Bruchid Seed Beetles for Control of *Parkinsonia aculeata* in Australia

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Abstract

*Parkinsonia aculeata*, is a spiny, leguminous tree that is a weed in northern Australia. It blocks access to waterholes, shades out desirable vegetation, and makes mustering of cattle difficult. The bark of *P. aculeata* can photosynthesize and as the plant can resprout from dormant buds if the stem is damaged, it may be difficult to control by leaf- or stem-feeding insects. In the New World *P. aculeata* is attacked by five species of bruchid seed beetle (Coleoptera: Bruchidae). Of these five, three species appear to have potential as control agents of *P. aculeata* in Australia. *Pentobruchus germaini* has only been collected from *P. aculeata*. *Mimosetes ulkei* only attacks the closely related genera of *Parkinsonia* and *Cercidium* in the field. Although *Mimosetes amicus* attacks four plant genera, two are *Parkinsonia* and *Cercidium*, one is *Prosopis* (not native and considered weedy in Australia), and the last genus, *Acacia*, is not an important host. The possibilities of introducing these species into Australia and their potential for controlling *P. aculeata* is discussed.

Utilisation des Bruches dans la Latte Biologique Contre *Parkinsonia aculeata* en Australie

*Parkinsonia aculeata* est un arbre légumineux epineux qui est une plante nuisible dans le nord de l'Australie. Elle empêche l'accès aux nappes d'eau, ombrage la végétation utile et nuit au rassemblement du bétail. L'écorce de *P. aculeata* est photosynthétique et, étant donné que la plante possède des bourgeois sensibles qui sont activés lorsque la tige est endommagée, la lutte biologique au moyen d'insectes qui mangent les feuilles ou la tige peut être difficile. Dans le nouveau-monde, *P. aculeata* est ravagé par cinq espèces de bruches (Coléoptères: Bruchidés). Parmi les cinq bruches, trois semblent prometteurs comme agents de lutte biologique contre *P. aculeata* en Australie. *Pentobruchus germaini* n'a été relevé que sur *Parkinsonia aculeata*. *Mimosetes ulkei* n'infeste que les deux genre étroitement apparentés, *Parkinsonia* et *Cercidium*, dans les champs. Bien que *M. amicus* possède quatre genres-hôtes, deux sont *Parkinsonia* et *Cercidium*, un est *Prosopis*, soit une plante nuisible non indigène en Australie et, finalement, un *Acacia*, qui n'est pas un hôte important. L'auteur étudie s'il est possible d'introduire ces espèces en Australie et si elles peuvent servir dans la lutte contre *P. aculeata*.

Introduction

*Parkinsonia aculeata* L. (Leguminosae: subfamily Caesalpinioideae) is a small (to 10 m), spiny, leguminous tree which has many common names including Retama, Mexican Palo Verde, and Jerusalem Thorn. It is thought to be native to tropical America but has been spread throughout the world as an ornamental and shade tree.

The caesalpinoid legumes include no species of wide agricultural importance but are highly valued as ornamentals; e.g. *Bauhinia*, *Caesalpinia*, *Cassia*, and *Delonix* (Isley 1975). Australian species of *Cassia* are an important component of the native Australian flora, as well as being increasingly cultivated as ornamentals.

The genus *Cercidium* is very closely related to *Parkinsonia* and putative hybrids have been found in the field (Carter 1974). There has been longstanding and continuing
debate as to whether *Cercidium* is a valid genus, or should be included in *Parkinsonia*. Brennan (1963) decided that there was no reason for maintaining *Cercidium* as a distinct genus from *Parkinsonia*, while Carter (1974) supported the validity of *Cercidium*, and Isley (1975) wrote 'the differences amongst the constituent spp. of *Parkinsonia* are not significantly great to merit generic segregation'. Polhill and Vidal (1981) concluded 'whether *Cercidium* is included in *Parkinsonia* (Brennan 1963) or excluded (Carter 1974) depends essentially on whether focus is made on the early radiation or on the secondary radiation responsible for the *Cercidium* core'.

In northern Australia *P. aculeata* is a troublesome weed. It grows in dense thickets beside rivers and dams and its sharp spines make mustering of cattle difficult and dangerous. These thickets prevent stock from gaining access to waterholes and shade out desirable vegetation (Miller and Pickering 1980). Areas where it is pestiferous are often remote and inaccessible and although it can be controlled chemically, this is difficult and costs are prohibitive. Mechanical control is seldom completely effective, with regrowth of suckers and germination of seed causing reinestation. Biological control appears to be the only feasible alternative.

