seedlings at the ground could be found. It was observed that after establishment of *P. pseudoinsulata* in Guam, plant development of *C. odorata* in the field was not synchronized as before.

Pennisetum polystachyon (L.) Schultes (Poaceae) was one of the major species during months of July to November at Two Lovers Point (Figure 3) and Hilaan (Figure 5). It started to flower in September-October and the seed dispersal occurred from November. Vigorous vegetative growth of this species was observed during the months of July and August.

Two other important plant species in this study were a neotropic species *Stachytarpheta jamaicensis* (Verbenaceae) and a fern, *Phymatodes scolopendria* (Polypodiaceae). *S. jamaicensis* had a higher species RIV during the first year at Hilaan (Figure 5) and *P. scolopendria* was the dominant species at NCS during the period of the two year study (Figure 4). Additionally, *Passiflora suberosa* (Passifloraceae) and *Conyza canadensis* (Asteraceae) showed the higher species RIVs at Two Lovers Point in early 1989.

REFERENCES

Moore, P.H. & P.D. Krizman. 1981. Field and Garden Plants of Guam. Cooperative Extension Service publication, College of Agriculture and Life Sciences, University of Guam. 183pp.

Moore, P.H. & P.D. McMakin. 1979. Plants of Guam. Cooperative Extension Service publication, College of Agriculture and Life Sciences, University of Guam. 186pp.

Seibert, T. 1989. Biological control of the weed, *Chromolaena odorata* [Asteraceae], by *Pareuchaetes pseudoinsulata* [Lep.: Arctiidae] on Guam and the Northern Mariana Islands. Entomophaga 34:531-539.

Stone, B.C. 1970. The flora of Guam. Micronesica 6:1-659.

Whistler, W.A. 1983. Weed Handbook of Western Polynesia. Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH. Eschborn. 151pp.

Table 1. Species found at three sites during the experiment in Guam.

Species	Two Lovers Point	NCS	Hilaan
Asteraceae			
Bidens pilosa	X	X	X
Chromolaena odorata	X	X	X
Conyza canadensis	X	X	X
Convolvulaceae			
Ipomoea congesta	X	X	X
Ipomoea sp.		X	
Euphobiaceae			
Euphorbia cyathophora	X	X	X
Euphorbia geniculata	X		X
Euphorbia hirta	X	X	X
Fabaceae			
Leucaena leucocephala		X	
Mimosa pudica			X
Malvaceae			
Sida acuta			X
Sida rhombifolia		X	
Passifloraceae			
Passiflora foetida var.*hispida*	X	X	
Passiflora suberosa	X	X	X
Rhamnaceae			
Colubrina asiatica	X		
Rubiaceae			
Spermacoce assurgens	X	X	X
Morinda citrifolia			X
Verbenaceae			
Stachytarpheta jamaicensis	X	X	X
Monocots:			
Cyperaceae			
Cyperus ligularis		X	
Cyperus rotundus		X	
Cyperus sp.			X
Poaceae			
Digitaria sp.		X	X
? *Panicum* sp.		X	
Paspalum sp.		X	X
Pennisetum polystachyon	X	X	X
Stenotaphrum secundatum		X	X
Ferns:			
Polypodiaceae			
Phymatodes scolopendria	X	X	X

X= species is present at a site.

