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The biology and taxonomy of *Hyperaspis pantherina* (Coleoptera: Coccinellidae) and the classical biological control of its prey, *Orthezia insignis* (Homoptera: Ortheziidae)

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Abstract

Between 1908 and 1959, the predatory coccinellid, *Hyperaspis pantherina* Fürsch, was released for the biological control of the ensign scale *Orthezia insignis* Browne in Hawaii, four African countries and Peru. Substantial control was reported after all the releases, although the outcome was disputed in Malawi. Other coccinellid species and predatory Diptera were released against *Orthezia* spp. in various programmes from 1952 to 1977. In most cases these agents failed to establish, and there were no reported effects on the target *Orthezia* spp. In 1993, *H. pantherina* was released in St Helena for the control of *O. insignis* on the endemic gumwood tree, *Commidendrum robustum* (Compositae). Preparatory investigations for this release revealed that the taxonomy and biology of this biocontrol agent were poorly known. *Hyperaspis pantherina* is redescribed and shown to be the correct name for the species previously known incorrectly as *H. jocosa* (Mulsant). *Hyperaspis laeta* Gorham and *H. levrati* (Mulsant) are transferred to the genus *Cyra* Mulsant (**comb. n.**). *Hyperaspis metator* (Casey) (**stat. rev.**) is resurrected from synonymy with *H. levrati* auctt. Studies of the life history revealed that *H. pantherina* normally lays its eggs directly onto the adult female *O. insignis* and that the first two instars of the larvae are frequently passed inside the ovisac of the female host, after which the host itself is often consumed. The information on the biology and taxonomy of *H. pantherina*, together with details of culturing methods, should facilitate the further use of this agent for the classical biological control of *O. insignis*, a pantropical pest.

Introduction

Hyperaspis pantherina Fürsch, previously known incorrectly as *H. jocosa* (Mulsant), was introduced in 1993 to the Atlantic island of St Helena in an attempt to control the ensign scale, *Orthezia insignis* Browne. *Orthezia insignis*, like other members of the family Ortheziidae, is native to South and Central America. The pest was accidentally introduced into St Helena in the 1970s or 1980s, since it was not recorded as a pest by Wallace (1960) or Simmonds (1973). *Orthezia insignis* is currently threatening the continued existence of the endemic gumwood tree, *Commidendrum robustum* (Compositae), part of the rich endemic flora of this isolated island (Cronk, 1986; Holland, 1986).

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Hyperaspis pantherina has a long history of use for biological control of *Orthezia* spp. in various parts of the world, but much of the information is unpublished or difficult to access, and there are few details available concerning the biology of this predator. Moreover, after most releases there appears to have been little or no attempt to monitor the impact of the control agents on the target *Orthezia* spp.

In this paper, the past use of classical biological control against *Orthezia* spp. worldwide is reviewed and the rate of successful control assessed as far as possible. A detailed taxonomic description of *Hyperaspis pantherina* is presented and other names used for this species are evaluated. Finally, information on the biology and rearing of *H. pantherina* is presented, based on observations and methods developed while culturing the predator in quarantine in the UK, in preparation for shipment to St Helena.

The history of *H. pantherina* and other predatory species in the biological control of *Orthezia* spp.

Attempts to control *Orthezia* spp. biologically, and the outcomes where known, are listed in table 1, beginning with the first introduction of *H. pantherina* from Mexico to Hawaii in 1908 for the control of *O. insignis*. Since then, *O. insignis* has reportedly been under effective control by *H. pantherina* in Hawaii (Zimmerman, 1948). From 1948 to 1955, *H. pantherina* and other potential biological control agents of *O. insignis* were introduced into Kenya, but *H. pantherina* was the only agent known to have become established. *Orthezia insignis* is no longer considered a major pest in Kenya (Greathead, 1971), which again is attributed to *H. pantherina*. Between 1953 and 1955, it was felt necessary to import into Kenya two other *Hyperaspis* spp. and two dipteran predators of *Orthezia* spp. from the Caribbean. Little is known about the dipteran predators, *Rhinoleucophenga* sp. (Drosophilidae) (shipped as *Gitona braziliensis* Costa Lima) and *Melaleucopis simmondsii* Sabrosky (Chamaemyiidae), except that their larvae are predators of *Orthezia* spp. in South and Central America (Beingolea, 1957; Cock, 1985).

