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Biology and field observations of *Penthobruchus germaini* (Coleoptera: Bruchidae), a biological control agent for *Parkinsonia aculeata* (Caesalpiniaceae)

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Abstract

The life cycle of the bruchid beetle *Penthobruchus germaini* (Pic) was studied in the laboratory and some field observations were recorded. Most adults (90.5%) emerged from the seeds of *Parkinsonia aculeata* L. by making an exit hole at the end of the seed opposite the radicle. Adult longevity with different food types ranged from 11.2 to 59 days and oviposition from 22 to 348 eggs per female. Females laid an average of 2 eggs per day during their life span. The life cycle (oviposition to adult emergence) was completed in 38.7 days at 30 °C in the laboratory, including 8.6 days for the egg stage, 21.8 for the larval stage, and 8.3 for the pupal stage. The larval stage had four instars. Larvae destroyed the seeds by consuming 90–100% of the cotyledons, preventing germination. They pupated inside the seeds, and only one adult emerged per seed. At three field sites, 48% of the pods were found to have eggs; the mean number of eggs per seed was 0.37 and per pod was 0.98. Females preferred the swelling of the pod as oviposition site. Mature (purple) and larger pods contained more eggs than immature (green) and smaller pods. Larvae overwintered in the seeds on the ground, began pupating in late winter, and adults emerged in the spring. Depending on plant phenology, two generations per year are possible. Natural parasitism of *P. germaini* was <5%. *P. germaini* has several attributes as an effective natural enemy of *P. aculeata.* Published by Elsevier Science (USA).

Keywords: *Penthobruchus germaini*; *Parkinsonia aculeata*; Biological control; Weed control; Brush control; Seed destroyer; Rangeland weeds

1. Introduction

Parkinsonia aculeata L. (parkinsonia, Mexican paloverde, or retama) is a small, thorny tree that spreads by seeds produced in pods. It has been proposed to have originated from tropical America and introduced to the southwestern United States. It is native to northern Argentina (Burkart, 1952), being an important species in near-climax communities in the provinces of Chaco, Formosa, northern Santa Fe, and northwestern Corrientes (Cabrera, 1976). Parkinsonia also occurs in Mexico, Central America, Africa, the Mediterranean area, southwestern Asia and India, and many Pacific islands. In Mexico and the United States, it is widely used as an ornamental tree (Bailey and Bailey, 1976) and has invaded rangelands from southern Texas to Arizona and northern Mexico. Beneficial values of this tree appear to be minimal. It was introduced into Australia as an ornamental but has become naturalized and is a serious weed of pastures and rangelands in north-central areas (Woods, 1985). It also occupies the most productive grassland in low areas and along streams. The taxonomic status and distribution of this plant were reviewed by Johnston (1924) and Woods (1985).

Parkinsonia can be controlled with herbicides (Scifres, 1980), but chemicals must be applied periodically and are costly in rangelands. The possibility of biological control by the introduction of natural enemies was suggested by DeLoach (1981) and Woods (1985). We have conducted several surveys for natural enemies in Argentina and Paraguay since 1976. Only a few insects were restricted to parkinsonia, among them, an unidentified geometrid

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moth that fed on foliage and a seed-feeding bruchid beetle, *Penthobruchus germaini* (Pic, 1894), described in this paper. According to Kingsolver (1973), *P. germaini* was known only from Argentina and Chile, although its only known host, *P. aculeata*, is widely distributed in tropical and subtropical America.

Several shipments of *P. germaini* (3120 adults) from Argentina (USDA-ARS-South American Biological Control Laboratory [SABCL]) were made to Australia (Alan Fletcher Research Station, Sherwood, Qld) from 1990 to 1993 for mass rearing. After host specificity tests were conducted in Argentina (unpublished information), and under quarantine in Australia (Donnelly, 1994, unpublished report), the insect was released in the field in 1995. *P. germaini* is now widely established in parkinsonia infestations in northern Australia. In Queensland, up to 99.95% of parkinsonia seeds have been destroyed by *P. germaini* (G. Donnelly, Alan Fletcher Research Station, Sherwood, Qld, Australia, personal communication).

However, basic information on *P. germaini* in its native habitat has never been published. The objective of this research was to study various aspects of the biology of *P. germaini* in both the laboratory and the field in Argentina. Research reported here was conducted in Argentina during 1986 to 1989 and might help to improve the field performance of this biocontrol agent in Australia.