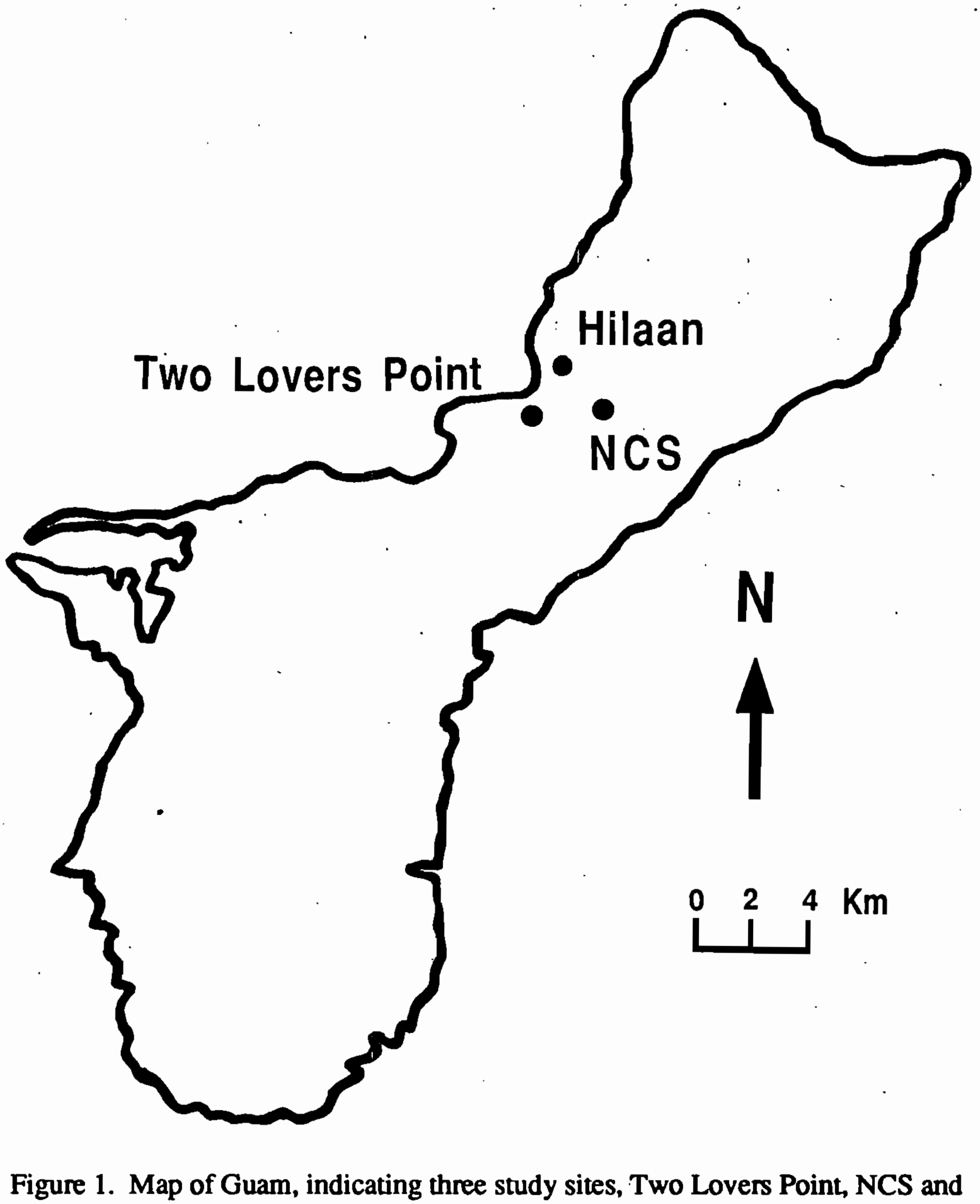

Figure 1. Map of Guam, indicating three study sites, Two Lovers Point, NCS and Hilaan in this experiment.

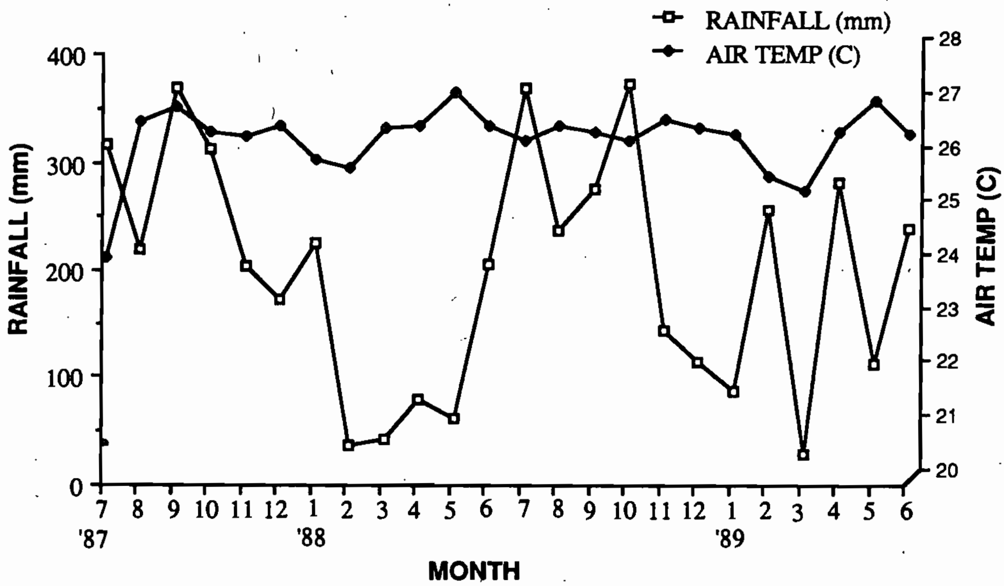

Figure 2. Rainfall and mean air temperature near three study sites in Guam during the experiment. Data was taken near NCS by National Oceanic and Atmosphere Administration.

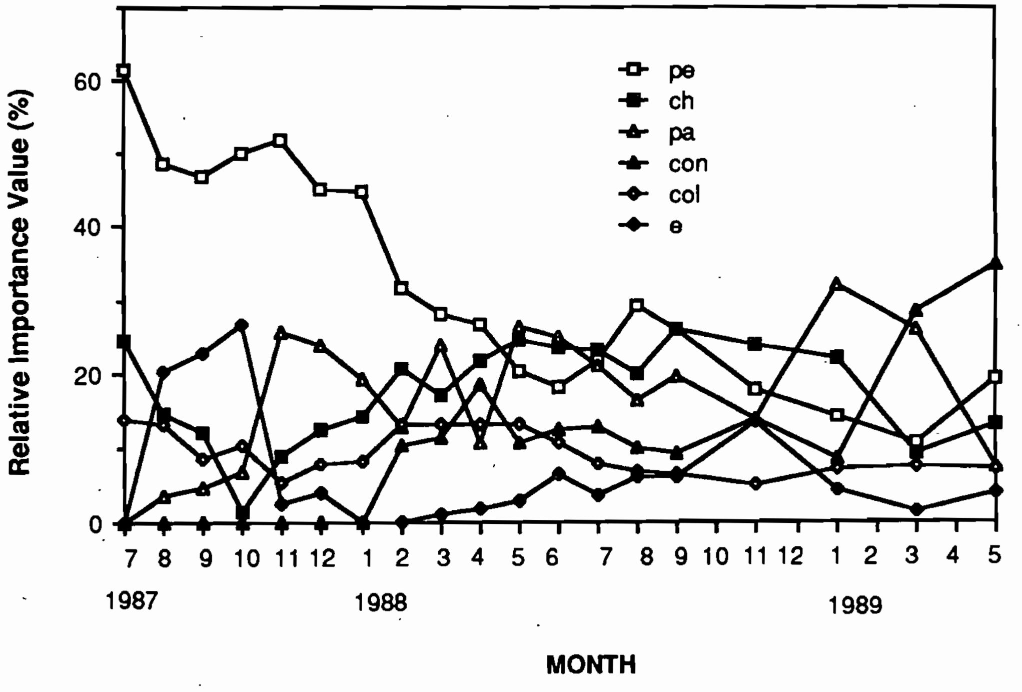

Figure 3. Species relative importance value of 6 major plants at Two Lovers Point during July 1987 - May 1969: (pc) = *Pennisetum polystachyon*, (ch) = *Chromolaena odorata*, (pa) = *Passiflora suberosa*, (con) = *Conyza canadensis*, (col) = *Colubrina asiatica* and (e) = *Euphorbia hirta*.

