CONTROL OF PARTHENIUM WEED (*PARTHENIUM HYSTEROPHORUS* L.): A CENTRE FOR TROPICAL PEST MANAGEMENT TEAM EFFORT

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Summary Parthenium weed (*Parthenium hysterophorus* L.) is an annual herbaceous plant native to the tropical Americas, which now occurs in south and east Africa, southern Asia and Australia. In Australia it has become widespread in grazing land from central Queensland to northern New South Wales. It causes direct losses to the grazing industry (about $A14-18 million per annum) and is a human health hazard, causing allergic rhinitis and contact dermatitis.

Starting in 1976, the Queensland Department of Lands (now Natural Resources, DNR) has had an on-going campaign to reduce the spread and impact of this public nuisance. However, the weed has never-the-less continued to increase and spread. Chemical control is possible but is too expensive to control all infestations over such large areas. Biological control is feasible and the search for natural control agents is on-going.

The Centre for Tropical Pest Management (CTPM) seeks to develop and implement cost-effective, environmentally friendly methods of control for parthenium weed. This is achieved through collaborative research and technology exchange and concerns the topics of biology and ecology and biocontrol. An additional component is looking at ways of transferring the knowledge generated into the agricultural community.

The studies on biology and ecology involve the characterization of ecotypes using genetic finger printing techniques, investigating the role of allelopathy, seed banks and phenological attributes in the weeds persistence mechanism(s). Process-based simulation models and geographical information systems are used to monitor and predict future spread. Biological control is developed and enhanced through the use of plant feeding insects and pathogens. Extension is carried out through the already existing networks of the CTPM and the central Queensland Parthenium Action Group (PAG).

The work undertaken at CTPM builds on earlier work undertaken by the University of Queensland (UQ), the Queensland Department of Natural Resources and the CSIRO. The CTPM provides the framework and some financial assistance for the co-ordination and integration of these studies on parthenium weed.

Figure 1. Distribution of Parthenium weed in Australia. Black is heavy manifestations, and shaded is scattered infestations.

INTRODUCTION

Weed biology Parthenium weed (*Parthenium hysterophorus* L.) is a herbaceous annual, or ephemeral, member of the Asteraceae (Navie *et al*. 1996), reaching a height of 2 m in good soil and flowering within 6–8 weeks of germination. Large plants can produce up to 15 000 seeds which can be distributed by floating on still or flood waters, or in mud adhering to animals, vehicles and machinery (Auld *et al.* 1982/83). It is thought that most seed germinate within two years if conditions are suitable, although a portion of buried seed may remain viable for several years (Butler 1984). Parthenium weed does best on alkaline to neutral clay soils (Dale 1981), but will grow less prolifically on a wide range of other soil types. The plant's water requirements are relatively high, and both germination rate and growth are limited by poor rainfall (Williams and Groves 1980).

Distribution Parthenium weed now occurs throughout the tropical and subtropical Americas from southern United States of America (USA) to southern Brazil and northern Argentina (Dale 1981). Parthenium weed was accidentally introduced into India in about 1956 (Chandras and Vartak 1970) and has since spread over most of the country. It is now in southern China, Taiwan and Vietnam (Nath 1981) but not reported from other south-east Asian countries. It is present in several Pacific island and African countries (Njoroge 1991).

Parthenium weed has been introduced into Australia from North America on at least two separate occasions. The most serious occurred in 1958, where seed was brought in as a contaminant of pasture grass seed from Texas, USA (Haseler 1976). This infestation originated in the Clermont area and did not spread very quickly until the mid 1970s. However, rapid spread since this time has led to 170 000 km^2 or 10% of Queensland being infested (Chippendale and Panetta 1994). The other introduction occurred near Toogoolawah in south-east Queensland. It has been suggested that this occurred during the 1940s and was due to the movement of aircraft and machinery parts from the USA (Parsons and Cuthbertson 1992). This infestation has not spread nearly as extensively as the one at Clermont. There are now minor infestations in New South Wales and one infestation in the Northern Territory (Figure 1).

The parthenium weed problem Parthenium weed causes severe human health problems as well as agricultural losses. Parthenium weed and related genera contain sesquiterpene lactones (Swain and Williams 1977) which induce severe dermatitis and often allergic symptoms. Agricultural losses can also be severe. In India, parthenium weed causes yield losses of up to 40% in several crops (Khosla and Sobti 1979) and is reported to reduce forage production by up to 90% (Nath 1981). In Australia parthenium weed is a serious problem in perennial grasslands in central Queensland where it can reduce beef production by as much as $A16.5 million annually (Chippendale and Panetta 1994). Stock, especially horses, suffer allergic skin reactions when grazing infested paddocks. Parthenium weed is generally unpalatable, but cattle and sheep will eat it when feed is scarce. Consumption of large amounts will produce taints in mutton (Tudor *et al.* 1981) or kill stock.