*P. aculeata* may be a difficult candidate for control by leaf- and stem-feeding insects. During much of the year the plant is without leaflets, and photosynthesis is carried out by the tough, flattened leaf rachis and by the green stem. If the stem is damaged the plant will regenerate from dormant buds at, or near ground level. These suckers can grow up to 250 cm in six months.

Insects that attack the seed appear to offer the best prospect for biological control. Five species of bruchid seed beetle (Coleoptera: Bruchidae) attack *P. aculeata* in the New World. Three of these species, *Mimosestes ulkei* (Horn), *M. amicus* (Horn), and *Pentobruchus germaini* (Pic), have potential as control agents. Of the other two, *S. limbatus* (Horn) is the extreme example of a generalist, attacking 39 species in eight genera (Johnson 1981a), while *Mimosestes mimosae* (Fabricius) is primarily an *Acacia* bruchid, attacking six species of *Acacia*, as well as *Parkinsonia*, *Caesalpinia*, and *Ceratonia* (Kingsolver and Johnson 1978).

**Materials and Methods**

Pods of *P. aculeata* were collected in Texas and Arizona in 1983 and 1984 and held for adult emergence in 500 ml paper cups with plastic lids.

Many pods of *P. aculeata* with a low incidence of bruchid damage were collected from trees at Temple, Texas, in November 1983. Undamaged pods were selected and placed in two 500 ml wide-mouth fruit jars, 30 unsexed adults of *M. ulkei* were added to each jar, and the jars incubated at 30°C. One container of pods, before addition of bruchids, was heated to 50°C overnight to kill any bruchid larvae that might be present. The two containers were sampled monthly until August 1984 and *M. ulkei* adults counted and removed from the containers. On 5 August 1984, 20 pods from each container were dissected and examined for presence of bruchid eggs and seed damage. Thirty damaged, and thirty seeds from which *M. ulkei* had emerged were weighed.

Seeds of *P. aculeata* collected from five different sites in south Texas in July 1983 were separated into *M. amicus*-damaged, and undamaged seeds. Ten seeds from which *M. amicus* had emerged and 10 undamaged seeds from each site were weighed, scarified and placed in a germination cabinet at 30°C. Each test unit was 10 seeds on filter paper, in a 100 × 15 mm petri dish with 7.5 ml distilled water added. Percent germination was measured after seven days.
At Brownsville, Texas, on 9 June 1984, 10 green, but almost mature pods were collected from each of five trees of *P. aculeata*. The green seeds were removed from the pods and 10 seeds sampled from each tree. As the seeds were still green, it was possible to dissect them and separate out embryo/cotyledon, endosperm and seed coat. These were air dried at 30°C for two months and then weighed.

In Tucson, Arizona, on 24 July 1984, 25 green, but almost mature pods, 25 maturing pods that were just changing colour from green to brown, and 25 mature pods, were collected and examined for eggs of *M. ulkei* laid on and inside the pods.

Approximately 3000 pods of *Cercidium floridum* Bentham collected at Scottsdale, Arizona, in September 1983, were placed in screw-top fruit jars (500 ml) which had the metal sealing disk removed and paper towelling inserted in its place. The containers were sampled fortnightly between October 1983 and March 1984 and adults of *M. amicus* and *M. ulkei* were removed and counted. Adults of *M. ulkei* used in host-specificity testing emerged from these pods.

In experiment 1, different numbers (in brackets) of mature pods of the following plant species were used: *Gleditsia triacanthos* L. (1); *Tamarindus indica* L. (2); *Caesalpinia pulcherrima* (3); *Acacia wrightii* (5); *Prosopis glandulosa* Torr. (5); *Bauhinia congeta*, immature pods (4); and *P. aculeata* (10). The number of pods used was calculated so that the area of pod of each species was approximately the same. The experiment was replicated three times. Large (18-l) plastic buckets were used as cages. Fifteen *M. ulkei* were added on 9 December and removed on 10 January. At this time pods were separated into species and held in paper cups at ambient laboratory temperature (15–25°C) until 1 May for emergence of the bruchids.