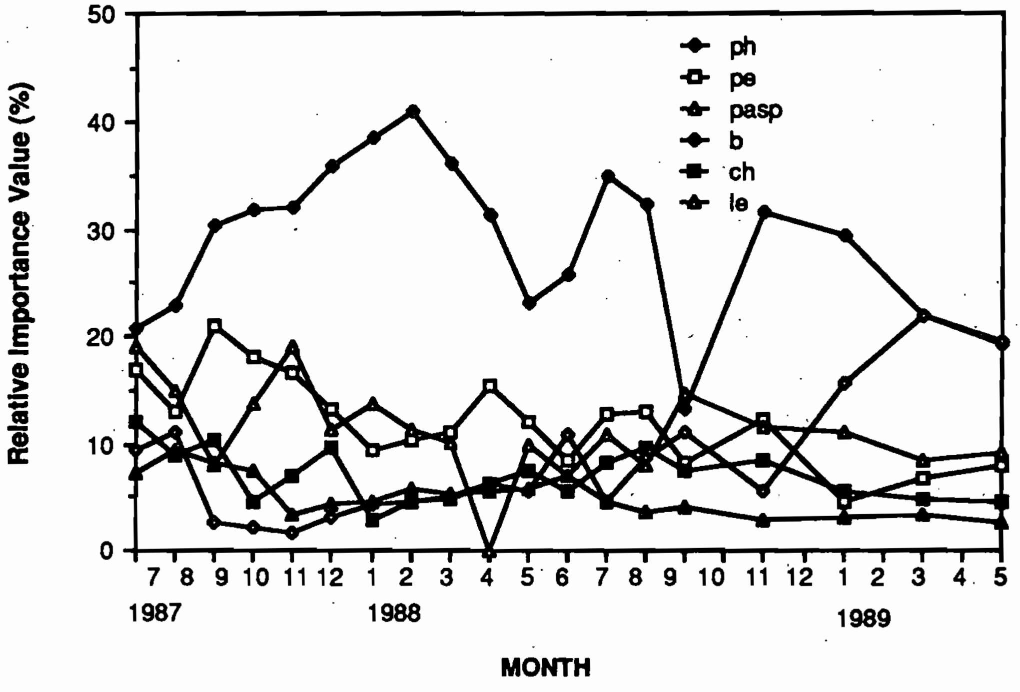

Figure 4. Species relative importance value of 6 major plants at NCS during July 1987 - May 1989: (ph) = *Phymatodes scolopendria*, (pe) = *Pennisetum polystachyon*, (pasp) = *Paspalum sp.*, (b) = *Bidens pilosa*, (ch) = *Chromolaena odorata*, and (le) = *Leucaena leucocephala*.

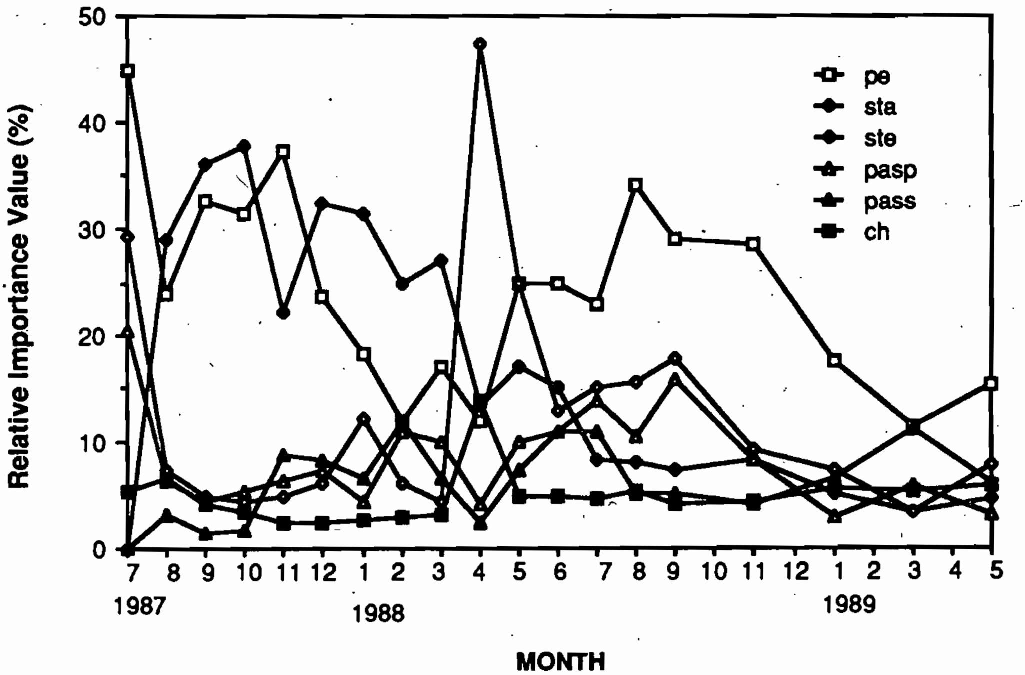

Figure 5. Species relative importance of major plants at Hilaan during July 1987 - May 1989: (pc) = *Pennisetum polystachyon*, (sta) = *Stachytarpheta jamaicensis*, (ste) = *Stenophrum secundatum*, (pasp) = *Paspalum* sp., (pass) = *Passiflora suberosa*, and (ch) = *Chromolaena odorata*.