From Kenya, *H. pantherina* was distributed to several countries in East Africa, where reports indicate that control of *O. insignis* was generally successful (Greathead, 1971). Finally, in South America and the Caribbean islands, *H. pantherina* and other potential biocontrol agents of *Orthezia* spp. were distributed from countries where they occurred as native predators of *Orthezia* spp. to countries where they were apparently absent (Cock, 1985). *Hyperaspis pantherina* is the only classical biological control agent for *Orthezia* spp. that has definitely become established and achieved substantial control of the pest; however in many cases, other agents were released in small numbers and it

Table 1. Examples of introductions of *Hyperaspis* and other predators for the control of *Orthezia* spp. The name *Hyperaspis jocosa* was used previously for *H. pantherina*. *Rhinoleucophenga* sp. is a drosophilid fly and *Melaleucopis simmondsii* Sabrosky is a chamaemyiid fly. *Cladis nitidula* (Fabricius) is a coccinellid beetle. Source references are (1) Clausen (1978), (2) Greathead (1971), (3) Commonwealth Institute of Biological Control (1963, 1975, 1976, 1977, 1978), (4) Simon *et al.* (1964), (5) Cock (1985).

Country	Date	Target	Agent released	Outcome
Hawaii[1]	1908	*O. insignis*	*Hyperaspis pantherina*	successful control
Kenya[1]	1948	*O. insignis*	*H. pantherina*	considerable control
Grenada[5]	1952-3	*Orthezia* spp.	*H. donzeli* (Mulsant), *Rhinoleucophenga* sp., miscellaneous coccinellids	failed to establish
Kenya[1]	1953	*O. insignis*	*H. donzeli*	failed to establish
Kenya[2]	1953-5	*O. insignis*	*Hyperaspis* sp., *Rhinoleucophenga* sp., *Melaleucopis simmondsi*	insufficient numbers of these species to release
Tanzania[2]	1950s	*O. insignis*	*H. pantherina*	'saved jacarandas'
Uganda[2]	1950s	*O. insignis*	*H. pantherina*	successful control
Malawi[2]	1959	*O. insignis*	*H. pantherina*	claims of success disputed
Brazil[1,3]	1962-3	*Orthezia* spp.	*H. donzeli*, *M. simmondsii*, *Rhinoleucophenga* sp.,	no establishment reported for any species
Peru[4]	1962-3	*Orthezia* spp.	*H. pantherina*	good control
Peru[5]	1969	*Orthezia* spp.	*Cladis nitidula*, miscellaneous coccinellids	outcome unknown
Peru[3]	1973-7	*Orthezia* spp.	*H. distinguenda* (Mulsant) *H. donzeli*	outcome unknown
Barbados[5]	1976-7	*O. praelonga* Douglas	*H. distinguenda*, *H. donzeli*, *H. jucunda* (Mulsant)	no recoveries reported

appears that post-release monitoring was inadequate or non-existent. Results from the current monitoring programme of the recent release of *H. pantherina* in St Helena will be presented in a future publication.

Taxonomic history

Cleothera (Cyra) jocosa was described by Mulsant (1850), but transferred to *Hyperaspis* by Crotch (1874). More recently, Chapin (1966) and Duverger (1989) both showed that the name *Cyra* Mulsant could be used for a valid genus distinct from *Hyperaspis* Dejean, a view supported by the present studies. Gorham (1894) figured and described a species under the name *Hyperaspis jocosa*?, but later decided that his earlier use of *jocosa* was incorrect, so he proposed *Hyperaspis laeta* as a new name for his species (Gorham, 1899). Kotinsky (1909) reported that specimens of *Hyperaspis jocosa* had been received in Honolulu from Mexico on 27 January 1908. Five larvae and pupae were reared to maturity, bred, and their progeny released in the city and suburbs of Honolulu. Subsequent references to this species in the Hawaiian literature as a predator of *Orthezia insignis* (Ehrhorn, 1914; Fullaway, 1920; Zimmerman, 1948; Leeper, 1976) have also used the name *H. jocosa*. Under this name, Le Pelley (1959) reported that the species had been introduced from Hawaii into Kenya in 1948 to control *Orthezia insignis*. It seems likely that the early Hawaiian entomologists identified their newly introduced species using Gorham's (1894) work.