Control In most areas of the world the high cost of herbicides prohibits their use in perennial grasslands. Control can be achieved by maintaining good grass growth to maximize competition against the weed; this is achieved is by lowering stocking rates (Holman 1981). When individual parthenium weeds are found, or the weed is a problem in certain crops, control can be achieved by using 2,4-D or residual herbicides such as atrazine (Holman 1981). Biological control is feasible and the search for natural control agents is on-going in Australia and India.

CTPM APPROACH

The objectives of the program at the CTPM are threefold. Firstly, to improve our understanding of the biology and ecology of the weed. This includes studies on seed biology, competitive ability, awareness of distinct

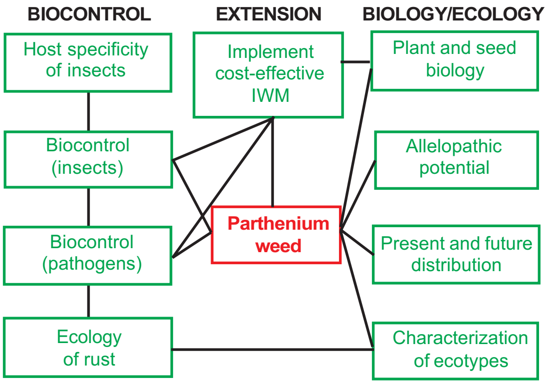

Figure 2. The interrelationship of the various sub-projects in the overall CTPM team effort to control parthenium weed.

biotypes, the future spread of the weed and its allelopathic potential. Secondly, the development of improved methods of biological control using insects and pathogens. This includes studies designed to improve the effectiveness of various agents. Thirdly, the development of ways to inform extension workers and farmers about new biological control methods, and how to integrate these into their weed management plan (Figure 2).

BIOLOGY AND ECOLOGY SUB-PROJECT

The objective of this sub-project is to undertake a comprehensive study of parthenium weed that will identify the life stages best targeted for biological control and other management methods. In addition, the sub-project will provide data for predicting the potential spread of the weed under present and future climate conditions, and for determining the best integrated weed management (IWM) option.

Table 1. Germinable soil seed bank from two central Queensland infested with parthenium weed. Site A is Clermont and site B is Moolayenber Creek.

Species/Genus	Seed m^{-2}	
	Site A	Site B
Parthenium weed	1544	22 597
Papaueraceae	–	4388
Poaceae	1133	641
Other Asteraceae	66	873
Cyperaceae	11	1293
Crassulaceae	–	647
Euphorbiaceae	48	–
Chenopodiaceae	11	–
Others	465	4245
Total	3282	34 682

Seed biology We are measuring seed production and testing for viability, dormancy, and ability to germinate at a wide range of temperatures and substrate moisture levels. Other studies are investigating the longevity of seed in contrasting soil types placed under different environmental conditions. So far we have confirmed that the weed is a very prevalent member in the soil seed bank in central Queensland. At two sites tested parthenium weed accounted for between half and two thirds of the total seed present (Table 1).

Long term burial studies have shown that after 12 months 90% of the seed is still viable. This indicates that buried parthenium weed seed remains viable for much longer than previously thought (Butler 1984). This has implications for future management of the weed, particularly in cultivated areas where seed burial occurs regularly.

Phenology Plants are being grown under controlled environmental conditions using different temperature and photoperiod regimes. We are gathering data on phenology, dry matter allocation and reproductive output. The results so far have demonstrated differences between the two biotypes coming from the Clermont and Toogoolawah introductions of the weed into Australia. When plants were grown under conditions simulating those of a cool, damp summer (23/13°C d/n, 14.5 h photoperiod) there was no significant difference between the two in the timing of most of their phenological events, however 85% of the Clermont biotype flowered before stem elongation whereas the reverse was true for the Toogoolawah plants. The Clermont plants were much larger in terms of dry weight (Figure 3) and height.