In experiment 2, different numbers of seed (in brackets) of each of the following species — *T. indica* (3), *Phaseolus vulgaris* L. (5), *G. trichanthos* (10), *C. pulcherrima* (10), *P. aculeata* (15), *P. glandulosa* Willd. (20), *C. floridum* (10), *Acacia tortuosa* Willd. (20), *Cassia fistula* L. (10), *Bauhinia purpurea* (5), and *Delonix regia* (Boj.) Raf. (5) — were placed in a petri dish and shaken to distribute. Different numbers of seeds were used so that the total area of seed of each species available to the bruchids was approximately the same (Willson 1982). Seeds were searched under the microscope for entry holes of other bruchids, and 10 unsexed *M. ulkei* were added on 5, 9 and 12 December. On 5 January, the seeds were removed and held by species until 21 March for emergence of adults. On 22 March the seeds were dissected for evidence of any larvae or pupae. The experiment was replicated three times. Replicate 1 was held at 30°C, and replicates 2 and 3 at 15–30°C.

In experiment 3, the seeds of each species were placed in 30 ml plastic cups inside a larger plastic container (26 × 35 × 9 cm), with a gauzed top. Seeds of *C. floridum*, *P. aculeata*, and *D. regia* were used. Five seeds of each species in a cup comprised the test unit and three replicates for each species were used. Thirty unsexed *M. ulkei* were added on 7 February, removed on 16 February, and the temperature maintained at 30°C. Seeds were held in individual cups until 1 May for emergence of adults.

Results

*M. amicus* emerged from 58 out of 89 (65%) pod collections in Texas and Arizona in 1983 and 1984.

In the culture of *M. ulkei* in *P. aculeata* pods, adults were found at each of the eight sampling dates. In the container that had been heated to 50°C overnight before addition of the bruchids, the 20 pods sampled had 43 eggs (22.75%) laid on the outside of the pod and 146 eggs (77.25%) laid on the inside. Eggs laid inside were either inserted
through cracks in the pod wall, laid near *M. ulkei* emergence holes, or laid through small holes (pin-prick size) in the pod surface. The unheated container had three eggs laid on the outside (1.85%) and 159 eggs (98.15%) laid on the inside of the pod. *M. ulkei* adults emerged from 61.90% of heated pods, and from 67.12% of unheated pods. Average weight of damaged seed was 0.074 g and of undamaged seed 0.103 g, a difference of 28.16%.

Average weight of seeds from which *M. amicus* had emerged, collected in S. Texas, was 0.075 g, and of undamaged seeds 0.111 g, a difference of 32.43%. In germination tests, percent germination of scarified, undamaged seeds was 92% and for damaged seeds, 6%.

Green seeds dissected to show weight of different seed parts, yielded an average weight of cotyledon/embryo of 0.024 g, of endosperm 0.030 g, and of seed coat 0.036 g. These were 26.66, 33.33, and 40% of total seed weight, respectively.

Pods sampled at Tucson for *M. ulkei* eggs showed three eggs outside and no eggs inside green pods; one egg outside and two eggs inside just-maturing pods; and two eggs outside and 74 eggs inside mature pods.

From the 3000 pods of *C. floridum* collected in Arizona, 684 adults of *M. ulkei* and 549 adults of *M. amicus* emerged October 1983 to March 1984.

In experiment 1 of the *M. ulkei* host-specificity testing, eggs were laid on all species except *A. wrightii*. Total number of eggs laid on each plant species was: *T. indica* — 1; *B. congesta* — 3; *P. glandulosa* — 25; *P. aculeata* — 26; *G. triacanthos* — 31; and *C. pulcherima* — 37. Two adults of *M. ulkei* had emerged from pods of *P. aculeata* in replicate 2 by 1 May.

In experiment 2, eggs were laid on seeds of all species tested. All seeds except *C. floridum* and *P. vulgaris* were entered by *M. ulkei* larvae. Only one *M. ulkei* emerged, from a seed of *P. glandulosa*. However, dissection of seeds on 21 March showed a live pupa in a seed of *P. glandulosa* and a dead *M. ulkei* adult within a seed of *D. regia*.

In experiment 3, 157 eggs were laid on or around *D. regia* seeds compared to 132 for *C. floridum* and 28 for *P. aculeata*. Seeds of *D. regia* and *C. floridum* were entered by *M. ulkei* larvae, and by 1 May, one *M. ulkei* had emerged from *C. floridum* in replicates 1 and 2. On dissection, one live *M. ulkei* adult was found in a seed of *D. regia*.

**Discussion**

*Mimosestes amicus*

*M. amicus* is a widespread and abundant bruchid (Kingsolver and Johnson 1978) and adults emerged from 65% of *P. aculeata* pod samples I collected in Arizona and Texas. It is a continuous breeder in the laboratory and probably has three or more generations/yr in the field (Swier 1974). Conway (1980) estimated that *M. amicus* destroyed 44.9% of the seed crop of *Cercidium microphyllum* (Torrey) Rose & Johnston in Arizona.