Studies by one of us (RGB) have shown that a history of misidentifications has prevailed. The subsequent interpretations of *H. jocosa* both refer to different taxa and neither fits the original description of *Cleothera jocosa* Mulsant, which was stated to bear four, not five, spots on each elytron. More significantly, the original description refers to a yellow marking on the centre of the frons in the female, the male being unknown. Such a mark is a common feature of female *Cyra* spp., but seems not to occur in true *Hyperaspis* spp., where the female almost always has a black or dark brown head.

Although the original material imported into Hawaii came from Mexico, the species' range just extends into the southern USA. It keys out readily to *Hyperaspis levrati* (Mulsant) in Gordon (1985) who followed the species' interpretation of Dobzhansky (1941). Examination of specimens in the United States National Museum (USNM) from Arizona determined by R.D. Gordon showed them indeed to be the same as the present species. However, neither the name *H. levrati* nor *H. metator* (Casey), listed as a synonym of *H. levrati* by Dobzhansky (1941), applies to the present species as shown below.

Fürsch (1975) described *Hyperaspis pantherina* based on specimens from Nairobi and Machakos, Kenya, which were predators on *Orthezia insignis*. The Kenyan material used in the present study fitted Fürsch's description well, matched the bionomic data, and was readily distinguished by its body shape and coloration from all native African species of *Hyperaspis*. Fürsch (1975) gave no indication that his was an introduced species. Our Kenyan material was also clearly the same species that was originally introduced into Hawaii, as shown by a comparison of material from the two regions.

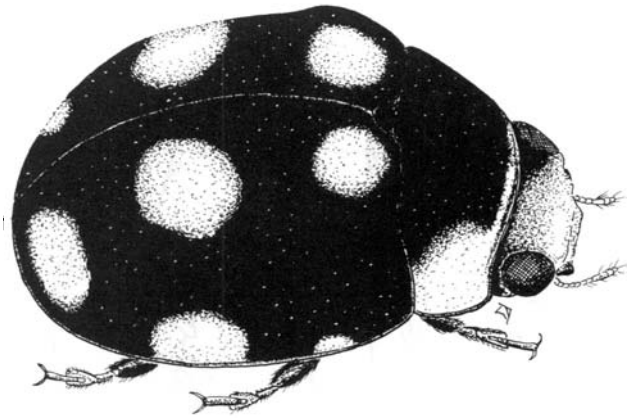
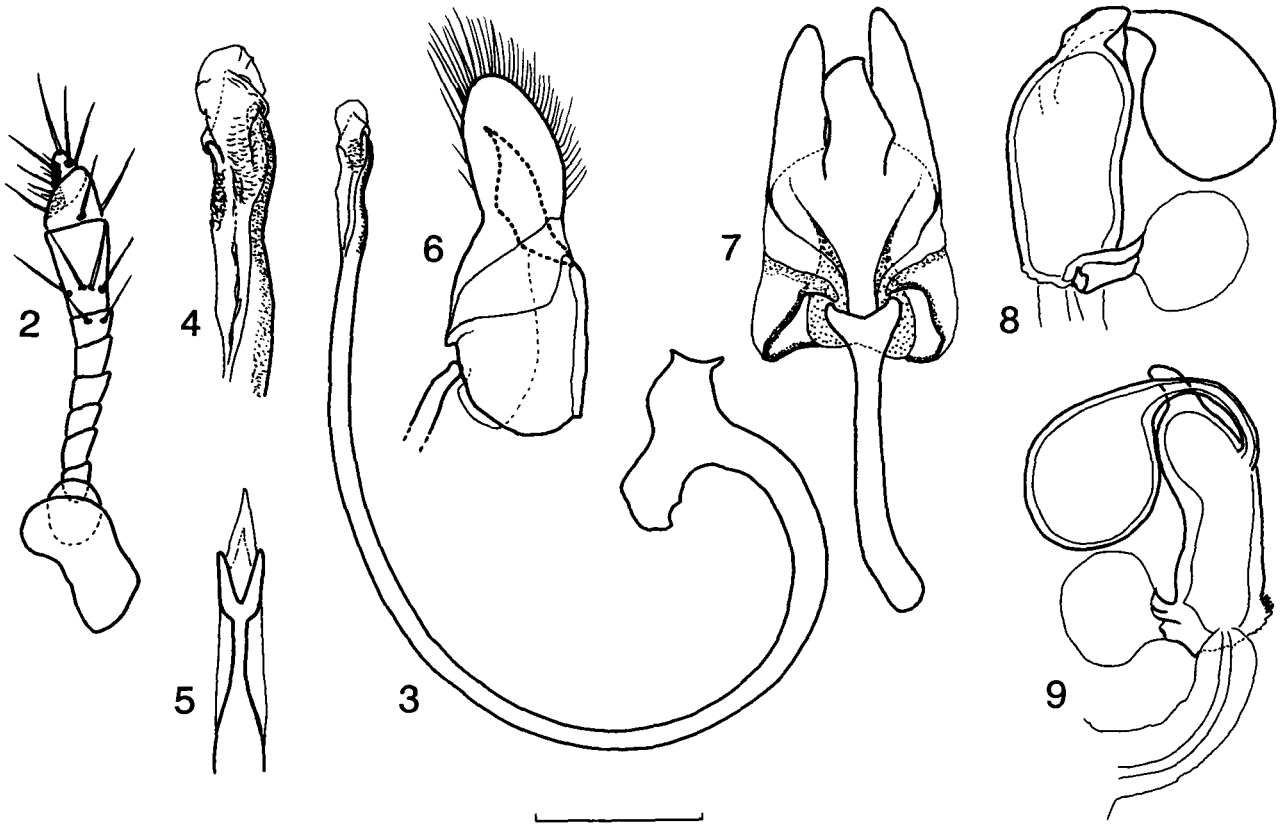