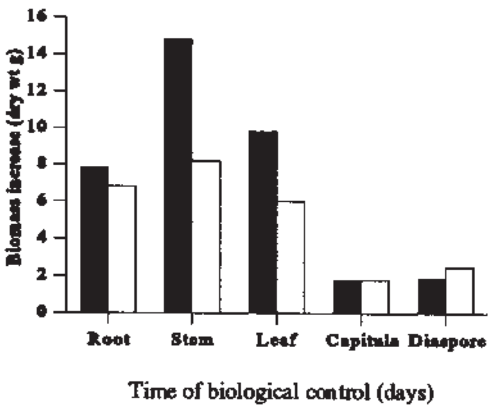

Figure 3. Biomass production measured at 150 days for two parthenium weed biotypes from Clermont (■) and Toogoolawah (□).

Only 60% of the Clermont seed was filled as compared with 90% of the Toogoolawah seed. Future studies will now look at the performance of the two biotypes under a series of other climatic conditions.

Biotypes Most weeds, including parthenium weed have a wide genetic base in their native range but when they are introduced into a new country possess only limited genetic variation. The purpose of this study is to determine how many distinct biotypes of this weed are present in Australia (is it just two?), how they relate to each other and to biotypes from overseas, and how wide the genetic base is of each introduction. This information may help us understand the differences in the invasiveness of the two Queensland infestations and how biocontrol agents may be selected and used for the control of each infestation.

Allelopathic potential Indian parthenium weed is known to be allelopathic (Parihar and Kanodia 1987) with root and shoot leachates and root exudates capable of reducing growth of numerous crops (Almodovar-Vega *et al.* 1988). The successful spread of parthenium weed in India may be partly attributed to its allelopathic properties (Mersie and Singh 1987). In the natural situation the main method of allelopathy is through the release of phytoinhibitors from the mature plant to the soil through leaching from the leaves and/or shoots, the roots and during decompostion of the residues in the soil (Adkins and Sowerby 1995). Several sesquiterpene lactones and phenolics are thought to be the water soluble compounds involved in these allelopathic responses.

A study was undertaken to provide information on the allelopathic potential of the central Queensland parthenium weed plants (Adkins and Sowerby 1996). Leaf aqueous leachates were tested on the germination and growth of five species. Germination of climbing buckwheat, liverseed grass, buffel grass and parthenium weed were all significantly depressed but not sunflower (Figure 4). Seedling growth, (measured by biomass production) of sunflower, liverseed grass, climbing buckwheat and buffel grass were all significantly depressed while a slight stimulatory effect was observed on parthenium (Figure 4). The most sensitive species to the leachate applied at the seedling stage was buffel grass which exhibited significant reductions in shoot and root biomass as well as plant height.

Potential spread Data sets are being developed that will help predict the potential spread of parthenium weed under present and future climatic conditions. From this it may be possible to determine the best practice management options for various areas.

It could be argued that climate change will advantage parthenium weed as compared to the grasses in the rangeland where it is found. As parthenium weed it is a C_3 plant it should benefit from the CO_2 enrichment, relative to the C_4 tropical grasses. It should also benefit from the projected increases in the frequency of extreme events such as flooding, which will facilitate its spread.

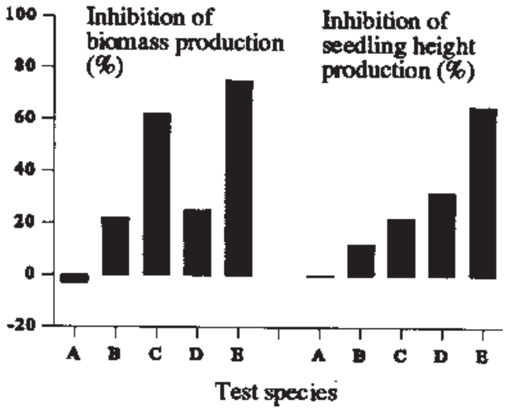

Figure 4. Influence of leachate (125 mg fresh leaf material mL^{-1}) derived from parthenium weed leaves on the seedling growth of five test species. Fourteen-day-old seedlings from parthenium weed (A), sunflower (B), liverseed grass (C), climbing buckwheat (D) and buffel grass (E) were grown for a further 14 days with the leachate before harvest.

Table 2. Biomass production of parthenium weed and buffel grass growing in competition under ambient or elevated CO_2 concentrations.

Factor	Ambient CO_2	Enhanced CO_2
Flowers per plant	468.3	958.2
Plant height (cm)	72.1	118.4
Dry weight (g)	6.3	11.7

Table 3. Biological control agents released against parthenium weed in Australia.