A NON-NUTRITIONAL RELATIONSHIP OF *ZONOCERUS* (ORTHOPTERA) TO *CHROMOLAENA* (ASTERACEAE) AND GENERAL IMPLICATIONS FOR WEED MANAGEMENT

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INTRODUCTION

For many insects, plants represent much more than food sources because they not only utilize the nutrients but also their "toxic" secondary compounds. These secondary substances are thought to have evolved as defensive principles under the pressure of selective herbivory. However, for a variety of insects the compounds have now lost their repellent effects and gained a new significance, *e.g.*, serving instead as signals for hostplant detection. Some insects have specialized to the extent of storing unconverted plant toxins for their own defence against predators, and/or even requiring them as precursors for the biosynthesis of intraspecific signal compounds (pheromones). Sequestration of secondary plant chemicals by insects is usually linked with feeding. There are, however, so-called "pharmacophagous" insects that search for specific secondary compounds directly, consume them independently of food uptake, and use them to increase their fitness, again either by storing these plant metabolites for their own defence and/or using them as pheromone precursors (Boppré 1984; for references see Boppré 1986, 1990).

This paper discusses the likely pharmacophagous relationship between the grasshopper *Zonocerus variegatus* and the weed *Chromolaena odorata* in west Africa and provides an example of the hidden or unpredictable effects the introduction of a foreign weed can have on native insects and on (agro-)ecosystems. The role of secondary plant substances in the ecology of exotic plants and their biological control is briefly considered in general, and specifically with respect to the use of *Pareuchaetes* moths for controlling *Chromolaena*.

The weed *Chromolaena odorata*

Chromolaena odorata King & Robinson 1970 (*Eupatorium odoratum* L.), the Siam weed, is a perennial shrub native to tropical America. Following its introduction into India, *C. odorata* has invaded south-east Asia from where it subsequently reached west Africa. In its new habitats it spreads quickly, forming dense thickets, and has become a weed which seriously interferes not only with natural vegetation but also with forestry, pastures and plantation crops. For recent synoptic accounts on *Chromolaena odorata* see, *e.g.*, Muniappan (1988), Cruttwell McFadyen (1989), Ambika & Jayachandra (1990) and several papers in this Proceedings.

The grasshopper *Zonocerus variegatus*

Zonocerus variegatus (L.) (Orthoptera: Pyrgomorphidae) is a polyphagous west African grasshopper; its dry season generation is a pest causing serious damage to various arable crops (*e.g.* cassava, maize, and cotton) and plantation trees (*e.g.*, teak and *Citrus*). For synoptic accounts on *Zonocerus* see, *e.g.*, Chapman *et al.* (1986) and Chiffaud & Mestre (1990).

Zonocerus has reached pest status only recently, and this has been assumed to be due to increasing agriculture. Toye (1974), however, suggested that there may be a correlation between the increased dry season populations of *Zonocerus* and the spread of *Chromolaena odorata*, but offered no clue regarding any possible causal link.

Zonocerus hatchlings and early instar hoppers partly feed on *Chromolaena*, and the thickets are preferred roosting sites. However, this plant is not an adequate nutritional host permitting normal development (see, *e.g.*, Bernays *et al.* 1975). Despite this, *Zonocerus* is strongly attracted to flowers of *Chromolaena* and the grasshoppers consume the flowers in large numbers (*cf.* Modder 1984, 1986; Boppré & Fischer 1991). However, insects fed exclusively *Chromolaena* flowers from the fourth instar failed to become adult (Chapman *et al.* 1986). If Siam weed is nutritionally inadequate for *Zonocerus*, why do the insects only become a pest where it occurs?

Zonocerus, pyrrolizidine alkaloids (PAs), and *Chromolaena*

Zonocerus elegans (Thunb.), a species closely related to *Z. variegatus* and which shares the same aposematic coloration, is known to be attracted to withered plants containing pyrrolizidine alkaloids (PAs), as well as to pure PAs, and to ingest these secondary plant substances (Boppré *et al.* 1984). *Zonocerus* thus seems to exhibit pharmacophagous relationships with PA-plants, as do numerous butterflies and moths (Lepidoptera), some flea beetles (Coleoptera: Chrysomelidae: *Gabonia*) and chloropid flies (Diptera: Chloropidae) (for review see Boppré 1986, 1990). Bernays *et al.* (1977) reported *Z. variegatus* to sequester and store PAs from *Crotalaria retusa* (Fabaceae); *Zonocerus* also consumes other PA-containing plants, *e.g.*, *Heliotropium* (Boraginaceae) and *Ageratum* (Asteraceae) (references in Chiffaud & Mestre 1990). Amongst the variety of plant genera containing PAs, species of *Eupatorium* have been recognized to possess several PAs (*cf.* Smith & Culvenor 1980, Brown 1984, Mattocks 1986).

This knowledge suggested that *Chromolaena*, or at least its flowers, might serve as a PA-source for *Zonocerus*. Recent field studies in Bénin (West Africa) revealed that larvae as well as adults of *Z. variegatus* are not only attracted to *Chromolaena* flowers (*cf.* Modder 1984) but dried parts of various PA-containing plants, extracts of PA-plants, and certain pure PAs were also effective lures; dry leaves of *Chromolaena*, however, are not attractive but the roots are (Boppré & Fischer 1991). Detailed chemical analyses by Biller *et al.* (1991) have revealed that *Chromolaena odorata* contains a mixture of five PAs (with rinderine as the major component) and proved that the highest concentrations occur in the roots and in the inflorescences; stems and leaves, however, are very low in PAs.