Fig. 1. *Hyperaspis pantherina*, male.

Hyperaspis pantherina Fürsch
(figs 1–9)

Hyperaspis pantherina Fürsch 1975: 43.
Hyperaspis jocosa (Mulsant): Kotinsky 1909: 109; Ehrhorn 1914: 8; Fullaway 1920: 240; Le Pelley 1959: 268; Leeper 1976: 295; Clausen 1978: 137 [misidentifications].
Hyperaspis levrati (Mulsant): Dobzhansky 1941: 5 partim; Gordon 1985: 459 partim [misidentifications].

Description. Body short oval, convex, elytral humeri only weakly suggested. Length 2.3-2.7 mm, breadth 1.7-2.3 mm. Head with frons and clypeus yellow, vertex behind eyes and lower surface black in male; anterior margin of clypeus yellow, rest of head black in female; labrum, antennae and palpi yellow in both sexes. Frons a little wider than long; finely but distinctly punctured, the punctures separated by 1.5 to 2 diameters, their interstices rather shining especially towards centre of frons but with somewhat irregular to reticulate microsculpture clearly visible at ×40. Anterior margin of clypeus moderately concave, without fine marginal bead; frons distinctly curved down anteriorly toward clypeus, a curved, transverse impression appearing to separate frons from anterior margin of clypeus. Antennae 11-segmented (fig. 2). Pronotum black centrally with lateral fifth yellow; males with anterior quarter to fifth yellow, the demarcation line more or less straight across; in females black reaching forward to anterior margin. Distinctly punctured, punctures larger than those on head, separated by 1.5 to 2.5 diameters, scarcely coarser laterally, their interstices rather shining but with very fine microsculpture giving a faint bloom to the surface. Posterior margin with a fine bead in front of scutellum. Elytra black, each with five clearly demarcated yellow spots in both sexes as in figure 1, the subhumeral and lateral spots may be partially joined, scutellar spot noticeably smaller than discal spot, subapical spot not reaching suture or hind margin. Elytral epipleura yellow adjacent to subhumeral and lateral spots, otherwise black. Punctation similar to that of pronotum, but interstices shining and without apparent microsculpture although surface bloom weakly suggested at ×80. Prosternum black, hypomera yellow in both sexes, prosternal carinae rather weak. Meso- and metasternum black, with mesepimeron yellow in males, infuscated in females. Abdomen mostly black, but paler marginally. Legs including trochanters mostly yellow except metafemora black in basal half in males and all femora black in basal half to two-thirds in females. Sixth visible sternite emarginate in males, entire in females. Male genitalia (figs 3-7) with short, broad, somewhat