Species	Origin and release date
Listronotus setosipennis	Brazil 1983
Smicronyz latulentus	Mexico 1980
Zygogramma bicolorata	Mexico 1980
Stobaero concimma	
Buccalatrix parthenica	Mexico 1983
Epiblema strenuana	Mexico 1984
Puccinia abrupta	Mexico 1982
	Mexico 1992

It will be possible to model the probability of invasion and occupation of a particular land area under different climatic and management regimes. The data obtained will be integrated into descriptions of risk that can be used by land managers in developing property management plans. The model will be based on population biology, climatic influences and invaded ecosystem characteristics and will be built on CTPM generic pest weed models (CLIMEX, GENSECT). CLIMEX is a computer program designed to predict the distribution of plants, based on climatic preferences only and does not take into account other factors such as soil type.

Data so far shows that parthenium weed increases in dry weight by up to 86% when grown under elevated CO_2 and is 60% taller with 105% more flowers (Table 2).

BIOLOGICAL CONTROL SUB-PROJECT

A biological control program involving the introduction of insects from the Americas started in Australia in 1975 and is still in progress. By 1995, seven species of insects had been released but only one, the moth *Epiblema stranuana*, was exerting significant control on the weed (Table 3). A rust fungus *Puccinia abrupta* var. *parthenlicola* has been recently released but drought conditions have hampered its establishment (Tomley and Evans 1995).

All but two of the insects are established in at least some areas. Virtually no evaluation of their effect on the plant has been undertaken. Under a new DNR initiative which started in 1995, evaluation studies are now underway on the impact of two of the major insect species, *Zygogramma bicolorata* and *Listronotus setosipennis*, upon parthenium weed survival, growth and seed production under controlled and field conditions. Two new insects from Mexico are being imported for testing and subsequent release (Dhileepan *et al.* 1996. At the same time, glasshouse studies are being conducted at UQ to evaluate the impact of the moth *E. strenuana*. Early results show this agent to be more effective if it can attack the host early especially when the weed is under competition from a pasture grass (Figure 5).

The CTPM Virtual Plants program models the growth of plants and their response to injury such as insect feeding damage. Parthenium weed is one of the species being studied, and these models show vital information for the selection of the most damaging agents.

A major project funded by the Meat Research Corporation is investigating the summer-active fungal pathogens attacking parthenium weed in Mexico. Based at the CSIRO field station in Vera Cruz, field studies over two full seasons are determining the natural host-range and phenology of the pathogens. These are supplemented by laboratory studies in the UK to test selected pathogens

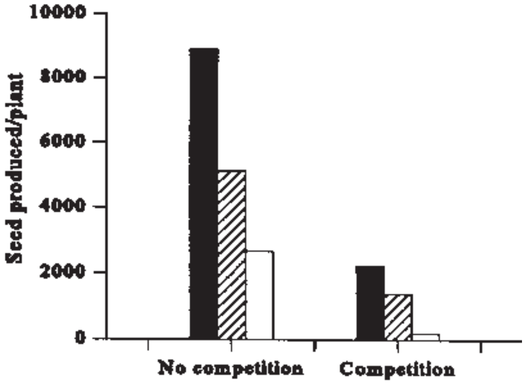

Figure 5. Parthenium weed seed production in the absence of the biological control agent (black bar), or the effect of *Epiblema strenuana* when applied to young plants (shaded bar) or old plants (white bar) in the presence or absence of competition from buffel grass.

against a range of related plants, native to Australia or of economic importance. If the test results are satisfactory, one or more pathogens will be imported and released in Queensland.

EXTENSION AND EDUCATION SUB-PROJECT

We believe that long-term parthenium weed management requires a flexible approach which is well integrated into farming systems in both a technical and sociological sense. We are adopting a participative process which will ensure that new strategies developed fit into the existing farming practices and therefore have a good chance of successful adoption.

Recently a workshop on parthenium was held at Rockhampton (October 1993). Participants included landholders, Government policy makers, extension officers, scientists and research funding bodies. Out of this workshop came a priority action plan which has provided a focus for research extension and education.

We now have involvement with the central Queensland community and farmer groups through our own Parthenium Weed Study Group (PSG) and the central Queensland Parthenium Action Group (PAG). These groups allow for stakeholders to retain a feeling of ownership of problems, opportunities and solutions. Posters, brochures, news releases, TV and radio interviews, field days and options for community education have been developed through PSG and PAG.

CONCLUSION

By bringing together scientists from UQ, DNR and CSIRO, together with Landcare groups and interested graziers, the CTPM is able to investigate many aspects of the ecology and control of this important weed. Out of this joint effort will come improved management methods which can be applied throughout its present and potential range.

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