In conclusion, the puzzle of the coincidence of the spread of *Chromolaena* and the pest status of *Zonocerus variegatus* seems to be explicable by the following hypothesis: *Zonocerus* enjoys a non-nutritional association with *Chromolaena* which provides PAs; these secondary plant compounds are stored and chemically protect the grasshoppers and particularly their diapausing eggs from predators (*e.g.*, larvae of *Mylabris* beetles) or parasitoides, and this gives rise to the increased fitness and population density of dry season *Zonocerus*. Without *Chromolaena*, *i.e.* either before its introduction, or in areas where it is lacking, or in the wet season when *Chromolaena* does not bloom, PAs seem to be a limited resource restricting the grasshoppers' reproductive success.

Behavioural, physiological and chemical studies in progress strongly support this unlikely hypothesis. Apart from gathering chemoecological knowledge, we aim to develop an attracticide based on PAs to control *Zonocerus* in a way harmless to both man and environment.

CONCLUSIONS AND GENERAL IMPLICATIONS

Regrettably, our findings on *Chromolaena* and *Zonocerus* do not provide good news for the biological control of Siam weed. Even though significant reduction in seed production of *C. odorata* is caused by *Zonocerus*, this does not seem to affect the plant populations at all. However, what this new finding does do is draw attention to the potential importance of the secondary compounds of *Chromolaena*, an aspect which has largely been neglected previously. Moreover, it indicates a novel and inconspicuous effect of Siam weed on (agro-)ecosystems which might not only affect additional insect species in Africa and Asia but may also occur in a similar way with other introduced or exotic plants.

The fundamental points arising from this story should also be considered in the general context of testing hostplant specificity of potential control agents prior to their release in foreign habitats. The common practice of testing only or mainly those native plants that are taxonomically related to the target species might be misleading because many secondary plant substances (and these are always, and not only in pharmacophagous species, essential for host specificity) have evolved polyphyletically, in unrelated taxa.

Pareuchaetes pseudoinsulata Rego Barros (Lepidoptera: Arctiidae), the only leaf-feeder on *Chromolaena* for which potential as a biological control agent against Siam weed is being ascribed at present (see Seibert 1989, several papers in this Proceedings, and references therein), is likely to be a "PA-insect", as are several other Arctiinae which obtain PAs either from their host plants and/or pharmacophagously as adults, store them and/or utilize PAs as male pheromone precursors (see Boppré 1990 for references). Schneider *et al.* (1991) have found hydroxydanaidal to be the major volatile of the male scent organs, and this compound is well known to be synthesized from PAs and play a major role as a sex pheromone in other arctiids. This does not, however, permit precise predictions based on present knowledge on PA-dependent moths because all exhibit specific differences (Boppré 1990). Studies in progress are intended to elucidate the chemoecology of *Pareuchaetes* which, incidentally, eagerly feeds in our laboratory on *Heliotropium*, boraginaceous plants rich in PAs and common throughout the tropics. It is not inconceivable that *Pareuchaetes* prefers *Heliotropium* (and/or other PA-containing plants?) to *Chromolaena* and that introduction of the moths could cause destruction of heliotrope instead of controlling Siam weed. Such an outcome would cause serious ecological harm. This sort of possibility is why the biology of *Pareuchaetes* - and any other insect associated with *Chromolaena* - needs to be investigated in detail from a chemoecological point of view, together with the Siam weed itself. Furthermore, biological control agents should only be released in foreign habitats if their establishment can be monitored, not only by observing the assumed target plant but also generally, *e.g.*, by using female sex attractants (*cf.* Schulz 1991 for sex pheromones of *P. pseudoinsulata*).

ACKNOWLEDGEMENTS

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REFERENCES

Ambika,S. R. & Jayachandra. 1990. The problem of *Chromolaena* weed. *Chromolaena odorata* Newsletter # 3: 1-6

Bernays, E. A., R. F. Chapman, A. G. Cook, L. J. McVeigh & W. W. Page. (1975) Food plants in the survival and development of *Zonocerus variegatus* (L.). Acrida. 4: 33-45

Bernays,E. A., J. A.Edgar & M. Rothschild. 1977. Pyrrolizidine alkaloids sequestered and stored by the aposematic grasshopper, *Zonocerus variegatus*. J. Zool. (Lond) 182: 85-87

Biller, A., M. Boppré & T. Hartmann, 1991. Pyrrolizidine alkaloids in *Chromolaena odorata* (Asteraceae: Eupatoriae). Manuscript

Boppré, M. 1984. Redefining "pharmacophagy". J. Chem. Ecol. 10: 1151-1154

Boppré, M. 1986. Insects pharmacophagously utilizing secondary plant substances (pyrrolizidine alka loids). Naturwissenschaften 73: 17-26

Boppré, M. 1990. Lepidoptera and pyrrolizidine alkaloids: exemplification of complexity in chemical ecology. J Chem Ecol 16: 165-185

Boppré, M. & O. W. Fischer. 1991. Attraction of *Zonocerus variegatus* (Orthoptera: Pyrgomorphidae) to *Chromolaena odorata* (Asteraceae) and other sources of pyrrolizidine alkaloids. Manuscript

Boppré, M., U. Seibt & W. Wickler. 1984. Pharmacophagy in grasshoppers? *Zonocerus* being attracted to and ingesting pure pyrrolizidine alkaloids. Entomol. Exp. & Appl. 35: 713-714

Brown, K. S. Jr. 1984. Chemical ecology of dehydropyrrolizidine alkaloids in adult Ithomiinae (Lepidoptera: Nymphalidae). Rev Brasil Bio 44: 435-460

Chapman, R. F., W. W. Page & A. R. McCaffery. 1986. Bionomics of the variegated grasshopper (*Zonocerus variegatus*) in West and Central Africa. Annu Rev Entomol 31: 479-505

Chiffaud, J. & J. Mestre. 1990. Le criquet puant *Zonocerus variegatus* (Linné, 1758). Paris: C.I.R.A.D.