Figs. 2-9. *Hyperaspis pantherina*: 2, antenna; 3, sipho; 4, apex of sipho, lateral view; 5, same, ventral view; 6, median lobe, parameres, trabes, lateral view; 7, same, ventral view; 8, 9, spermatheca, two views. (Scale marker=250 μm, figs 3, 6 & 7; 125 μm, figs 2, 4, 5, 8 & 9).

spoon-like parameres, enclosing median lobe. Female spermatheca (figs 8-9) with short appendix, accessory bulb with short duct.

Most of the material examined from Hawaii and Kenya had the subhumeral and lateral spots separated. Material examined from Arizona had these two spots partly joined, although it was obvious that two spots and not a continuous band of colour was involved. Gordon (1985) figured a specimen with joined spots, but also stated that the spots were often separated. Perhaps the more consistent colour pattern of the Hawaiian and Kenyan material results from the very small size of the originally introduced founder population. Voucher material from Hawaii, Kenya and the laboratory culture in the UK has been deposited in The Natural History Museum, London.

Cyra laeta (Gorham) comb. n.

Hyperaspis laeta Gorham 1899: 262 [replacement name].
Hyperaspis jocosa? (Mulsant): Gorham 1894: 192 [misidentification].

There are two syntypes of *H. laeta* Gorham in The Natural History Museum (NHM). The specimen fitting the male description, and which was the specimen figured, bears several labels including 'V. de Chiriqui, 3-4000 ft. Champion [printed]/ H. laeta Gorh. [in Gorham's handwriting]/Sp. figured. [printed]/Type [red bordered printed Museum label]/ LECTOTYPE Hyperaspis laeta Gorham Gordon 1970'. It is a male specimen and is here designated as the lectotype of *Hyperaspis laeta* Gorham. Although the specimen carries Gordon's lectotype label, his designation does not appear to have been published. The lectotype is not a *Hyperaspis* species, but belongs in the genus *Cyra* Mulsant (**comb. n.**). The second NHM specimen (paralectotype) fitting the female description is a true *Hyperaspis* species with four yellow spots on each elytron. The specimen has a yellow head, which means that it is probably a male, and not a female as Gorham presumed, although it has not been dissected to confirm this.

Cyra levrati (Mulsant) comb. n.

Cleothera (*Cyra*) *levrati* Mulsant 1850: 613.

Booth & Pope (1989) were able to locate a syntype of *Cleothera levrati* in Hope's collection in the Oxford University Museum, and they designated it as the lectotype. They showed that it was not the same species as that referred to by Dobzhansky (1941) or Gordon (1985). A recent re-examination of this lectotype shows that it too belongs in the genus *Cyra* (**comb. n.**).

Hyperaspis metator (Casey) stat. rev.

Brachyacantha metator Casey 1908: 413.

Examination of the female holotype (USNM Type 35153) of *H. metator* (Casey) and of a male specimen from the type locality (Del Rio, Texas) (USNM) showed them to be true *Hyperaspis*, but a different species from *H. pantherina*.

Table 2. The positions of eggs laid by four female *Hyperaspis pantherina* cultured with adult female *Orthezia insignis*.

Female no.	Number of eggs		Percentage of eggs on		
			Dorsal surface of abdomen	Ovisac	Substrate
1	311		58	35	7
2	129		47	47	6
3	102		42	44	14
4	115		59	39	2
Total	657	Means	51.5	41.3	7.3

Hyperaspis metator (Casey, 1908) (**stat. rev.**) is therefore resurrected from synonymy as a valid species. Both species share the same elytral pattern of spots, but the head shape separates them. In *H. metator*, the frons is relatively narrower, almost quadrate, and dull, with rather strong, regular, reticulate microsculpture: the frons does not curve down anteriorly toward the clypeus which therefore lies in the same plane as the frons: the anterior margin of the clypeus is only weakly concave and has a very fine marginal bead. The male genitalia are distinct, the parameres being more elongate and more pointed, and the sipho apex different in *H. metator*. Casey's type was not dissected to examine the female genitalia.

