

Biocontrol Agents for *Parthenium hysterophorus* from Mexico

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Abstract

Parthenium hysterophorus (Compositae) is an opportunistic annual weed native to Mexico, which has been introduced into a number of tropical and subtropical countries and has become a particularly serious problem in Queensland (Australia) and in India. A five-year study in Mexico was conducted by the Commonwealth Institute of Biological Control on behalf of the Queensland Department of Lands, and as a result six species of insects were sent to Queensland for trial as biocontrol agents. These are a seed-feeding weevil (*Smicronyx lutulentus*), a defoliating chrysomelid (*Zygogramma bicolorata*), a stem-gall-forming tortricid (*Epiblema strenuana*), a delphacid plant-hopper (*Stobaera concinna*), a leaf-mining moth (*Bucculatrix* sp. 'D') and a root-feeding weevil (*Thecesternus hirsutus*). Brief details are given of the biology and effects on the plant of each of these species. All except *T. hirsutus* have now been released in Queensland. Several diseases of *P. hysterophorus* were also found including a rust caused by *Puccinia abrupta* var. *parthenicola*, and this appears to be worth further investigation.

Agents Biologiques de Lutte Contre *Parthenium hysterophorus* du Mexique

Parthenium hysterophorus (Composées) est une plante nuisible annuelle opportuniste d'origine mexicaine, qui a été importée dans un grand nombre de pays tropicaux et sub-tropicaux, et qui pose des problèmes particulièrement graves dans l'État de Queensland (Australie) et en Inde. L'Institut du Commonwealth pour la lutte biologique a mené une étude de cinq ans au Mexique pour le compte du Department of Lands (ministère des Terres) de Queensland et, comme résultat, il a envoyé espèces d'insectes à Queensland pour qu'elles soient essayées comme agents de lutte biologique. Il s'agit d'un charançon granivore (*Smicronyx lutulentus*) d'une chrysomèle défoliatrice (*Zygogramma bicolorata*), d'une tortricide provoquant la galle des tiges (*Epiblema strenuana*) d'une cicadelle delphacide (*Stobaera concinna*), d'un lépidoptère mineuse des feuilles (*Bucculatrix* sp. 'D') et d'un charançon racidivore (*Thecesternus hirsutus*). Le rapport donne quelques détails sur la biologie de chacune de ces espèces d'insectes et sur leurs effets sur la plante. Toutes les espèces ont actuellement été libérées à Queensland, sauf *T. hirsutus*. Plusieurs maladies s'attaquant à *P. hysterophorus*, dont une rouille causée par *Puccinia abrupta* var. *parthenicola*, ont été relevées, et il semble approprié de poursuivre les recherches.

Introduction

The annual weed *Parthenium hysterophorus* L. (Compositae), native to Mexico and the southern U.S.A., was introduced to Queensland, Australia, in the 1950s and now infests thousands of square km in the State (Haseler 1976; McFadyen 1984). These infestations occur mainly in grazing land in central Queensland, where the plant persists in dense monospecific stands, excluding beneficial pasture species. Its persistence is aided by its profuse seed production and ability to germinate at any time when temperature and moisture conditions allow. Extensive infestations of *P. hysterophorus* also occur in

India, and it is reported from tropical and subtropical areas of a number of other countries (Towers *et al.* 1977).

From 1978–83, the Commonwealth Institute of Biological Control carried out studies of the natural enemies of *P. hysterophorus* in north-eastern Mexico on behalf of the Queensland Department of Lands. A preliminary report on these studies was presented by McClay (1981). By 1983, 109 species of phytophagous arthropods had been identified feeding on *P. hysterophorus* in Mexico, biological and host-specificity studies had been carried out on 22 of these, and 6 species had been shipped to Queensland as candidate biocontrol agents (McClay 1983a). Five of these have now been released, and the results of the field release program are reported by McFadyen (1984). This paper describes the biology, host-specificity and effects on the host-plant of these six species.

Some observations were also made on pathogens attacking *P. hysterophorus*, and preliminary studies on some of these were made by Dr. H.C. Evans of the Commonwealth Mycological Institute during a visit to Mexico from March–May 1983 (Evans 1983). The most damaging pathogen observed was a rust fungus, *Puccinia abrupta* Diet. & Holw. var. *partheniicola* (Jackson) Parmelee (Uredinales). This species produces abundant telia and urdinia which occur on leaves, stems and flowers. It occurs mainly in more elevated areas of north-eastern Mexico where there is a well-defined cool season. Field observations and preliminary tests suggest that this rust is specific to *P. hysterophorus*, and it merits further study as a possible biocontrol agent.