Cruttwell McFadyen, R. E. 1989. Siam weed: a new threat to Australia's north. Plant Prot. Quarterly 4: 3-7

Mattocks, A. R. 1986. Chemistry and Toxicology of Pyrrolizidine Alkaloids. London: Academic Press

Modder, W. W. D. 1984. The attraction of *Zonocerus variegatus* (L.) (Orthoptera: Pyrgomorphidae) to the weed *Chromolaena odorata* and associated feeding behaviour. Bull. Ent. Res. 74: 239-247

Modder, W. W. D. 1986. An integrated pest management strategy for the African grasshopper *Zonocerus variegatus*. Nigerian Field 51: 41-52

Muniappan, R. (ed). 1988. Proc. 1st Intern. Workshop on Biol. Control of *Chromolaena odorata*. Agricultural Experiment Station, Univ. of Guam, Mangilao, Guam.

Schneider, D.,S. Schulz, R. Kittmann & P. Kanagaratnam. 1991. Pheromones of both sexes of the weed-defoliator moth *Pareuchaetes pseudoinsulata* (Lepidoptera: Arctiidae). J. Appl. Entomol. in press.

Schulz, S. 1991. The chemistry of the putative female sex attractant pheromone of *Pareuchaetes pseudoinsulata* Rego Barros (Lep.: Arctiidae). In: R. Muniappan & P. Ferrar (eds). Proc. 2nd Intern. Workshop on Biol. Control of *Chromolaena odorata* pp. 113-117, Agri. Expt. Sta., Univ. Guam, Mangilao, Guam.

Seibert, T. F. 1989. Biological control of the weed, *Chromolaena odorata* (Asteraceae), by *Pareuchaetes pseudoinsulata* (Lepidoptera: Arctiidae) in Guam and the Northern Mariana Islands. Entomophaga 34: 531-539

Smith, L. W. & C. C. J. Culvenor. 1980. Plant sources of hepatotoxic pyrrolizidine alkaloids. J. Nat. Prod. 44: 129-152

Toye, S. A. 1974. Feeding and locomotory activities of *Zonocerus variegatus* (L.) (Orthoptera, Acridoidea). Rev. Zool. Afr. 88: 205-212

INSECT INDUCED CHANGES IN *CHROMOLAENA ODORATA*

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ABSTRACT

Pareuchaetes pseudoinsulata was introduced to Guam to control the noxious weed, *Chromolaena odorata*. Biochemical and physiological studies have been conducted to reveal changes in *C. odorata* leaves when the larvae of *P. pseudoinsulata* attack the plant. The rate of photosynthesis and the amount of chlorophyll were reduced in insect-infested plants. Polyacrylamide gel electrophoresis indicated a distinct change in the small subunit of ribulose-1,5-bisphosphate carboxylase of insect induced yellow leaves. A preliminary experiment of flavonoid analysis suggested additional compounds present in insect induced yellow leaves.

INTRODUCTION

Pareuchaetes pseudoinsulata Rego Barros (Lepidoptera Arctiidae) was established in Guam to control *Chromolaena odorata* (L.) R. M. King & H. Robinson (Muniappan et al. 1989, Seibert 1989). When caterpillars of *P. pseudoinsulata* feed on *C. odorata*, green leaves turn yellow. This yellowing is a reversible senescence in which removal of *P. pseudoinsulata* results in yellow leaves returning to a green color. Palatability and insect survival are influenced by physiological and biochemical changes in the plant (Marutani & Muniappan 1991). This paper presents the results of a preliminary study on biochemical and physiological changes in insect-induced yellowing leaves of *C. odorata*.

RESULTS

1. Gel electrophoresis of proteins from *C. odorata*.

In the first experiment, roots, young green stems, older stems, young leaves (tip of stem), mature leaves (middle of stem), and old leaves (base of stem) from *C. odorata* were sampled to examine the variation in the total protein composition in various plant parts. In the second experiment, mature leaves of either non-infested green *C. odorata* or insect-induced yellow leaves were sampled from populations in the field. In the third experiment, six plants of *C. odorata*, in pots, were covered with a muslin cloth. Five caterpillars of 3rd to 5th instar of *P. pseudoinsulata* were placed on each one of the four plants. The plants were compared over time for physiological and biochemical changes due to the feeding insects.

The same gel electrophoresis procedure was used in all experiments. About 1 g plant samples were macerated in extraction buffer solution in a plastic bag. The gels used were 12% SDS polyacrylamide prepared according to Laemmli (1970) and Ausubel et al. (1989). Samples of 40 ul were used per well. The gels were run with 1x SDS buffer at 30mA for 5 hours.

In the first experiment, differences in the protein profile were found among the various plant parts. Roots and older stems were found to have fewer protein bands. There were no qualitative differences in total proteins among the young, mature or old leaves.

In the second experiment, leaf tissues of all green plants in the field populations of *C. odorata* were identical whereas leaves of insect-induced yellow plants displayed variation of protein banding. There was also variation within the yellow examples. Major changes were noted in the region of the large and small subunits of ribulose-1,5-bisphosphate carboxylase. The bands become faint in yellow leaves.