The life history of *Hyperaspis pantherina*

Observations on the life history of *H. pantherina* were made while culturing it in quarantine facilities at the International Institute of Biological Control in the UK and in St Helena. Development times, adult size, longevity and fecundity varied considerably depending on the availability of the *O. insignis* prey. To measure the duration of the life history stages of the predator, without this limitation, a cohort of 18 individuals was reared from egg to adult with plentiful daily supplies of *O. insignis*. In all other respects the rearing methods and environmental conditions were identical to those in the laboratory culturing of *H. pantherina* described in the next section. The results from rearing the cohort through to the adult stage are given in tables 3 and 4.

Adult beetles commence egg production after a pre-oviposition period of 10-14 days. The eggs are oval (0.7×0.3 mm), strongly flattened dorso-ventrally and pale yellow-green when laid. They become darker greyish green as they develop, until shortly before hatching when the dark markings on the larval thorax become visible. The larvae hatch via a characteristic longitudinal split in the dorsal surface of the egg. The oviposition sites chosen by four adult female *H. pantherina* were recorded in detail (table 2). Over 90% of their eggs were laid on adult female *O. insignis*, confirming observations from the overall culture, and, of these, nearly all were on the dorsal surfaces of either the abdomen or ovisac. Only 7.3% of the eggs were laid on the substrate including *O. insignis* exuviae and other fragments, the host-plant, and other suitable surfaces such as filter paper. Despite being presented with a surplus of apparently suitable female hosts, it was common for the female *H. pantherina* to deposit several eggs on only a few of the hosts. In extreme cases, where the supply of suitable adult female *O. insignis* was limited, eggs were laid more haphazardly, with 15 eggs being laid on one female host in one instance. However, in the complete absence of live *O. insignis*, exuviae or other remains, only one egg was laid in nearly two years of culturing. During the six day journey

Table 3. The developmental periods of the life stages of *Hyperaspis pantherina*. Data from a cohort of 18 *H. pantherina* larvae reared with a plentiful supply of *Orthezia insignis* prey.

	Eggs	1st instar larvae	2nd instar larvae	3rd instar larvae	4th instar larvae	Pupae	Egg-adult emergence
Mean duration of stage (days)	11.1	3.6	3.1	3.1	7.8	14.1	42.5
95% confidence limits	±0.73	±0.46	±0.55	±0.43	±0.55	±0.54	±1.35
Range	8-14	2-5	2-5	2-5	6-10	11-15	38-46

Table 4. The number of nymphs of *Orthezia insignis* consumed by larvae of *Hyperaspis pantherina*. Data from a cohort of 18 *H. pantherina* larvae reared with a plentiful supply of *O. insignis* nymphs of a range of instars.

	1st instar larvae	2nd instar larvae	3rd instar larvae	4th instar larvae
Mean number of prey consumed	4.8	7.0	13.4	36.3
95% confidence limits	±0.86	±1.36	±2.39	±5.22
Range	2-8	3-13	6-22	23-61

to St Helena, when female *H. pantherina* were provided only with honey agar and moist filter paper, no eggs were laid. On arrival in St Helena, one female *H. pantherina* laid an egg within 30 seconds of exposure to *O. insignis*, and several more eggs were laid by a range of females overnight.

The first instar *H. pantherina* larvae are mostly grey, with darker markings on the thoracic segments and black head and legs. Second to fourth instar larvae develop a thick, whitish grey, waxy pile that covers all except the underside of the body shortly after each moult. The larvae of other *Hyperaspis* spp. are similar in shape and also develop a waxy covering from the second instar (Nsiama She *et al.*, 1984). Larvae hatching from eggs laid singly on a healthy adult female *O. insignis* usually enter the ovisac and feed on the eggs, hatching host larvae and wax filaments. If the larvae are undisturbed the first moult normally occurs within the ovisac. The second instar larvae then continue to feed on the eggs and ultimately may consume the host itself. However, it the adult female *O. insignis* is in poor condition, or eggs were laid elsewhere, the first instar larvae behave as free-living predators, feeding on very small or young *O. insignis* nymphs. Later instars become increasingly capable of attacking all stages of prey, including adults. Increasing numbers of *O. insignis* nymphs are consumed by *H. pantherina* larvae as development proceeds (table 4). The fourth instar larva enters a prepupal stage lasting about 3 days until the waxy coat splits longitudinally revealing the olive green pupa.