Materials and Methods

A base for the project was selected at Monterrey, Nuevo Leon, in facilities kindly made available by the Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM). The selection of this area was based upon the known distribution of *P. hysterophorus* and other *Parthenium* species in Mexico, and its climatic similarity to the infested areas of Queensland. *P. hysterophorus* is abundant in north-eastern Mexico, and several other species of the genus also occur in the region (Rollins 1950) suggesting that this is a centre of diversification for *Parthenium*. The climatic similarity can be seen in Fig. 1, which shows climate diagrams for Apodaca, Nuevo Leon (near Monterrey, and the site of the ITESM field station where experimental plots of *P. hysterophorus* were set up) and Emerald, Queensland (located in the *P. hysterophorus*-infested area of Queensland). Both locations receive around 630 mm of precipitation/year, occurring mainly in the summer. Both experience mean summer temperatures around 28°C and mean winter temperatures around 14°C, with occasional frosts in winter. Considerable year-to-year fluctuation in the total amount and seasonal distribution of rainfall is also a feature of both sites. The criteria for selection of areas for exploration for biological control agents for weeds (Wapshere 1981) were thus fulfilled.

The methods used were described in the previous report (McClay 1981) and will thus only be briefly summarized here. Collections of natural enemies were made on naturally occurring stands of *P. hysterophorus*, mainly in north-eastern Mexico but also in other areas. Periodic sampling on plots sown with *P. hysterophorus* at Apodaca, N.L., was carried out to provide information on the phenology of some of the main natural enemies.

Host-specificity testing was carried out mainly by means of multiple-choice tests in cages (1 high × 1 × 0.80 m). The test plants used included economic Compositae and species in several genera of the tribe Heliantheae, to which *Parthenium* belongs (Table 1). Particular importance was given to testing against sunflower (*Helianthus annuus*

L.; Compositae), an important crop plant closely related to *P. hysterophorus*, and against guayule (*Parthenium argentatum* A. Gray), a rubber-yielding species regarded as a potential crop in Australia. These tests were supplemented by field observations and literature searches. Species which gave indications of sufficient host-specificity in these tests were then sent to the Sir Alan Fletcher Research Station of the Department of Lands in Sherwood, Queensland, where extensive testing was carried out under quarantine against a wide range of economic plants.