2. Materials and methods

2.1. Laboratory studies

Laboratory studies were conducted using the F_1 generation of adults of *P. germaini* emerged from seeds of parkinsonia collected several times at Suipacha and Lincoln (Buenos Aires Province, 130 and 300 km W of Buenos Aires), and Quetrequén (La Pampa Province, 530 km W of Buenos Aires).

Adult. The emergence of adults was studied in a random sample of 200 seeds of different shapes and sizes. The longevity and oviposition of adults were measured by rearing the adults in glass tubes (12 cm diameter and 12 cm high) containing gypsum in the bottom to keep moisture and nylon mesh on top to keep the adults from escaping. The test was conducted in a growth chamber at 30 ± 2 °C and 14 h photoperiod. Adults were fed on (1) 10% honey-water solution (soaked in cotton balls) and pollen collected by bees from thistles, *Carduus* spp. in Buenos Aires Province, Argentina (obtained from a local bee shop); (2) pollen only; (3) 10% honey-water solution only; (4) water only; and (5) no food. The pollen balls were ground into a powder and placed in a plastic vial cap at the bottom of the tubes. Twelve females and 12 males were used per treatment.

Oviposition during the day and night periods was compared by exposing 840 seeds to 600 adults during four days. The adults were placed in a plastic tray ($34 \times 25 \times 8$ cm) covered with nylon mesh and fed 10% honey-water solution and pollen. The test was conducted in a rearing cabinet at 30 ± 2 °C.

The rate of oviposition was recorded in a separate study with six newly mated females reared as above. Parkinsonia seeds exposed to oviposition were removed and replaced with new ones daily.

Egg. The duration of the egg stage and their viability were measured in a sample of 840 eggs obtained from the day–night oviposition test.

Larva. Development and number of instars were determined by using 354 parkinsonia seeds exposed in the day–night oviposition test. The seeds were placed in plastic cups covered with nylon mesh. After the eggs hatched, 10 seeds each day were sampled, the larvae were killed by placing the seeds in boiling water for 10 min, and the seeds examined to determine larval development.

The survival of *P. germaini* larvae was also tested at five low temperatures (4, 0, −4, −8, and −15 °C), using eight exposure periods (1, 2, 4, 8, 16, 32, 64, and 128 days). In each treatment, 10 parkinsonia seeds infested with second to fourth instars were placed in 20-ml glass vials plugged with cotton. After exposure, the seeds were kept at 25 ± 2 °C and adult emergence was recorded. Seeds with no emergence were dissected to determine larval mortality. Control seeds ($n = 50$) were kept at 25 ± 2 °C.

Pupae. The duration of pupal stage and pupal orientation within the seed before adult emergence were also determined. The orientation of the pupae was determined by dissecting the seeds and checking the position of the heads in relation to the hilum of the seeds.

Life cycle. The complete life cycle was determined from the duration of each stage of development. Generation time and the parameters for the rate of increase were calculated according to Birch (1948).

Seed damage. The progressive damage exerted by the larvae in the seeds since penetration to complete development was measured. Every 1–3 days after the egg hatches, 10 seeds were dissected, making longitudinal and cross sections. Percentage of seed damage was visually estimated over time.

2.2. Field studies

Natural occurrence. In March 1986 and February 1988, 1940 pods were collected at Suipacha, Lincoln, and Quetrequén to determine the natural occurrence of *P. germaini* attacking *P. aculeata*. The percentage of pods with eggs and the number of eggs per seed and per pod were recorded.

Oviposition. The number of eggs and their location on the pod were recorded in a subsample of 597 pods collected in the three field sites in March 1986. In February 1988, at Lincoln and Quetrequén, pods of different maturity were sampled to determine the preference of females for oviposition, using purple color as the indicator of pod maturity.

Overwintering. The overwintering stage of *P. germaini* was determined by collecting pods of parkinsonia in Lincoln and Quetrequén from September to November 1986. A total of 148 seeds was dissected to record the stages of *P. germaini* present within the seeds.

Natural parasitism. Parasitoids that emerged from seeds infested by *P. germaini* were collected and the rate of natural parasitism was estimated.