It attacks 11 species of plants in four genera but is probably most common in *Cercidium* (Kingsolver and Johnson 1978). *Prosopis* and *Acacia* spp. are also attacked. Conway (1980) reported it causing an estimated 5% mortality to the seed of *Acacia constricta* Benth.

There are c. 660 *Acacia* spp. in Australia (Maslin 1981) and they form a major component of the Australian flora. *Prosopis* spp. are introduced and have become weeds in some parts of the country. A *Prosopis* sp. has invaded 200,000 ha of Western
Australian rangeland, since introduction of a so-called spineless variety in the 1920s (Anon. 1978; Ritchie 1983). *Prosopis* and *Acacia* are in the subfamily Mimosoideae, and this lack of specificity may be a barrier to introduction of *M. amicus* into Australia.

However there is evidence (Evans *et al.* 1977) that seeds of most Australian *Acacia* spp. are very different in chemical composition than seeds of *Acacia* spp. from other parts of the world. Chemical composition of seeds is an important determinant of bruchid specificity (Janzen 1977) and therefore *M. amicus* may not be able to breed in seed of most Australian *Acacia* spp. It is relevant that no *M. amicus* were reared from any of the five species of *Acacia* sampled in Costa Rica (Janzen 1980), while it emerged from 87 and 100% of all *P. aculeata* and *P. velutina* L. samples, respectively.

Another barrier to importation of *M. amicus* is that it will oviposit, and larvae will develop to maturity on green pods (Mitchell 1977). Probably these pods are almost mature and Swier (1974) commented that *M. amicus* would only oviposit on pods with developed cotyledons. Nevertheless there are many problems involved in host-specificity testing with green pods and these may not be easily overcome.

*Mimosestes ulkei*

*M. ulkei* is a large, robust bruchid that is easily distinguished from other *Mimosestes* spp. by dark markings on the edge of the elytra. Kingsolver and Johnson (1978) catalogued it as a marginal species outcompeted by *M. amicus* and *S. limbatus*. However, a collection of *C. floridum* pods from Arizona yielded 684 *M. ulkei*, compared to 549 *M. amicus*, which suggests that in certain situations *M. ulkei* may be relatively abundant.

In host-specificity tests, *M. ulkei* was not specific in ovipositional preference, laying eggs on seeds of all species tested, and on pods of all but one species. Adults however only emerged from *P. aculeata, C. floridum* and *P. glandulosa*, and one dead and one live adult were found inside seeds of *D. regia* on dissection.

In field collections *P. aculeata* and *C. floridum* are the only verified hosts of *M. ulkei* (Kingsolver and Johnson 1978). These two species are very closely related, and in this instance, *M. ulkei* can be considered to attack across, or within generic lines, depending on which taxonomic view is followed. I have not seen any records reporting *Cercidium* spp. growing in Australia.

*M. ulkei* developed to maturity in seeds of *P. glandulosa* and *D. regia* but in 3 out of 4 cases, the adults had not emerged by the time the trials were completed. This suggests some factors unfavourable to bruchid development.

As there are no field collections of *M. ulkei* from either *Prosopis* spp. or *D. regia* (Johnson 1981b), the barrier to bruchid development may be the pod itself. The legume of *P. aculeata* has a thin, papery wall that offers easy access to bruchid larvae. *P. glandulosa* pods have a leathery outside coat, and seeds are encased inside a hard endocarp within the glutinous pod body. *D. regia* pods are large (up to 50 cm long), and have hard, woody walls, 0.5–1 cm thick. Pods of both species may present a considerable barrier to entry of bruchids not adapted to them.

*M. ulkei* adults will occasionally lay eggs on green pods but the much preferred site of oviposition is mature pods. Many more eggs are laid within the interior pod cavity than on the pod surface. This may be a mechanism to reduce parasitism or desiccation of the eggs.

*M. ulkei* appears to breed continuously in the laboratory on mature seeds of *P. aculeata*. In southern Arizona, adults have been observed emerging from mature pods remaining on the tree in April, and have emerged from mature pods collected in
September, and therefore there is the potential for multiple generations of *M. ulkei* to develop in a year.

Although these initial results are promising, further host-specificity testing with both green and mature pods are required before *M. ulkei* could be considered for introduction into Australia. Very large cages may need to be used to give a true idea of ovipositional preference, especially with large pods such as those of *D. regia*. Problems in obtaining pods of different species at the same time, preventing fungal contamination and maintaining seed development, may occur, when testing with green pods.