In the third experiment, artificial infestation of *C. odorata* confirmed the results of the second experiment. Among the four plants infested, two turned yellow faster than the others. The change in the band for the small subunit of ribulose-1,5-bisphosphate carboxylase occurred to a greater degree in the faster yellowing plants. The plants with no insects displayed the same protein pattern as the green plants in experiment 2.

2. Rate of photosynthesis, chlorophyll content and measurement of color in insect infested *C. odorata*.

The caged plants in experiment three described above were also examined for their changes in rate of photosynthesis, chlorophyll content and quantitative measurement of color. Rate of photosynthesis was estimated from the rate of CO_2 uptake as measured with an LI-6200 photosynthesis meter (Licor). Chlorophyll content was estimated with colormetric readings using a chlorophyll meter (SPAD Minolta Corp.). A chromometer (Minolta Corp.) was used to measure color in three components, L (luminance), a (green-red) and b (blue-yellow).

Insect-infested plants displayed reduced rates of photosynthesis and reduced chlorophyll levels.

3. Leaf chlorophylls in green and insect-induced yellow leaves by HPLC.

Acetone extracts of leaf chlorophylls were analyzed by HPLC. Leaf tissues of 2-4g fresh weight were immersed in deionized water for 15 min. Leaves were gently wiped dry and homogenized in 75 ml acetone. A slurry was filtered through glass wool using a Buchner funnel connected to a water aspirator and residue was extracted repeatedly with acetone until filtrate was colorless. The amount of filtrate was measured and an equal amount of petroleum ether was added. The entire mixture was placed in a separatory funnel and water (15% of mixture volume) added. The funnel was inverted several times and then immobilized until two distinct layers were present. After the lower layer was drained and discarded, the upper layer was poured into a round flask wrapped with aluminum foil. The solvent was evaporated and the residue was resuspended in 3 ml of acetone and stored at -20°C. Samples were separated in an HPLC with a reverse phase column.

HPLC chromatograms of the chlorophyll extractions were compared at 445 nm. There was a great reduction in all pigments detected at this wavelength. The pigments were collected as separated and are being identified.

4. Protein analysis of *C. odorata* leaves and salivary gland of *P. pseudoinsulata* by HPLC.

In addition to separating the proteins of *C. odorata* and *P. pseudoinsulata* by electrophoresis, a size exclusion column (SEC) has been used with an HPLC. The reason for using this method was due to difficulty in obtaining the chemicals needed for preparing acrylamide gels. The column was 4.6 mm ID x 25 cm long and was packed with 5 um particle size silicon chemically bonded with a hydrophilic polymer layer. The pore size was 300 Å. This columns separates the proteins by molecular size.

The peaks observed were similar to the results obtained by electrophoresis. Most noteworthy, again, were the changes of the sub units of ribulose-1,5-bisphosphate carboxylase.

CONCLUSIONS

The response observed in *C. odorata* appears to be an example of reversible senescence. When *P. pseudoinsulata* larvae feed on the leaves of *C. odorata*, there is a response in the entire plant which results in the degradation of compounds associated with the normal functioning of the plant. Specifically compounds associated with photosynthesis have been found to degrade. If the caterpillars are removed the degradation is reversed resulting in a fully recovered plant.

REFERENCES

Ausubel, F. M., R. Brent, R. E. Kingston, D. D. Moore, J. G. Seidman, J. A. Smith, & K. Struhl. 1989. Short protocols in molecular biology. Greene Publishing Associates and Wiley-Interscience. New York.

Laemmli, U. K. 1970. Cleavage of structural proteins during the assembly of the head of bacteriophage T4. Nature (London) 227:680-685.

Marutani, M.& R. Muniappan. 1991. Interactions between *Chromolaena odorata* (Asteraceae) and *Pareuchaetes pseudoinsulata* (Lepidoptera: Arctiidae). Annals of Applied Biology. In Press.

Muniappan, R., V. T. Sundaramurthy & C. A. Viraktamath. 1989. Distribution of *Chromolaena odorata* (Asteraceae) and bionomics and consumption and utilization of food by *Pareuchaetes pseudoinsulata* (Lepidoptera:Arctiidae) in India. Proc. VII. Int. Symp. Biol. Contro. Weeds, Delfosse, E. S. (ed.) Ist. Sper. Patol. Veg. (MAF) pp.401-9.

Seibert, T. F. 1989. Biological control of the weed, *Chromolaena odorata* (Asteraceae) by *Pareuchaetes pseudoinsulata* (Lepidoptera:Arctiidae) on Guam and the Northern Mariana Islands. Entomophaga. 34:531-539.

COUNTRY REPORT

ACTIVITIES CARRIED OUT BY FRANCE

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In France, research activities on *Chromolaena odorata* control are carried out by CIRAD. CIRAD, the International Center for Agricultural Research for Development, is a scientific organization specializing in tropical and subtropical agriculture. It participates in research programs, rural and agricultural development operations and training activities in cooperation with more than 60 countries in Africa, Asia, the Pacific region and Latin America.

It employs 1900 people including 900 senior scientists. It has 11 separate departments including IRCA (Rubber Department), IRCT (Cotton and other Textile Crops Department), IRHO (Oil Crops Department), IEMVT (Livestock Protection and Veterinary Medicine Department) and others. The headquarters is located in Paris. The research center in Montpellier, in the southern part of France, has more than 500 scientists and technicians.

The Tropical Weed Science Laboratory (AMATROP) belongs to IRCT and develops programs of general interest. Each department develops weed research in relation to its broader programs.

Departments in charge of perennial crops have undertaken research works on mechanical and chemical control of *C. odorata*.

The Oil Crops Department (IRHO) coordinates the European Economic Community Project on biological control of C. odorata in cooperation with the International Institute of Biological Control, Cote d'Ivoire and Indonesia.