2.3. Statistical analysis

Statistical tests were run with Minitab Statistical Software (1991) and Systat (1996). The following tests were used: chi-square test to compare the presence of eggs in different pod maturity; 2-sample t test to compare oviposition during day versus night periods and oviposition in pods of different thickness; one-way analysis of variance (ANOVA) to compare adult longevity and oviposition with different food types, egg fertility, egg location on pods, and number of eggs per seed in different pod maturity; and regression analysis to compare number of eggs per seed and per pod versus pod sizes. Tukey's Multiple Comparisons procedure was used for mean separation. Means are reported $\pm$ one standard deviation.

3. Results and discussion

3.1. Laboratory biology

Adult description. Adults of *P. germaini* are light reddish-brown to fuscous, elytra mottled with black mediocentral stripes half the length of the elytra, and with a black spot at the anterior end (laterally); yellowish pygidium, plain in male, with black central X-shaped mark in female (Fig. 1). Body 4.5–5.0 mm long by 3.5–4.0 mm wide. The complete description of *P. germaini* is given by Kingsolver (1973).

Adult emergence. The mean emergence of adults occurred at 30.1 ± 2.5 days (Table 1). Seed dimension and shape influenced the behavior of adult emergence. In large seeds (3.8 ± 0.4 mm thick), most adults (90.5%) emerged by making an exit hole in one end of the seeds, most of them (82%) at the end opposite to the hilum and the radicle. In smaller or compressed seeds (2.7 ± 0.2 mm thick), adults (the remaining 9.5%) emerged laterally by making an exit hole between the middle and the end of the seeds. Again, most of them (79%) emerged