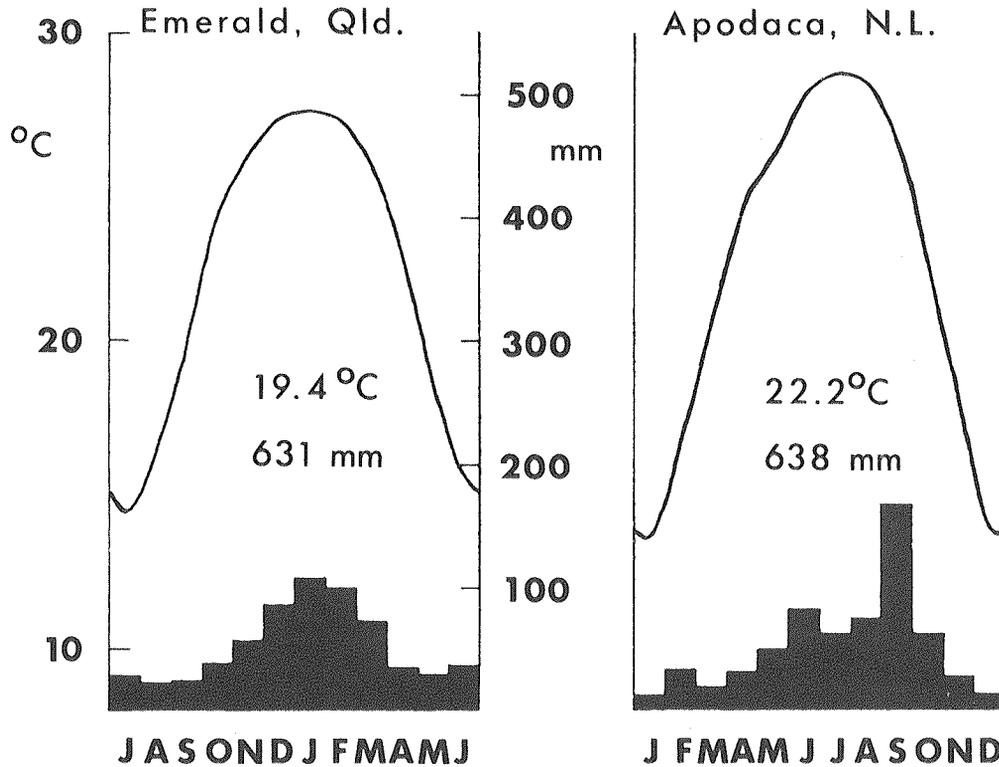


Fig. 1. Climate diagrams for Emerald, Queensland, and Apodaca, Nuevo Leon. Curves: mean monthly temperature (°C). Histograms: mean monthly precipitation (mm). Figures below curves: mean annual temperature and precipitation.

Results and Discussion

Smicronyx lutulentus Dietz (Coleoptera: Curculionidae)

This small weevil lays eggs in the young flower buds of *P. hysterophorus*, and larvae feed inside developing seeds. It is bivoltine in north-eastern Mexico, overwintering as larvae in the soil. The first generation of adults usually appears in May, and the second in late August or early September. After the appearance of the second generation the adults are often abundant on *P. hysterophorus*. This species may cause up to 30% seed destruction in the field in Mexico. The larvae are parasitized by *Zatropis* sp. nr. *incertus* Ashmead (Hymenoptera: Pteromalidae) and *Paracrias* sp. (Hymenoptera: Eulophidae). Tests showed that *S. lutulentus* is highly host-specific, feeding and ovipositing only in *P. hysterophorus* and the closely related *P. confertum* Gray, and its release in Australia has been approved.

Zygogramma bicolorata Pallister (Coleoptera: Chrysomelidae)

This leaf beetle, initially identified as *Zygogramma* sp. v. nr. *malvae* Stål, is common on *P. hysterophorus* in Nuevo Leon. It was also collected in a wide range of habitats from humid tropical lowlands in Veracruz to the arid central plateau in San Luis Potosi. Adults and larvae both feed on the foliage of *P. hysterophorus*, and when populations are high can cause considerable defoliation in the field. There are probably 2–3 generations during the summer; overwintering occurs as adults in the soil, although if fresh *P. hysterophorus* foliage is available, some adults may remain feeding on the plant until January or February. Host-specificity testing showed that in addition to *P. hysterophorus* and *P. confertum*, development can also be completed on *Ambrosia confertiflora* DC. (Compositae). Development on this host, however, is considerably slower than on *P. hysterophorus*. Slight adult and larval feeding also occurred on sunflower (*H. annuus*) in tests, but development cannot be completed on this plant. *Z. bicolorata* has the highest fecundity of any of the agents discussed here, producing a mean of 836 eggs/female. It has been approved for release in Australia, and is established in Queensland (McFadyen 1984). *Z. bicolorata* has also been shipped to India.

Table 1. Species of Compositae used in preliminary screening of candidate biological control agents for *Parthenium hysterophorus* L. in Mexico.

Species	Tribe	Status
<i>Ambrosia confertiflora</i> DC.	Heliantheae	Weed
<i>Bidens pilosa</i> L.	Heliantheae	Weed
<i>Carthamus tinctorius</i> L.	Cynareae	Economic
<i>Chrysanthemum morifolium</i> Ramat.	Anthemideae	Ornamental
<i>Cichorium intybus</i> L.	Cichorieae	Economic
<i>Coreopsis lanceolata</i> L.	Heliantheae	Ornamental
<i>Cosmos bipinnatus</i> Cav.	Heliantheae	Ornamental
<i>C. sulphureus</i> Cav.	Heliantheae	Ornamental
<i>Dahlia coccinea</i> Cav.	Heliantheae	Ornamental
<i>Helianthus annuus</i> L.	Heliantheae	Economic
<i>H. ciliaris</i> DC.	Heliantheae	Weed
<i>Heliopsis</i> sp.	Heliantheae	Weed
<i>Lactuca sativa</i> L.	Cichorieae	Economic
<i>Parthenium argentatum</i> Gray	Heliantheae	Economic
<i>P. confertum</i> Gray	Heliantheae	Weed
<i>Rudbeckia serotina</i> Nutt.	Heliantheae	Ornamental
<i>Viguiera dentata</i> Cav. & Spreng.	Heliantheae	Weed
<i>Xanthium chinense</i> Mill.	Heliantheae	Weed
<i>Zinnia elegans</i> Jacq.	Heliantheae	Ornamental

