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LARVAL DEVELOPMENT AND METAMORPHOSIS OF THE HAWKMOTH, *PERGESA ACTEUS* (CRAMER) IN SINGAPORE (LEPIDOPTERA: SPHINGIDAE: MACROGLOSSINAE)

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INTRODUCTION

The hawkmoth, *Pergesa acteus* (Cramer, 1779) is widely distributed throughout South and Southeast Asia, having been recorded from India, Sri Lanka, Myanmar, Nepal, Thailand, Vietnam, western and southern China, Taiwan, south Japan, Sundaland, Moluccas and the Philippines (Inoue et al., 1997; Beck & Kitching, 2008). Previously, the species was widely referred to as "*Rhyncholaba acteus*" by other authors (e.g., Barlow, 1982; Fink, 1995). In Singapore, the green larval forms of this sphingid have been occasionally encountered and reared by both authors from various localities. We trace the key developmental stages for this sphingid, with brief descriptions and illustrations of its five instars, unique pupa and eventual metamorphosis. An account of larval parasitism is also included.

Fig. 1. First instar larva of *Pergesa acteus* on its hostplant, fancy leaf caladium (*Caladium bicolor*), from Tyersall Avenue, found on the afternoon of 3 Dec.2008 at ca. 1600 hours. Its body length was 11 mm, tail horn length: 5 mm. A pair of faint, lateral false eye-spots is present on the anterior of its first abdominal segment (A1). Upon close inspection, the apex of its tail horn is noticeably bifid.

OBSERVATIONS

The earliest larval stage of *Pergesa acteus* encountered was a first instar found on fancy leaf caladium (*Caladium bicolor*; family Araceae) at Tyersall Avenue on the afternoon of 3 Dec.2008 (Fig. 1). It had an initial body length of 11 mm, with a tail horn length of 5 mm. Its body was an overall, pale whitish green, with a transition to yellow on the anterior thoracic segments. Its thoracic legs and entire head were yellow. On the anterior half of its first abdominal segment (A1), there was a pair of ocelli consisting of a white ellipse with a black base. Its tail horn was straight, glossy black, with a thickened, orange base. There were minute hairs along its entire length and the apex was clearly bifid.

In the second instar (Fig. 2, body length: 15 mm, tail horn length: 4 mm), the head and tail horn colours were retained, but the green shade of the body had darkened. In addition, the ocelli on A1 were more defined and a row of smaller, diagonal ellipses made their first, faint appearance on A2 to A7. The apex of its tail horn had lost its bifid character and was now a single, sharp point.

In the third instar (Fig. 3, body length: 23 mm, tail horn length: 6 mm), its thoracic legs were still yellow, but the head was turning green. A dark, olive-green ring encircled the ocellus on A1. Within this outline, the anterior portion was aquamarine with a black centre, the posterior half was yellowish and later became green. The lateral ocelli on A2–A7 were now distinctly white, edged with a thin, black line. On its tail horn, a broad, white band had appeared in the middle, and its apex was white.

In the fourth (penultimate) instar (Fig. 4, body length: 45 mm, tail horn length: 7 mm), the body acquired a deeper shade of jade green and the A2–A7 ocelli transformed to an attractive blue with green centres. Ventral to these ocelli, diagonal ghostly-white streaks began to appear. On the tail horn, the middle white band had disappeared, while the white portion at its apex increased. The tail horn also acquired a slight, upturned curvature.

In the fifth (final) instar (Fig. 5, body length: 70 mm, tail horn length: 2 mm), we observed a drastic reduction in the length of the tail horn, which was now a stout, curved stump. The whitish, diagonal streaks on its flanks were more obvious and its ivory white spiracles were prominent. The anterior ocelli at A1 were most captivating and convincing as false eye-spots, when viewed either from the side (Fig. 5a) or the top (Fig. 5b). Between these ocelli, a thin, blackish, mid-dorsal line ran towards the head, flanked by a sub-parallel pair of chalky white streaks.

When the final instar larvae were crawling about the hostplant, or manoeuvering their heads along the leaf margins to feed, their false eye-spots were observed to continually change in shape and size, depending on the contraction and extension movements (Fig. 6). Such a dynamic visual display may enhance the startling effect intended as a defence against potential predators.