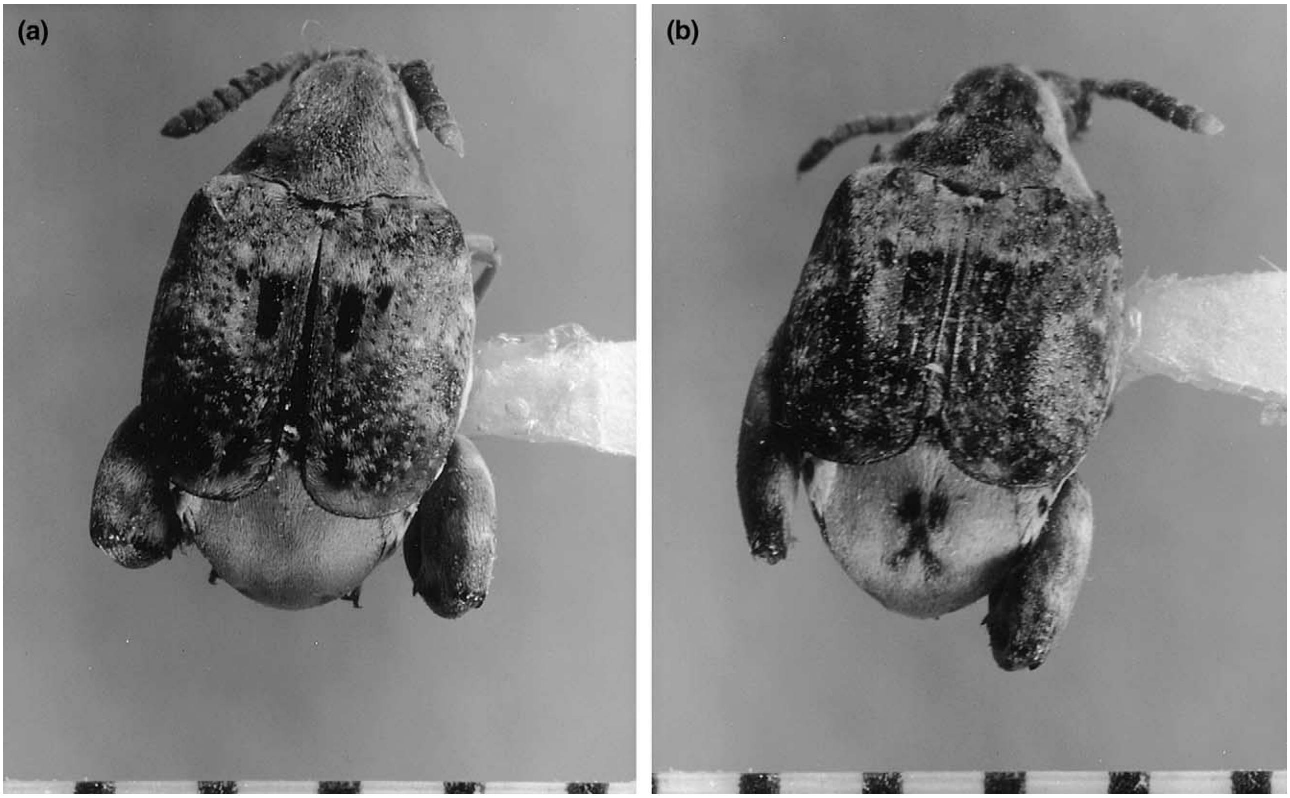

Fig. 1. *Penthobruchus germaini* adults: (a) male; (b) female. White region of ruler = 1 mm.

Table 1
Life cycle of *Penthobruchus germaini* in the laboratory at 30 °C

Stage	Individuals examined	Presence in cohort (days since eggs hatched)	Width of head capsule (mm)
		Mean ± SD (range)	Mean ± SD
Egg	840	8.6 ± 0.4 (8–9)[a]	
Larva			
First instar	38	2.3 ± 1.1 (1–5)	0.20 ± 0.02
Second instar	41	6.1 ± 1.5 (4–11)	0.37 ± 0.04
Third instar	36	11.4 ± 3.0 (7–34)	0.49 ± 0.03
Fourth instar (active)	64	12.5 ± 2.3 (10–34)	0.75 ± 0.09
Prepupa	96	15.8 ± 2.3 (12–34)	
Pupa	34	24.1 ± 5.2 (16–34)	
Adult emergence	33	30.1 ± 2.5 (27–35)	
Oviposition to adult		38.7	

[a] Duration of egg stage, determined in a separate test.

at the end opposite the hilum. This is probably because the mouthparts could not reach the end of the seed to make an end cut.

Adult longevity and oviposition. Mean adult longevity in the laboratory ranged from 59 ± 14.8 to 11.2 ± 1.9 days and was strongly influenced by the type of food (Table 2; $F = 100.08$; df = 4, 115; $P < 0.001$). The best food types in decreasing order were: (1) the combination of pollen and 10% honey-water solution, (2) pollen only, (3) 10% honey, and (4) water only or no food. Total oviposition ranged from 4173 to 268 eggs (347.8–22.3 eggs per female), and was also strongly influenced by the type of food, (Table 2). The mean number of eggs per female per day ranged from 5.6 ± 2.3 to 1.0 ± 1.2 ($F = 6.47$; df = 4, 36; $P < 0.001$). The fertility of the eggs was high in all treatments, ranging from 89.9 ± 5.1% to 98.3 ± 1.5%, and no differences were observed with the food type ($F = 0.452$; df = 4, 29; $P = 0.77$).

During oviposition, the females spread a liquid over the egg that quickly dried, forming a cover from front (nearest the female) to back. The liquid-covered eggs attached to the seed or pod. Then, the females touched the seed or pod surface with the ovipositor (at the rear of the egg) and wiped forward, forming a second cover over the first. This process was described and illustrated by Teran (1962) for the closely related bruchid *P. cercidicola* Kingsolver and, as best as we could observe, was identical for *P. germaini.*

In the day-and-night-oviposition test, females laid a total of 1933 eggs in 4 days, 1162 (60.1%) at night, and 771 (39.9%) during the day. This difference was not statistically significant ($t = -1.03$; df = 6; $P = 0.34$).

In the test to measure the rate of oviposition, mean survival of females ($n = 6$) was 89.0 ± 51.8 (range 1–128) days. They began egg-laying on the day of emergence and the rate decreased through time. Females laid a mean of 2.0 ± 2.3 eggs per day during the entire oviposition period. They laid on average 7.6 ± 3.6 (range 4.5–11.6) eggs per day during the first five days, 2.1 ± 1.2 (range 0.7–3.7) eggs from 5 to 20 days, 1.6 ± 0.6 (range 0.8–2.2) eggs from 20 to 50 days, and 0.8 ± 0.5 (range 0–1.8) eggs from 50 to 128 days of age.