Epiblema strenuana (Walker) (Lepidoptera: Tortricidae)

The larvae of this moth, which is sometimes abundant in Mexico, form large galls in stems and growing points of *P. hysterophorus*, which can severely stunt the growth of the plant, and thus limit flower and seed production. Plants attacked in the rosette stage or as the stem begins to elongate can be converted into distorted masses of gall tissue, which almost completely fail to flower. In Mexico the moth has 2–3 generations in the summer and overwinters as prepupal larvae (McClay, *in press*). Host-specificity tests and literature records show that, as well as *Parthenium*, it will attack and develop on species of *Ambrosia* and *Xanthium*. However, as these genera are represented in

Australia only by introduced weeds, and as they are closely related to *Parthenium*, the field release of this species was authorized. The establishment of *E. strenuana* in Queensland and its effects on *P. hysterophorus* there are reported by McFadyen (1984).

Stobaera concinna (Stål) (Homoptera: Delphacidae)

Work on this plant-hopper was prompted by the desire to find a vector for a phyllody disease of *P. hysterophorus* caused by a mycoplasma (Phatak *et al.* 1975). The disease causes sterility of affected flower heads, and was previously ascribed (McClay 1981) to the attack of a mite, *Eriophyes parthenii* Keifer (Acarina: Eriophyidae); this, however, has now been shown not to be the causal agent. The mycoplasma is already present in Queensland, but disease incidence is low. It was hoped that incidence could be increased by the introduction of a vector specific to *P. hysterophorus*. As most known vectors of plant mycoplasmas are Homoptera, a series of species of this group found associated with *P. hysterophorus* was screened. Most were easily shown to be insufficiently host-specific, the exception being *S. concinna*. An attempt to show transmission of the disease by *S. concinna* was unsuccessful, but it was decided to proceed with the introduction of this species on the basis that: (a) the possibility of its being a vector had not been eliminated; and (b) it might prove damaging to *P. hysterophorus* in its own right.

S. concinna is rare on *P. hysterophorus* in the field in Mexico, and does not cause observable damage (McClay 1983b). In cages, however, it breeds readily on this host, rapidly building up dense populations which cause yellowing of the leaves and generally reduced vigor. It also breeds on *A. confertiflora*, but no breeding occurred on any of the other composites tested, and females confined on them failed to mature eggs. It therefore resembles *E. strenuana* and *Z. bicolorata* in its host range, and its release in Australia has been approved.

Bucculatrix sp. 'D' (Lepidoptera: Lyonetiidae)

The larvae of this small moth mine the leaves of *P. hysterophorus* in the first two instars and then emerge to feed externally on the leaves. It appears to be an undescribed species, as it does not agree with any named material in the British Museum (Natural History) or the U.S. National Museum, or with any of the species described by Braun (1963). It is provisionally referred to by the letter 'D', to distinguish it from other *Bucculatrix* species which were present in the same batch of material sent for identification.

This species is also scarce in the field, and field-collected larvae are frequently parasitized. In cages, it breeds readily on *P. hysterophorus*, and builds up high population densities, causing fairly heavy defoliation. In host-specificity tests, no attack occurred on any species outside the genus *Parthenium*. Occasional slight feeding occurred on *P. argentatum* in some tests, but this is thought to have been due to larvae transferring to this plant after initially feeding on *P. hysterophorus*. No evidence of oviposition or mining on *P. argentatum* was found. Some doubt persisted as to the possibility of attack on *P. argentatum*, as a few adults and larvae found in the field on this species appeared to be of *Bucculatrix* sp. 'D'. Further tests were therefore conducted in Mexico and subsequently in Queensland, and these showed that, at least as far as the particular population which was shipped to Queensland is concerned, *Bucculatrix* sp. 'D' shows no tendency to attack *P. argentatum*. Its release in Australia has therefore been authorized.

Thecesternus hirsutus Pierce (Coleoptera: Curculionidae)

The larvae of this large weevil feed externally on the roots of *P. hysterophorus*, on which they produce a gall-like swelling (McClay and Anderson, *in press*). The adults feed on the foliage. It is locally common in north-eastern Mexico, usually in dry, relatively undisturbed sites. The adults are flightless and long-lived, and there is a single generation/year, with possibly a partial second generation over the summer. Overwintering occurs as mature larvae.