Adults emerge 12-24 h after the pupal case splits, once their full colour has developed. Live adults are black with white to pale yellow markings rather than the dull yellow markings of preserved specimens. They are voracious predators on all stages of *O. insignis*. When attacking the adult female, the beetles often partially consume the ovisac without killing the prey. Throughout their lifetime, a pair of beetles could kill up to 250 *O. insignis* adults and damage the ovisacs of many more. Mating was observed throughout the adult lifetime, which in some cases was over 3 months in laboratory culture. The fecundity of *H. pantherina* females varied greatly depending on their size and on the supply of prey. Adult beetles reared from larvae with a shortage of prey were sometimes only half the normal size. One female of a normal sized breeding pair, consistently provided with a good supply of prey, survived for a further 57 days after the pre-oviposition period and produced a total of 325 eggs. Four other females that were studied closely produced maximum numbers of 9-15 eggs per female per day, with means varying from 3.1-6.4.

Laboratory culturing of *Hyperaspis pantherina*

The following methods were developed for the continued maintenance of a small laboratory population of *H. pantherina* with the occasional production of 50-100 individuals for shipment to St Helena. A major constraint was the limited supply of *O. insignis* which it was also necessary to culture in quarantine. All rearing was conducted in a greenhouse insect quarantine unit maintained at 25 ± 3°C and a relative humidity (r.h.) of 50 ± 10%. *Hyperaspis pantherina* activity was greatly reduced below 20°C and oviposition severely reduced at over 30°C. Eggs required an r.h. of about 60% to prevent desiccation, but higher humidities needed to be avoided to prevent fungal development. Larvae and adults were best maintained at slightly lower humidities, but avoiding very dry conditions. Natural daylight was supplemented with the use of high pressure lights to regulate the light regime at L:D 16:8.

Plants used for culturing *O. insignis* were themselves maintained in large ventilated Perspex cages ($45 \times 45 \times 55$ cm) with four to nine plants per cage depending on pot size. Air was pumped through each cage to reduce humidity and prevent condensation. This minimized general fungal growth and prevented fungal pathogens becoming a problem. Host-plants included *Asystasia gangetica* (Acanthaceae), *Lantana camara* (Verbenaceae) and potato plants or sprouting tubers. With the first two hosts, rearing *O. insignis* was more successful on plants with woody stems. On these more mature plants, large colonies of *O. insignis* developed rapidly on the stems, shoots and leaves. New culture plants were set up either by placing cut shoots infested with the insect onto clean plants or, less effectively, by placing clean plants in contact with a heavily infested one. In both cases, a few individuals would remain on the old material, and consequently perished, but the numbers were of no consequence if the culture was well established. A more labour intensive method was to transfer late nymphs or adults with a fine paintbrush to a new host, after first agitating them for a few seconds to ensure that they had removed their stylets from the old plant material. Further details of the biology of *O. insignis* were given by Epila (1986).

Pairs of newly emerged adult *H. pantherina*, or two males and one female, were set up in clear polystyrene dishes (12 cm diameter, 5 cm deep) which had loose fitting lids that allowed adequate air movement whilst still retaining the beetles. The base of each dish was lined with filter paper. The beetles were provided daily with a range of ages of *O. insignis* on shoots cut from the culture plants. The requirement for prey depended on the individual voracity of the beetles, and this declined particularly with increasing age. It was important to provide sufficient hosts for oviposition and feeding because adults appeared to devour their own eggs when food was scarce. A section of well infested foliage with five to ten adult *O. insignis* (for oviposition) and their progeny was usually sufficient for the daily feeding of one pair of beetles. In addition to prey, the adults were usually given small pieces of honey agar on alternate days, to provide an additional source of fluid and energy. The honey agar (1 g agar, 5 g sugar and 25 g honey in 100 ml of distilled water) remained usable for 1-2 weeks if prepared and kept under sterile conditions.