Egg. The eggs of *P. germaini* are cream-colored, transparent, shiny, ovoid but flattened on the bottom, and 1.01 ± 0.06 mm long by 0.62 ± 0.03 mm wide. They are protected by two hyaline covers as described in the oviposition process. The round entry hole of the larva into the pod was clearly visible through the transparent covers and the chorion after hatching. Duration of the egg stage was 8.6 ± 0.4 days (range 8–9) (Table 1).

Table 2
Adult longevity and oviposition of *Penthobruchus germaini*

Food type	Longevity (days) mean ± SD[a] (range)	Total eggs laid[b]	Eggs/female/day mean ± SD[a]	% Eggs hatched mean ± SD[c]
10% Honey + pollen	59.0 ± 14.8 a (23–79)	4173	5.6 ± 2.3 a	92.1 ± 10.5 a
Pollen	38.8 ± 12.6 b (21–69)	1472	2.9 ± 3.1 b	91.2 ± 7.6 a
10% Honey	31.2 ± 9.9 c (25–61)	536	1.0 ± 1.2 c	89.9 ± 5.1 a
Water only	11.2 ± 1.9 d (7–12)	385	2.5 ± 1.9 b	98.3 ± 1.5 a
No food	11.8 ± 1.0 d (7–12)	268	1.7 ± 1.5 bc	94.8 ± 2.0 a

[a] Treatments followed by the same letter are not significantly different, Tukey's Multiple Comparisons procedure. $P < 0.001$.
[b] All treatments started with 12 females.
[c] Treatments followed by the same letter are not significantly different, one-way ANOVA. $P = 0.77$.

Table 3
Survival of *Penthobruchus germaini* larvae at low temperatures

Temperature (°C)	Days at low temperatures								
	0	1	2	4	8	16	32	64	128
	Number of adults emerged from exposed seeds[a]								
4	–	9	9	8	9	7	8	7	4
0	–	10	8	4	7	7	7	7	2
−4	–	9	8	7	5	7	7	–	–
−8	–	7	4	9	9	8	0	–	–
−14	–	1	0	–	–	–	–	–	–
25 (control)[b]	25	–	–	–	–	–	–	–	–

[a] 10 infested seeds per treatment.
[b] 50 infested seeds in control.

Larval development and instars. Based on head-capsule measurements, the larvae had four instars. The average growth ratio of head capsules between instars was 1.57 (Table 1). The mean age when each instar was present provided a measure of the progressive development of the cohort until adults were produced. Most of first instars were present during days 1–3, followed by second instars during days 4–8, third instars during days 8–13, fourth instars during days 10–14, and prepupae during days 13–22. In the third and older instars, one or two individuals in the 10 seeds dissected each day persisted in that stage until all seeds of the cohort had been dissected after 36 days. These were not included in the mean values because we could not determine whether they were in a state of arrested development or would survive.

Larval survival at low temperatures. Larvae of *P. germaini* are moderately cold-tolerant (Table 3). Minimum survival temperature within the seeds was ca. −10 to −12 °C. At −14 °C, only 1 larva survived for 1 day; at −8 °C, 8 larvae survived 16 days; at −4 °C, 7 larvae survived 32 days. At 0 °C, 7 larvae survived 64 days and only 2 survived 128 days. At 4 °C, 7 larvae survived 64 days and 4 survived 128 days. *P. germaini* is at least as cold-tolerant as is parkinsonia and could survive as far into colder climatic zones as does its host plant. In the control seeds, only 25 (50%) adults emerged from infested seeds. The reasons for this low emergence rate are not clear. The test should be repeated to confirm results.

Larval behavior and seed damage. At hatching, the larvae entered the seed through the bottom of the seed. Hatched eggs could be identified by their white appearance caused by frass from feeding larvae. In field-collected seeds, 96% of the larvae entered the seeds laterally near the vertical center, and the remaining 4% entered the top or bottom of the seeds. Of those entering laterally, 65% entered the central area, 33% the fourth nearest the hilum, and 2% near the hilum. None entered the opposite end to the hilum. Possibly, this distribution could be explained by the difference in tegument thickness in the seeds that was thinner near the center and thicker toward the ends and the top of the seed. We did not observe larval movement through the pod and into the seed.

Larvae fed progressively on the cotyledons, damaging 90–100% of them after 16–17 days of entering the seeds (Fig. 2). They also fed slightly on the radicle of 45% of the seeds. The destruction of the cotyledons alone effectively prevented germination of the seeds.