This group of weevils has been little studied, and almost no information on its biology could be found. The only information on food habits which could be found in the literature was a 19th-Century reference to feeding by the adults on grape blossoms. This was not confirmed in tests carried out in Mexico. Field observations and laboratory tests showed that its host-range is restricted to a few closely related species in the genus *Parthenium*.

Despite its specificity, this insect is not regarded as a highly promising biological control agent for *P. hysterophorus*. The larval feeding affects only the cortical tissues of the root, and thus is unlikely to reduce significantly the plant's water uptake. Defoliation caused by the adults is very light. The insect's long life cycle and low reproductive rate would also limit its effectiveness as a biocontrol agent. It is possible that heavy root galling on young plants might be a sufficient metabolic sink to inhibit their growth and seed production.

T. hirsutus was, however, the only root-feeding insect found on *P. hysterophorus* in Mexico which could be recommended for further study in Queensland. Other root-feeding Coleoptera and Lepidoptera were either insufficiently specific, could not be reared in the laboratory, or were too scarce to be studied. A shipment of *T. hirsutus* was therefore sent to Sherwood for further host-range testing in quarantine. Owing to difficulties with rearing, however, the tests with this species were not completed and application for permission to release it in Australia was not made.

Discussion

The studies reported here have made available a complex of biocontrol agents for *P. hysterophorus*, which includes a seed-destroyer, a gall-former, a defoliator, a leaf-miner/defoliator, a sucking insect and an external root feeder. Some of these are specific to *P. hysterophorus* and one or two other closely related *Parthenium* species, while others will also attack *Ambrosia* spp. As far as introduction into Australia is concerned, attack on *Ambrosia* is not a problem, as this genus is represented there only by undesirable, introduced weeds. This applies also to the ability of *E. strenuana* to attack *Xanthium* spp. (McFadyen 1984).

The availability of a complex of biocontrol agents with different modes of attack is encouraging, as it has frequently been suggested that successful biological control is more likely where a number of different types of stress can be applied simultaneously to the target weed (Harris 1979; Haseler 1981).

On a subjective assessment, the most damaging of the agents discussed here is *E. strenuana*, as attack can occur at any growth stage of the weed, and a single, well-placed gall can be highly effective in restricting growth and hence seed production. *Z. bicolorata* is also regarded as promising because of its high fecundity, high consumption of foliage by both adults and larvae, and the wide range of environments in which it occurs in Mexico.

To assess the potential of the biocontrol agents discussed here, each agent was scored according to the scheme of Harris (1973) and the revised version of this scheme

published by Goeden (1983). Where ambiguity or lack of information resulted in doubt as to what score should be assigned to a particular agent under a particular category, both possible scores were assigned and the results presented as the range of lowest to highest possible total scores. In order not to bias the scores in favour of earlier-released agents, no information derived from field release experience in Queensland was incorporated into the scores.

The results are shown in Table 2. Both schemes produce an essentially similar ranking of the six agents, and agree with the intuitive assessment in making *E. strenuana* the most promising agent and *T. hirsutus* the least. A surprising feature is the high ranking given to *S. concinna* by both schemes, particularly as it was not assumed that this species is a vector for the mycoplasma which causes phyllody of *P. hysterophorus*. If *S. concinna* were to be shown to transmit this disease, its score under both schemes would be further boosted.

Table 2. Scores assigned to biocontrol agents for *Parthenium hysterophorus* L. from Mexico according to the schemes of Harris (1973) and Goeden (1983)

Agent	Harris Score	Goeden Score
<i>Epiblema strenuana</i> (Walker)	23-30	53-57
<i>Stobaera concinna</i> (Stål)	18-22	42-48
<i>Zygogramma bicolorata</i> Pallister	20	43
<i>Smicronyx lutulentus</i> Dietz	18	43
<i>Bucculatrix</i> sp. "D"	11-17	36-45
<i>Thecesternus hirsutus</i> Pierce	7-13	32-39

Whether these scores accurately reflect the real potential of these insects for control of *P. hysterophorus* will be shown only by further experience with field releases. For the present it is recommended that consideration should be given to release of any or all of these species, but especially *E. strenuana*, in any area where *P. hysterophorus* is an important introduced weed.

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