Plant and host material in each dish was renewed every 1-2 days and the old material examined under a stereo microscope. Any material with *H. pantherina* eggs was placed on moistened filter paper in small (5.5 cm diameter) vented polystyrene petri dishes, with up to about five eggs per dish. As an additional precaution against desiccation, dishes were stored within large clear polystyrene boxes. After hatching, larvae were set up singly or in small groups depending on prey availability. With abundant prey, larvae could be kept in small groups, minimizing the number of dishes needing attention. With limited prey, larvae were kept separate to avoid cannibalism. Larvae hatching from eggs laid on an adult female *O. insignis* did not require further prey as they normally entered the host's ovisac to feed on the eggs and nymphs within. In these circumstances, it was necessary to provide fresh plant material, usually a cut section of stem, to maintain the host in good condition

until the larva emerged from the ovisac. As larvae developed, increasing amounts of prey were required (table 4), and regular addition of honey agar to their petri dishes was found to be beneficial. At pupation all prey were removed and the pupae kept in empty petri dishes until adult emergence. The adults were then set up in 12 cm diameter dishes to mate and reproduce as above.

Although the above rearing procedure was labour intensive, it did allow the continued maintenance of small cultures of both predator and prey. Attempts at rearing *H. pantherina* in large cages, on whole infested plants, were unsuccessful; very few larvae matured and monitoring their development or the supply of prey was virtually impossible. On St Helena, where abundant *O. insignis* were available from the field, slightly larger culture containers with larger groups of larvae could be maintained with adequate prey supplied two to three times per week rather than daily. These latter methods were less labour intensive and also allowed the production of larger numbers of the predator for mass releases.

During culturing or shipment, the relative distension of the abdomen indicated adult condition. In healthy specimens, the terminal abdominal segments could be seen protruding behind and underneath the wing cases. In malnourished or dehydrated adults, the segments had shrunk back and, in such a condition, females were unlikely to oviposit. Following a period of short-term deprivation, oviposition resumed in about seven days after the presentation of a regular abundance of prey if the females were not too old. Long-term starvation usually prevented oviposition permanently, irrespective of later feeding regimes.

Honey agar was not only beneficial in rearing, but also proved essential in keeping the predators alive during shipment. With honey agar provided, *O. insignis* prey was not required in shipment, thus preventing any further introduction of pest material to the recipient country. Under these conditions, the survival rates (88% for third, 90% for fourth instar larvae and 100% for pupae and adults) were good. However, despite daily feeding with fresh honey agar, the survival of young *H. pantherina* larvae was poor during the six days transit to St Helena. Only 13 of the 24 second instar larvae survived, and all three first instar larvae died. The egg survival rate was 29%. Where air freight could be used to send a shipment in one to two days, survival on honey agar would be substantially better than this for the younger life stages.

The potential for further use of *H. pantherina* for the classical biological control of *O. insignis*

Hyperaspis pantherina is a classical biological control agent with an excellent record of success against *Orthezia insignis*. Now that its taxonomy, biology and culturing methods have been established, *H. pantherina* could easily be used in further control programmes in countries where *O. insignis* is an exotic pest. Contrary to recent concern over the host specificity of many coccinellid predators, *H. pantherina* appears to be specific to *Orthezia* spp. No reports have been found of *H. pantherina* attacking prey other than *Orthezia* spp. in the field, although in laboratory conditions the adult beetles did attack two mealybug species (*Planococcus* sp. and *Pseudococcus* sp.), when deprived of their normal prey. In the cultures maintained for the current programme, adult female *H. pantherina* never (except for one egg in almost two years) laid eggs without the presence of *O. insignis* prey. Indeed, it was normal for eggs to be attached to adult female *O. insignis*, and common for the first two instars of the larvae to remain in the ovisac of the adult host. Further research on the host specificity of *H. pantherina* is probably advisable before it is considered for release into countries with a native community of Coccoidea that might provide an alternative food source for at least the adult beetles. Such work was not considered necessary for St Helena where all the Coccoidea recorded are considered to have been accidentally introduced (G. Watson, pers. comm.) and most are pests of crops of indigenous vegetation (Wallace, 1960; Simmonds, 1973; Fowler, 1993).

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