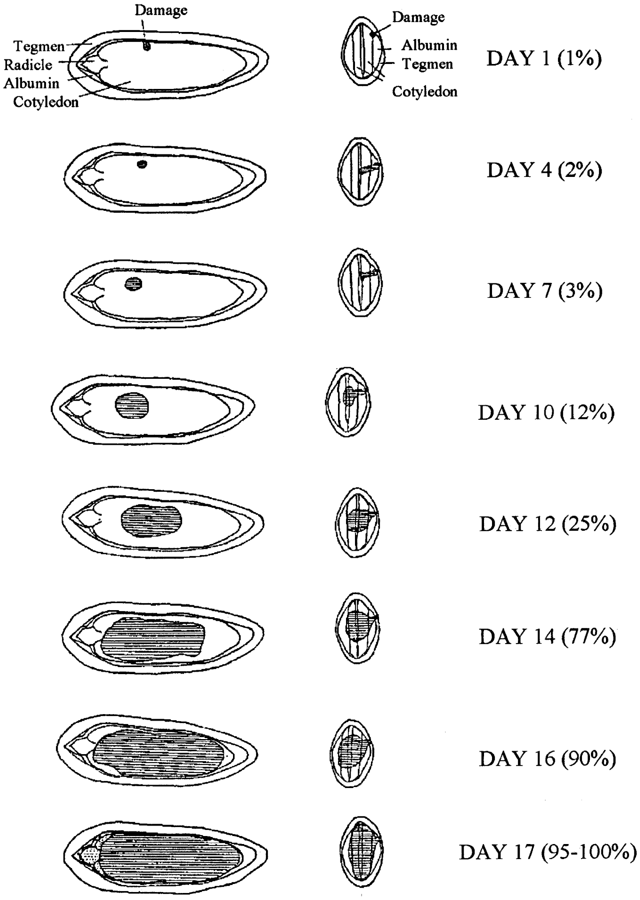

Fig. 2. Progressive damage to a seed of *Parkinsonia aculeata* caused by the feeding of one larva of *Penthobruchus germaini* throughout its development. Longitudinal and cross sections of the seed.

Circumstantial evidence suggested that the larvae were cannibalistic. Although females frequently laid more than one egg on a seed, two neonate larvae were found to enter the seed only in 13% of the seeds. We never observed more than one adult emerging from a seed. The finding of seeds with more than one larva was only until day 11 after egg hatching (third instar), thereafter, we found only one larva per seed.

Pupa. On average, pupae were present at 24.1 ± 5.2 (range 16–34) days after egg hatching (Table 1) and prepupae at 15.8 ± 2.3 (range 12–34) days, which allowed an average 8.3 days for duration of the pupal stage. In dissected seeds, 77% of the pupae was with their head opposite the hilum of the seed.

Life cycle. The life cycle (oviposition to adult emergence) was completed in 38.7 days at 30 °C in the laboratory, including 8.6 days for the egg stage, 21.8 for the larval stage, and 8.3 for the pupal stage (Table 1). Calculation of the reproductive parameters, according to Birch (1948), gave a mean generation time (mean of the period over which progeny is produced) of 48.1 days. Generation time is longer since adult life is calculated to the age of mean contribution to the next generation. The net reproductive rate (R_0) was 23.8, the innate capacity for increase was 0.066, and the population would double in 10.5 days at 30 °C in the laboratory.

3.2. Field studies

Natural occurrence. The natural occurrence of *P. germaini* attacking parkinsonia in three field locations is summarized in Table 4. The mean percentage of pods with eggs was $48.6 \pm 18.9\%$ (range 33–78), the mean number of eggs per seed was 0.4 ± 0.2 (range 0.1–0.6), and per pod was 1.1 ± 0.7 (range 0.4–2.3).