The Livestock Protection and Veterinary Medicine Department is developing a method for evaluation and mapping of *C. odorata* infestations in pastures of savannah regions, using high resolution data provided by Spot satellite.

The Weed Science Laboratory has undertaken a research project to define the taxonomic status of *C. odorata* from different geographic origins and coordinates the activities of the *C. odorata* control program developed by the National Agency of Livestock Production (ANDE) in the Central African Republic.

CIRAD has developed these activities in cooperation with the tropical countries involved.

BIOTROP SPECIAL PUBLICATIONS

No. 1 Proceedings of the Southeast Asian Workshop on Aquatic Weeds, Malang, 25–29 June 1974. BIOTROP, 1976. 45 p., US$ 5.- (individual papers not included).

No. 2 Proceedings of the Symposium on Forest Pests and Diseases in Southeast Asia, Bogor, 20–23 April 1976. BIOTROP, 1977. 225 p., US$ 10.-

No. 3 Proceedings of the Symposium on the Long-term Effects of Logging in Southeast Asia, Darmaga, Bogor, Indonesia, 24–27 June 1975. BIOTROP, 1978. 177 p., US$ 10.-

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No. 17 Proceedings of the Symposium on Mangrove Forest Ecosystem Productivity in Southeast Asia, Bogor 20–22 April 1982. BIOTROP, 1982. 226 p., US$ 12.-

No. 18 Proceedings of the Symposium on Pest Ecology and Pest Management, Bogor, 18–20 September 1979. BIOTROP, 1983. 286 p., US$ 10.-

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No. 20 Proceedings of BIOTROP Symposium on Forest Pests and Diseases in Southeast Asia, Bogor, 14–16 October 1981. BIOTROP, 1983. 243 p., (photocopied), US$ 12.50.-

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No. 24 Proceedings of the Symposium in Weed Science, Bogor, 10–12 April 1984. BIOTROP, 1986. 376 p., US$ 25.-

No. 25 Proceedings of the Symposium on Forest Regeneration in Southeast Asia, Bogor, 9–11 May 1984. BIOTROP, 1986. 227 p., US$ 17.50.-

No. 26 Proceedings of BIOTROP Symposium on the Status of Forests Pests and Diseases in Southeast Asia, Los Banos, Philippines, 3–15 May 1985. BIOTROP, 1987. 187 p., US$ 15.-

No. 27 Proceedings of BIOTROP Seminar on Production and Exploitation of Open Waters (With Special Emphasis on Reservoirs), Bogor, 15–17 June 1982. BIOTROP, 1987. 125 p., US$ 7.50.-

No. 28 Proceedings of BIOTROP Symposium on Practical Measures for Preventing and Controlling Fish Diseases, 24–26 July, 1985. BIOTROP, 1988. 155 p., US$ 11.50.-

No. 29 Proceedings of BIOTROP Symposium on Coral Reef Management, Bogor, 22–24 April, 1986. BIOTROP, 1987. 186 p., US$ 12.50.-

No. 30 Proceedings of BIOTROP Symposium on the Conservation and Management of Endangered Plants and Animals, Bogor, 18–20 June 1986. BIOTROP, 1987. 246 p., US$ 20.-

No. 31 Proceedings of the international Conference on Tropical Plant Ecophysiology Bogor 4–6 December 1985. BIOTROP, 1988. 308 p., US$ 25.-

No. 32 Proceedings of the Symposium in Pest Ecology and Pest Management, Bogor, Indonesia. 9–11 April 1985, BIOTROP, 1988. 309 p., US$ 20.-

No. 33 Proceedings of the Symposium on Pests of Stored Products, Bogor, Indonesia, 2 – 4 December 1986. BIOTROP, 1988. 161 p., US$ 15.-

No. 34 Proceedings of the Symposium on Crop Pathogens and Nematodes, Bogor, Indonesia, 7 – 9 April 1987. BIOTROP, 1988, US$ 22.50.-

No. 35 Proceedings of the Symposium on the Application of Tissue Culture Techniques in Economically Important Tropical Trees, Bogor, Indonesia, 7 – 9 December 1987. BIOTROP, 1988. 230 p., US$ 20.-

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No. 37 Proceedings of the Symposium on Mangrove Management: Its Ecological and Economic Considerations, Bogor, Indonesia, 9 – 11 August 1988. BIOTROP, 1989. 353 p., US$ 28.-

No. 38 Proceedings of the Symposium on Weed Management, Bogor, Indonesia, 7 – 9 June 1989. BIOTROP, 1990. 282 p., US$ 25.-

No. 39 Proceedings of the Symposium on Agroforestry Systems and Technologies, Bogor, Indonesia, 19 – 21 September 1989. BIOTROP, 1990. 239 p., US$ 28.-

No. 40 Proceedings of the Symposium on Aquatic Weed Management, Bogor, Indonesia, 15 – 17 May 1990. BIOTROP, 1991. 253 p., US$ 23.-

No. 41 Proceedings of the Fourth Round-Table Conference on Dipterocarps, Bogor, Indonesia, 12 – 15 December 1989. BIOTROP, 1991. 574 p., US$ 50.-

No. 42 Proceedings of the Second Asian Conference on Mycorrhizae (ACOM), Chiangmai, Thailand, 12 – 14 March 1991 (In press).

No. 43 Proceeding of the Symposium on Inland Aquatic Environmental Stress Monitoring, Bogor, Indonesia, 25 – 27 July 1990. BIOTROP, 262 p., US$ 25.-

No. 44 Proceedings of the Second International Workshop on Ecological Control of *Chromolaena odorata* Bogor, Indonesia, 4 – 8 February 1991. BIOTROP, 167 p., US$ 15.-

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