*Pentobruchus germaini*

Little is known of the biology of this species, and its potential as a biological control agent of *P. aculeata* is unclear. However it is likely to be specific, as it has only been collected from *P. aculeata* in Argentina and Chile (Kingsolver 1973), and the only two species of *Pentobruchus* are 100% specific to *Parkinsonia* and *Cercidium* within the subfamily Caesalpinioideae (Johnson 1981b).

*Potential for Control of P. aculeata in Australia*

Many authors have reported that bruchids can infest a large percent of host seeds (Southgate 1979). However even in damaged seeds a small percent of seeds may still germinate (Halevy 1974).

Only 6% of seeds from which *M. amicus* adults had emerged germinated compared to 96% germination for undamaged but scarified seeds. It is likely that some of the damaged seeds that germinated would not survive, and growth of seedlings that did would be retarded. Janzen (1976) in artificial damage studies with seeds of *Mucuna andreana*, reported a decline in seedling fitness when only 1% of the seed weight was removed.

*M. amicus* larvae consumed 32.43% of the seed's weight, while *M. ulkei* larvae ate 29.16%. As the cotyledon/embryo together comprise only 26.66% of the seed’s weight, this suggests that most of the cotyledonary tissue, and some of the endosperm was eaten. Observations of damaged seeds confirmed this fact. Janzen (1977) reported that larvae of *Callobruchus maculatus* F. (Coleoptera: Bruchidae) did not grow at all in the polysaccharide rich endosperm of *P. aculeata*.

The seed coat of *P. aculeata* comprised a large 40% of the total weight of the seed. The thickness of this seedcoat is in itself a barrier to bruchid penetration (Janzen 1977), and toxic chemical compounds contained in the seed coat are an additional barrier to bruchid entry (Johnson 1981a).

The seed coat of *P. aculeata* is impermeable to water and will not germinate readily unless scarified or chemically treated. Everitt (1983) found that only 1% of untreated 'hard' seed of *P. aculeata* germinated, while there was no change in viability of stored seed after 2 yrs of storage.

In Australia there is probably a large reserve of hard seed already in the soil, and this seed will germinate gradually as the seed coat becomes permeable. This is an important adaption for survival in areas of low and uncertain rainfall, to ensure that the entire seed stock is not destroyed in one false 'break' to the season.

Seeds that have dropped over the years and have been covered by soil remain immune to attack by bruchids. Naked seeds on the surface are also unlikely to be attacked by either *Mimosestes* spp. or *P. germaini*, as these bruchids probably belong to the guild of bruchids that oviposit only on pods. The bruchids that oviposit on scattered seeds on the ground are rare, and are generally in the genus *Stator* (Johnson 1981c). Pods
on the tree, or mature pods on the ground, before being broken down by weathering, or dispersed by water, are the target for attack by the bruchids considered here.

In Texas, *M. amicus* eggs are attacked by an unidentified egg parasite, while bruchid larvae or pupae in seeds of *P. aculeata* are attacked by three wasp species — *Heterospilus prosopidis*, *Stenocorse bruchivora*, and *Urosigalps* sp. (Hymenoptera: Braconidae). Center and Johnson (1976) have reported on the many parasites attacking bruchids in Arizona. Introduction of bruchids without their extensive parasite fauna can only increase the chance of successful biological control.

Compared to the New World, Australia has a poor bruchid fauna (Southgate 1979), and there may be a correspondingly smaller, and perhaps more specialized, number of bruchid parasites than in the Americas. Thus, introduced bruchids may escape the severe depredation from native parasites that has caused considerable high mortality to to some previously introduced biological control agents (Haseler 1981). In Australia, no parasites have yet been found attacking the bruchid, *Bruchidius sahilbergi* (Schilsky), introduced for control of *Acacia nilotica indica* (Benth.) Brenan (Willson, pers. comm.).

Little is known of the ecology of *P. aculeata* populations in Australia, or of the reduction in germination percent that would be required to reduce the population below a self-sustaining level. If one, or all of these bruchid species were introduced into Australia, we know that some seeds would be killed, other seeds would germinate but produce unhealthy seedlings, while others, in which bruchid larvae had entered but died, would germinate more readily than undamaged seeds (Halevy 1974). Unfortunately the total effect of all this on *P. aculeata* populations is impossible to predict, albeit that the potential exists for high levels of infestation to develop, and the level of seed mortality is likely to be far greater than it is at present.

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