Oviposition. We found 456 eggs of *P. germaini* from the pods ($n = 597$) (Table 5). The pods contained from 1 to 11 seeds, and the total number of seeds examined was 1774. Curiously, no pods were found containing 10 seeds. Most pods (86%) contained 1–4 seeds. The mean number of eggs per seed and per pod were 0.3 and 0.8, respectively. The number of eggs per seed was independent of pod size ($r^2 = 0.354$; $F = 4.39$; df = 1, 8; $P = 0.069$) but more eggs per pod were found on larger pods (Table 5, $r^2 = 0.65$; $F = 15.158$; df = 1, 8; $P = 0.005$). *P. germaini* strongly preferred the seed swelling as oviposition site. A total of 415 eggs (91%) was laid on the seed swelling of the pod, 69% on the

Table 4
Natural occurrence of *Penthobruchus germaini* attacking *Parkinsonia aculeata*

Location	Date	No. of pods examined	No. of seeds examined	% of pods with eggs	No. of eggs found		
					Total	Per seed	Per pod
Suipacha	Mar 86	99	353	78	224	0.6	2.3
Lincoln	Mar 86	229	608	38	123	0.2	0.5
	Feb 88	688	1475	37	660	0.4	1.0
Quetrequen	Mar 86	269	813	33	109	0.1	0.4
	Feb 88	655	1902	57	782	0.4	1.2
Total/mean ± SD		1940	5151	48.6 ± 18.9	1898	0.4 ± 0.2	1.1 ± 0.7

Table 5
Oviposition and egg location on pods of different sizes

Pod size (seeds/pod)	No. of pods examined	No. of seeds examined	No. of eggs found			Egg location on pod[a]			
						Seed swelling		Between seeds	
			Total	Per seed	Per pod	Side	Suture	Side	Suture
1	84	84	37	0.4	0.4	22	12	1	2
2	193	386	120	0.3	0.6	85	27	1	7
3	135	405	103	0.3	0.8	72	22	3	6
4	99	396	101	0.3	1.0	65	25	5	6
5	42	210	49	0.2	1.2	40	4	2	3
6	23	138	18	0.1	0.8	14	3	0	1
7	17	119	20	0.2	1.2	10	7	2	1
8	2	16	4	0.3	2.0	3	0	0	1
9	1	9	1	0.1	1.0	1	0	0	0
11	1	11	3	0.3	3.0	3	0	0	0
Total/mean	597	1774	456	0.3	0.8	315 a	100 b	14 b	27 b

[a] Totals followed by the same letter are not significantly different, Tukey's Multiple Comparisons procedure. $P < 0.001$.

sides, and 22% on the sutures. The remaining 9% of the eggs was located on the constriction between seeds (Table 5; $F = 6.806$; df = 3, 36; $P = 0.001$). The egg location did not vary with the size of the pod. On bare seeds, females laid most eggs on the lateral two thirds of the seed where the outer integument was thinnest. They never oviposited on the ends of the seeds.

In 1988 at Lincoln and Quetrequén, fewer immature (green) pods were found with eggs than mature (purple) pods (Table 6; $P^2 = 42.4$; df = 3; $P < 0.001$). This was, in part, because mature pods had been exposed longer to the beetles and because mature pods might be more attractive for oviposition. This needs to be confirmed. The mean number of eggs per seed was 0.8 ± 0.8 in mature pods, significantly higher than in immature pods (Table 6; $F = 6.673$; df = 3, 196; $P < 0.001$). The stimulus for oviposition seemed to be the appearance of the seed swellings. Pods without eggs were thinner than those with eggs. At Lincoln, pods without eggs were 2.8 ± 0.7 mm (range 1.5–4.3) thick and pods with eggs were 3.9 ± 0.6 mm (range 2.3–5.2) ($t = -7.44$; df = 78; $P < 0.0001$). At Quetrequén, pods without eggs were 4.6 ± 1.1 mm (range 1.3–6.4) thick and pods with eggs were 5.4 ± 0.4 mm (range 4.2–6.6) ($t = -4.50$; df = 78; $P < 0.0001$). As stated above, the preferred site for oviposition was the seed swelling, where 93.5% of the eggs was laid. However, almost 80% of the eggs was laid along the suture of the pods (Table 6; $F = 14.916$; df = 3, 12; $P < 0.001$). This was inconsistent with previous collections conducted in 1986 (Table 5) where 72% of the eggs was laid on the sides of the pods. The reason for this difference is unknown but it may be irrelevant to the life cycle of *P. germaini.*

Overwintering. In the late-winter collections (September 6), 73% of the stages present was larval, mostly third and fourth instars, and prepupae; the remaining 27% was pupae (Table 7). In spring (October 9 and November 9), teneral adults were present in 11% and 23%, respectively. On November 9, most larvae were fourth instars.