Fig. 2. Second instar larva (as in Fig. 1) photographed and measured on 4 Dec.2008. Its body length was 15 mm, tail horn length: 4 mm. Note the initial appearance of faint, diagonal ellipses along its flanks from A2 to A7. The tip of its tail horn is no longer bifid.

Fig. 3. Third instar larva (as in Figs. 1, 2) photographed and measured on 6 Dec.2008. Its body length was 23 mm, tail horn length: 6 mm. The lateral row of ocelli is now more prominent and the tail horn colour patterns have also changed.

Fig. 4. Late fourth instar larva (from Lengkok Mariam, on fancy leaf caladium) adopting pre-moult posture and behaviour. Photographed and measured on 28 Mar.2008. Its body length was 45 mm, tail horn length: 7 mm.

When the caterpillar entered its prepupal phase, there was a significant change in colouration, as the overall green body colour was replaced by a light, cocoa brown shade (Fig. 7). The anterior ocelli on A1 acquired a dark brown eye-ring, while the lateral ocelli became carrot orange, with adjacent dark brown patches dorsally. In the next 24 hours, its body continued to contract further, accompanied by the release of fluids from within (Fig. 8).

Upon complete pupation, the pupa is coloured light and dark brown, with whitish blotches on its abdominal segments (Fig. 9). At its posterior end, the cremaster is elongate and tapered, somewhat resembling a gardening hand trowel. At its anterior, the pupa is characterised by the unique and diagnostic shape of its proboscis sheath, which is projected as a recurved circular tube, reminiscent of a French horn (Fig. 10). A similar "jug-handle" proboscis sheath is seen in many members of the subfamily Sphinginae, where the structure has evolved independently and differs in details of its formation. *Pergesa acteus* is the only macroglossine known to have evolved this type of tongue-case.