This age structure indicated that *P. germaini* overwintered as larvae in seeds. The larvae began pupating in late winter (mild at this latitude) and adults began emerging in mid-spring. Parkinsonia flowered from October through February but mostly in January and February. Fruit pods were present on trees from November through May but mostly in February and March. Because flowering varied greatly with rainfall, this variation would allow two generations of *P. germaini* per year and would account for the presence of different ages of larvae that were found during the winter.

Table 6
Oviposition and egg location on pods of different maturity

Pod maturity	No. of pods examined	No. (%) of pods with eggs[a]	No. of seeds examined	No. of eggs in sample	No. of eggs per seed[b]	Egg location on pod[c]			
						Seed swelling		Between seeds	
						Side	Suture	Side	Suture
Green	317	107 (34) c	789	202	0.3 ± 0.6 b	31	147	1	23
Mostly green	400	201 (50) b	1172	427	0.3 ± 0.5 b	50	369	5	3
Green–purple	326	144 (44) b	770	303	0.5 ± 0.6 b	53	200	2	48
Mostly purple	300	177 (59) a	646	510	0.8 ± 0.8 a	68	430	7	5
Total/mean	1343	629 (47)	3377	1442	0.5 ± 0.7	202 b	1146 a	15 c	79 c

[a] Treatments followed by the same letter are not significantly different, chi-square test. $P < 0.001$.
[b] Calculated from a sub sample of 50 pods per treatment (Total pods = 200). Treatments followed by the same letter are not significantly different, Tukey's Multiple Comparisons procedure. $P < 0.001$.
[c] Totals followed by the same letter are not significantly different. Tukey's Multiple Comparisons procedure. $P < 0.001$.

Table 7
Stages of *Penthobruchus germaini* in *Parkinsonia* seeds during late winter and spring

Date	Number of seeds[a]		Stage present in seeds (%)						
	Exam.	Infested	Larvae					Pupa	Adult
			1st	2nd	3rd	4th	Prepupa		
Sept. 6	80	37	0	2.7	19.0	27.0	24.3	27.0	0
Oct. 9	37	27	0	3.7	26.0	40.7	3.7	14.8	11.1
Nov. 9	31	30	0	0	3.3	43.4	6.7	23.3	23.3

[a] On September 6, 40 seeds were collected from Lincoln and 40 from Quetrequén; all other seeds were from Quetrequén.

Natural enemies. The following parasitoids emerged from seeds attacked by *P. germaini* in Argentina: *Monoksa dorsiplana* Boucek (Hymenoptera: Pteromalidae), *Eupelmus cushmani* (Crawford) (Hymenoptera: Eupelmidae), and *Horismenus depressus* Gahan (Hymenoptera: Eulophidae). The rate of parasitism was estimated at ca. 5% or less. The nature of the parasitism was not determined and the presence of hyperparasitism was not established.

In Australia, parasitism is an emerging threat to the continuous success of *P. germaini*. *Dinarmus simus* (Girault) (Hymenoptera: Pteromalidae), an ectoparasitoid of larvae and pupae, has been found affecting up to 22% of *P. germaini* immatures, and *Uscana* sp. (Hymenoptera: Trichogrammatidae) has been found parasitizing up to 69% of *P. germaini* eggs in Queensland (G. Donnelly, personal communication).

Penthobruchus germaini has several attributes as an effective natural enemy of *P. aculeata*. First, it destroys the seeds, the only means of dispersal for parkinsonia. The use of a seed-destroying natural enemy would check the spread of this weed into new or previously cleared areas without harming its ornamental values. This approach was successful in South Africa where introduced seed-feeding insects controlled the weedy shrub *Sesbania punicea* (Cavanilles) Bentham (Hoffmann and Moran, 1991) and the small weedy tree *Hakea sericea* Schrader (Kluge and Neser, 1991). Second, under natural field conditions in Argentina, *P. germaini* is highly prevalent, infesting almost 50% of the pods and destroying almost 40% of the seeds produced by parkinsonia in one season. Third, short generation time (48.1 days) allows possibly two generations per year. In addition, *P. germaini* shows high egg fertility (>89%) and cold tolerance. These results, indicate that *P. germaini* is a good agent for the biological control of parkinsonia.

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