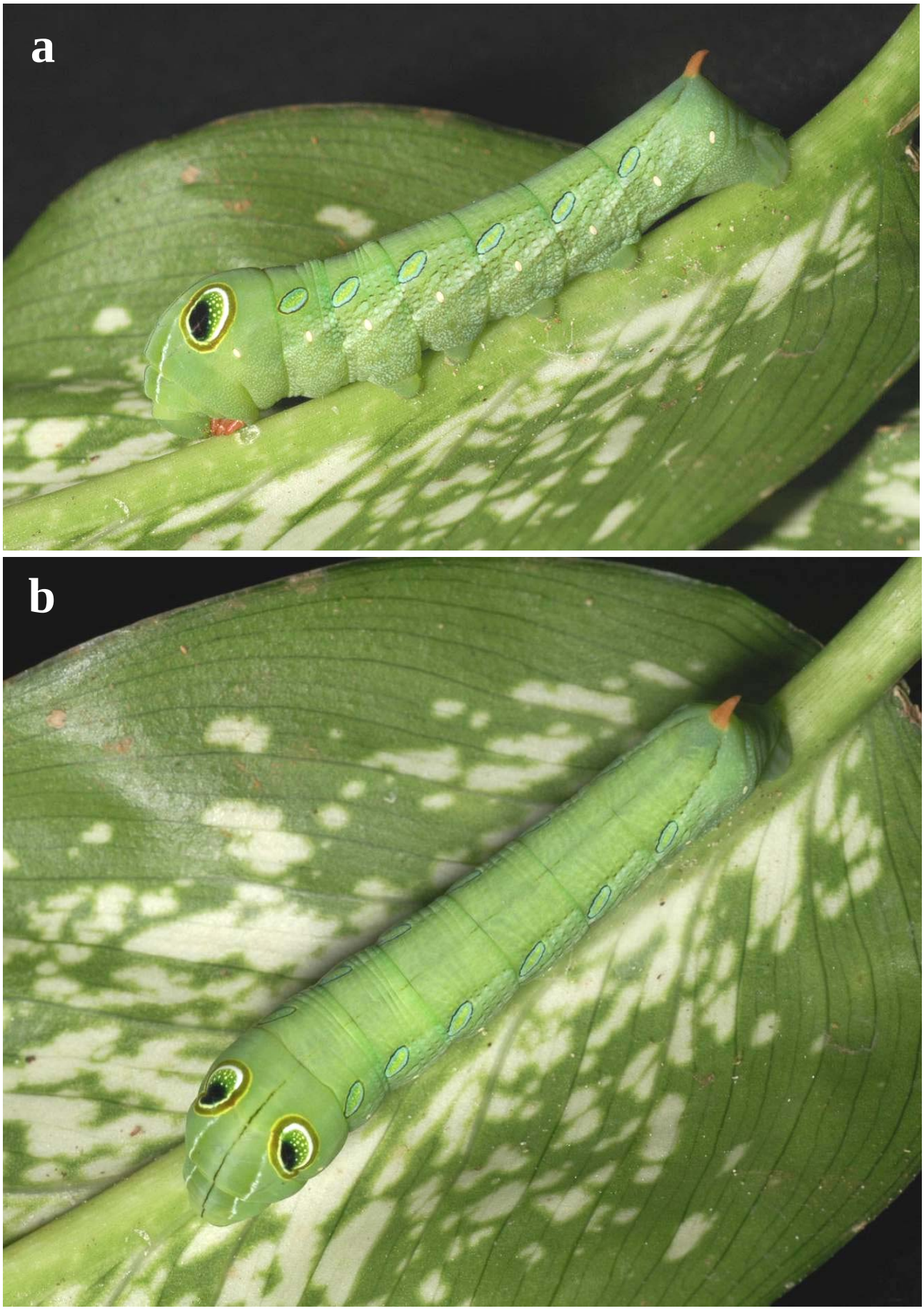

Fig. 5. Lateral (a) and dorsal (b) views of the fifth and final instar larva (from Lengkok Mariam), tentatively fed with dumb cane (*Dieffenbachia sequine*; family Araceae) when leaves of fancy leaf caladium were temporarily unavailable. It attained a maximum body length of 70 mm, with tail horn length: 2 mm. At this stage, its spiracles were most prominent, coloured ivory white.

Fig. 6. Anterior close-up of a mature final instar larva, feeding on fancy leaf caladium at Kew Drive. The relative shape and size of the false eye-spots changed continually when the caterpillar's head was extended or retracted as it was feeding and climbing around.

Fig. 7. Pre-pupal colouration of *Pergesa acteus* from Kew Drive. At this point, it had just begun to weave silken threads onto adjacent leaves to enshroud itself. Initial contractions of its body had also commenced. Photographed on the morning of 3 Dec.2008, ca. 0900 hours.

Fig. 8. Advanced pre-pupal stage (as in Fig. 7), in the gradual process of releasing fluids, accompanied with further bodily contractions. Photographed on the evening of 4 Dec.2008, ca. 1800 hours.

Fig. 9. Ventral (a) and lateral (b) views of the pupa, reared from a larva on fancy leaf caladium in Mar.2008 (as in Fig. 4). This pupa was 51 mm × 11 mm. Photographed on 13 Apr.2008.

Fig. 10. Lateral close-up of head region of pupa (as in Fig. 9) to show the shape and structure of its proboscis sheath.

With the eventual emergence of the adult moth, the beauty of the wing and body patterns may be admired (Figs. 11, 12). The colour scheme and shading (green-yellow-brown) of its forewing, in particular, confers a striking resemblance to leaves in the process of gradual desiccation, an undeniable adaptation for optimum camouflage amongst foliage. After successful eclosion, the pupal case, including the proboscis sheath, remained largely intact, with the exception of the detached apical headpiece, which served to cover the moth's eyes during development (Fig. 13).

The single larva from Tyersall Avenue that pupated on 17 Dec.2008 later emerged on 2 Jan.2009. It was preserved as a voucher specimen in the Zoological Reference Collection (ZRC) of the Raffles Museum of Biodiversity Research (BL = body length, FW = forewing length), and catalogued as ZRC.LEP.85 (male, BL: 41 mm, FW: 31 mm). An advanced larva that was found on 28 Mar.2008 at Lengkok Mariam (also feeding on fancy leaf caladium) pupated on 4 Apr.2008 and emerged on 19 Apr.2008 (ZRC.LEP.84, female, BL: 40 mm, FW: 32 mm).

Two larvae found on 25 Sep.2008 at Kew Drive (on fancy leaf caladium) pupated between 4–5 Oct.2008, with the first emerging on 21 Oct.2008 (released, sex not determined). The second pupa failed to eclose, but both pupae were preserved nevertheless (ZRC.LEP.96–97). On 30 Nov.2008, four larvae were again found at Kew Drive (on fancy leaf caladium), of which one was preserved as a final instar (ZRC.LEP.61, body length: 69 mm, preserved: 3 Dec.2008). The remaining three larvae pupated between 5–6.Dec.2008 and their pupal lengths were between 49–53 mm. On 19 Dec.2008, a male moth emerged and was released. However, the remaining two pupae never eclosed and were suspected to have been attacked by mites. Thereafter, all three pupae were preserved (ZRC.LEP.62–64).

An incidence of parasitism of a caterpillar of *Pergesa acteus* was noted on the 13 Dec.2008 in the Bukit Timah Nature Reserve. A mature, third instar larva (body length: 33 mm, tail horn length: 12 mm) was found motionless on fancy leaf caladium near the staff car park of the visitor's centre. On its left flank, a dark, exit wound could be seen in the diagonal, ellipse pattern of A6. Immediately to its right was the golden brown, silken cocoon (8 mm × 3 mm) of the emerged ichneumonid wasp (Fig. 14). This parasitic wasp cocoon was similar to those previously observed from other sphingid larval hosts in Singapore, for example, in *Enpinanga borneensis* (Butler, 1879), as reported by Leong (2008). As its chance of survival was virtually nil, this parasitised larva was preserved as a voucher specimen (ZRC.LEP.65).

Fig. 11. A newly emerged female (ZRC.LEP.84, forewing: 32 mm, body length: 40 mm), reared as larva on fancy leaf caladium from Lengkok Mariam. Pupation was complete by 4 Apr.2008. Eclosion occurred in the pre-dawn hours of 19 Apr.2008.

Fig. 12. Frontal view of female (ZRC.LEP.84), shortly after eclosion.

Fig. 13. Lateral view of empty pupal case upon successful eclosion (ZRC.LEP.84).

Fig. 14. An advanced third instar larva found fatally parasitised by an ichneumonid wasp on 13 Dec.2008 at the Bukit Timah Nature Reserve. The body length of the caterpillar was 33 mm, tail horn length: 12 mm. Note exit wound on the left side of A6, made by the emerged ichneumonid larva. The elliptical wasp cocoon (8 mm × 3 mm) was fastened onto the surface of the fancy leaf caladium leaf via a silken thread. The lifeless larva was subsequently preserved (ZRC.LEP.65).

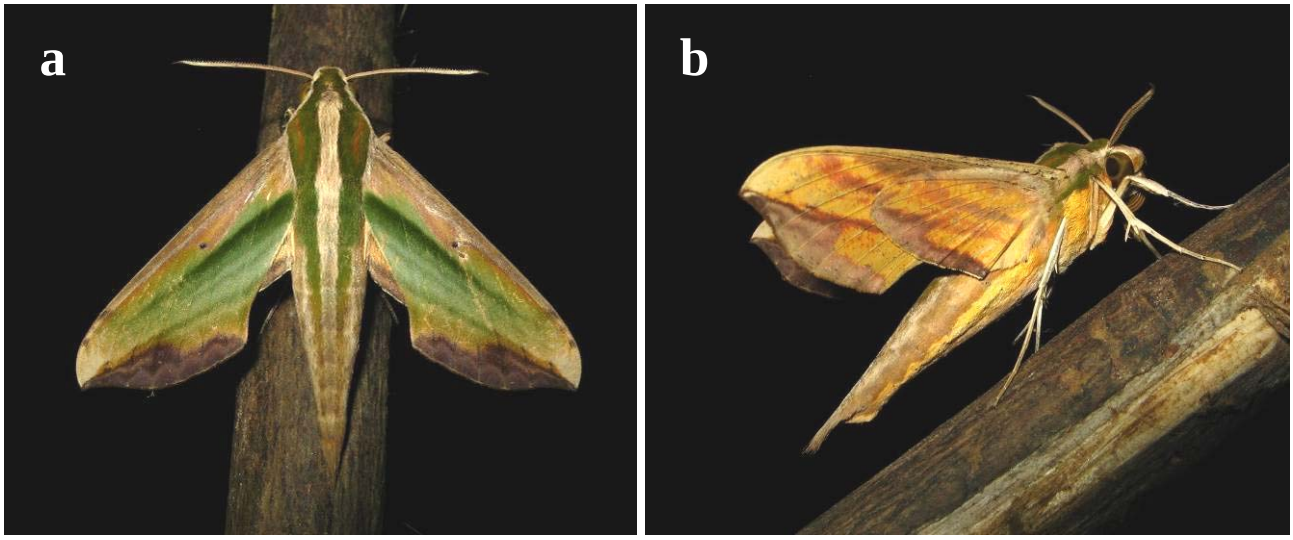

Fig. 15. Dorsal (a) and lateral (b) views of a male, encountered at Samarakan, Bintulu Division, Sarawak, East Malaysia (Borneo) on the night of 19 Apr.2007, ca. 2220 hours.

In addition to those reared by the present authors, there are further specimens of *Pergesa acteus* collected in Singapore and Malaysia by other individuals, and deposited at the ZRC. These include: ZRC.LEP.77 (male, BL: 39 mm, FW: 32 mm, collector unknown, 24 Apr.1948, Stevens Road), ZRC.LEP.78 (female, BL: 40 mm, FW: 36 mm, collector unknown, 17 Jan.1949, "Singapore"), ZRC.LEP.79 (male, BL: 43 mm, FW: 35 mm, coll. C. H. Ong, 15 Oct.1980, Bukit Timah campus), ZRC.LEP.80 (male, BL: 40 mm, FW: 31 mm, coll. Morgany d/o Thangavelu, 25 Jul.2002, Department of Biological Sciences botanical nursery, National University of Singapore, reared from larva on *Vitis javanus*, Vitaceae), ZRC.LEP.82 (female, BL: 35 mm, FW: 31 mm, coll. ?Morrell, Mar.1949, "Singapore-bred", presumably reared from larva), ZRC.LEP.83 (female, BL: 41 mm, FW: 35 mm, coll. T. M. Leong & Nasir, 17 Jun.2004, Jalan Lada Hitam, Mandai, on *Vitis*). The oldest specimen of this species in the ZRC Lepidoptera collection is ZRC.LEP.81 (male, BL: 39 mm, FW: 30 mm, coll. H. M. Pendlebury, 25 Apr.1924, Kuala Lumpur, Selangor, Peninsular Malaysia).

The first descriptions and illustrations of the caterpillar and pupa of *Pergesa acteus* date back more than half a century (Mell, 1922; Bell & Scott, 1937; Dupont & Roepke, 1941). In addition to the green larval form described in this article, there have also been records of red and brown forms of this sphingid in Singapore. On 30 Aug.2005, a final instar red larva was encountered under the leaf of a red, ornamental *Begonia* plant (Begoniaceae) by Yeo Suay Hwee in King Albert Park, displaying perfect colour camouflage. On 5 Feb.2006, a final instar brown larva was spotted in the Singapore Botanic Gardens by Teo Nam Siang (foodplant not noted). Although neither of these larvae were reared, they were photographed in-situ and subsequently featured on the "Sphingidae of the Eastern Palaearctic" website (Pittaway & Kitching, 2009).

Effects of hostplants on larval coloration may be fairly widespread among hawkmoths, with colour correlations having been documented between hostplant variation and sphingid larval morphs for at least 18 species, including *Pergesa acteus* (Fink, 1995). However, most of these reports are anecdotal, rather than experimental (Fink, 1995). Thus far, cumulative records of hostplants for *Pergesa acteus* have attained a total of 15 genera in seven families. The greatest representation is from the aroid family, Araceae, including the genera *Alocasia*, *Amorphophallus*, *Arisaema*, *Caladium*, *Colocasia*, *Dieffenbachia* and *Typhonium* (Inoue et al., 1997; Robinson et al., 2009). Beyond Singapore, TML has also encountered adult *Pergesa acteus* in Borneo, while conducting field surveys in Bintulu Division, Sarawak, East Malaysia, between Mar.–Apr.2007 (Fig. 15).

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