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DESCRIPTIONS OF TWO NEW SPECIES OF *SIMULIUM* (*SIMULIUM*) (DIPTERA: SIMULIIDAE) FROM TIOMAN ISLAND, PENINSULAR MALAYSIA

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ABSTRACT. — Two new species of black flies, *Simulium* (*Simulium*) *jasmoni* and *S.* (*S.*) *tiomanense*, are described on the basis of adult, pupal and larval specimens collected from Tioman Island, Pahang, Malaysia, and are placed in the *tuberosum* species-group in the subgenus *Simulium* (*Simulium*) Latreille. *Simulium* (*S.*) *jasmoni*, new species, is characterised by the female tarsal claw with a minute subbasal projection, an unusual characteristic within the species-group, and *S.* (*S.*) *tiomanense*, new species, is striking in having a dichoptic male head, a characteristic rarely recorded in the family Simuliidae, as well as the pupal thoracic integument with a pit-like organ near the base of each gill. Taxonomic notes are given to separate these new species from other related species.

KEY WORDS. — black fly, *Simulium*, Tioman Island, Malaysia, new species

INTRODUCTION

The fauna of black flies (Diptera: Simuliidae) in Peninsular Malaysia is represented by 39 named and 3 unnamed species, which are all classified in the genus *Simulium* Latreille and are further placed in four subgenera: one species of *Daviesellum* Takaoka & Adler, 20 species (19 named and 1 unnamed) of *Gomphostilbia* Enderlein, four species of *Nevermannia* Enderlein, and 17 species (15 named and 2 unnamed) of *Simulium* Latreille (Edwards, 1928; Crosskey, 1973; Takaoka & Davies, 1995, 1997; Takaoka & Adler, 1997; Takaoka, 2000, 2008a; Takaoka et al., 2010, 2011a, 2011b).

In a recent survey of pupae and larvae of black flies on Tioman Island, the largest (110 square kms) of 62 islands of the Tioman Archipelago, located in the southern section of the South China Sea, about 37 km east from the southeast coast of Peninsular Malaysia, one of us (D. M. Belabut) of us collected two new species belonging to the *tuberosum* species-group of the subgenus *Simulium* and another species that is assignable to the *ceylonicum* species-group of the subgenus *Gomphostilbia* Enderlein, redefined by Takaoka (2003). The two new species of the *tuberosum* species-group are described here on the basis of reared or pharate (dissected-out) adults, pupae and larvae.

The affinities of these two new species with other related species in two lineages of the *tuberosum* species-group, as well as keys to 10 Malaysian species of the *tuberosum* species-group are presented in another paper in this volume (Takaoka et al., 2012).

MATERIAL AND METHODS

The methods of collection of larvae and pupae, description and illustration, as well as terms for morphological features used here follow those of Takaoka (2003). The holotypes and paratypes are deposited at the Institute of Biological Sciences, Faculty of Science, University of Malaya, Kuala Lumpur, Malaysia.

TAXONOMY

Simulium (*Simulium*) *jasmoni*, new species
(Figs. 1A–G, 2A–H, 3A–L)

Material examined. — Holotype: male (with associated pupal exuviae and cocoon) (preserved in 80% ethanol) reared from pupa, collected from a small stream (width 0.2–0.3 m, water temperature 25.0°C, shaded), slowly flowing in a forest, near Sungai Tedau, Tioman Island, Pahang, Malaysia, coll. D. M. Belabut, 3–7 Apr.2011.

Paratypes: 1 pharate female (with associated pupal exuviae and cocoon), 1 male pupal exuviae and cocoon, and 3 mature larvae, all preserved in 80% ethanol, same data as those of holotype.

Description. — **Pharate female** (dissected out of pupa). Only following features are observed: ***Head***. Narrower than thorax. Frons shiny, bare except several stout dark hairs along each lateral margin; frontal ratio 1.30:1.00:1.06; frons-head ratio 1.00:3.37. Fronto-ocular area moderately developed, directed laterally and with pointed tip. Antenna composed of scape, pedicel and 9 flagellomeres. Clypeus moderately covered with dark stout hairs except mediolongitudinal area widely bare. Labrum 0.54 times as long as clypeus. Maxillary palp composed of 5 segments; 3rd segment (Fig. 1A) moderately enlarged; sensory vesicle (Fig. 1A) elongate, 0.61 times as long as 3rd segment, with medium-sized round opening. Maxillary lacinia with 11 or 12 inner and 18 outer teeth. Mandible with 28 inner and 10–13 outer teeth. Cibarium with numerous pointed minute processes near posterodorsal margin. ***Thorax***. Scutum shiny, moderately covered with medium to dark brown recumbent short hairs interspersed with dark brown long upright hairs on prescutellar area. Scutellum shiny, with dark brown long upright hairs. Postnotum shiny and bare. Pleural membrane bare. Katepisternum longer than deep, bare, shiny when illuminated. ***Legs***. Fore basitarsus greatly dilated, 4.29 times as long as its greatest width. Hind basitarsus nearly parallel-sided; calcipala nearly as long as width at base; pedisulcus well defined; claw (Fig. 1B) with minute subbasal projection. ***Wing***. Costa with spinules and hairs. Subcosta haired except near apex bare. Basal section of vein R bare; R_1 with spinules and hairs; R_2 with hairs only. Hair tuft on stem vein dark brown. Basal cell absent. ***Abdomen***. Ventral surface of abdominal segment 7 without pair of hair tufts. ***Genitalia***. Sternite 8 (Fig. 1C) well sclerotized and bare medially, covered with 9 or 10 long and medium-long stout hairs and few short fine hairs on each side. Ovipositor valves (Fig. 1C) nearly triangular, rounded posteromedially, membranous except inner margins weakly sclerotized, densely covered with microsetae together with

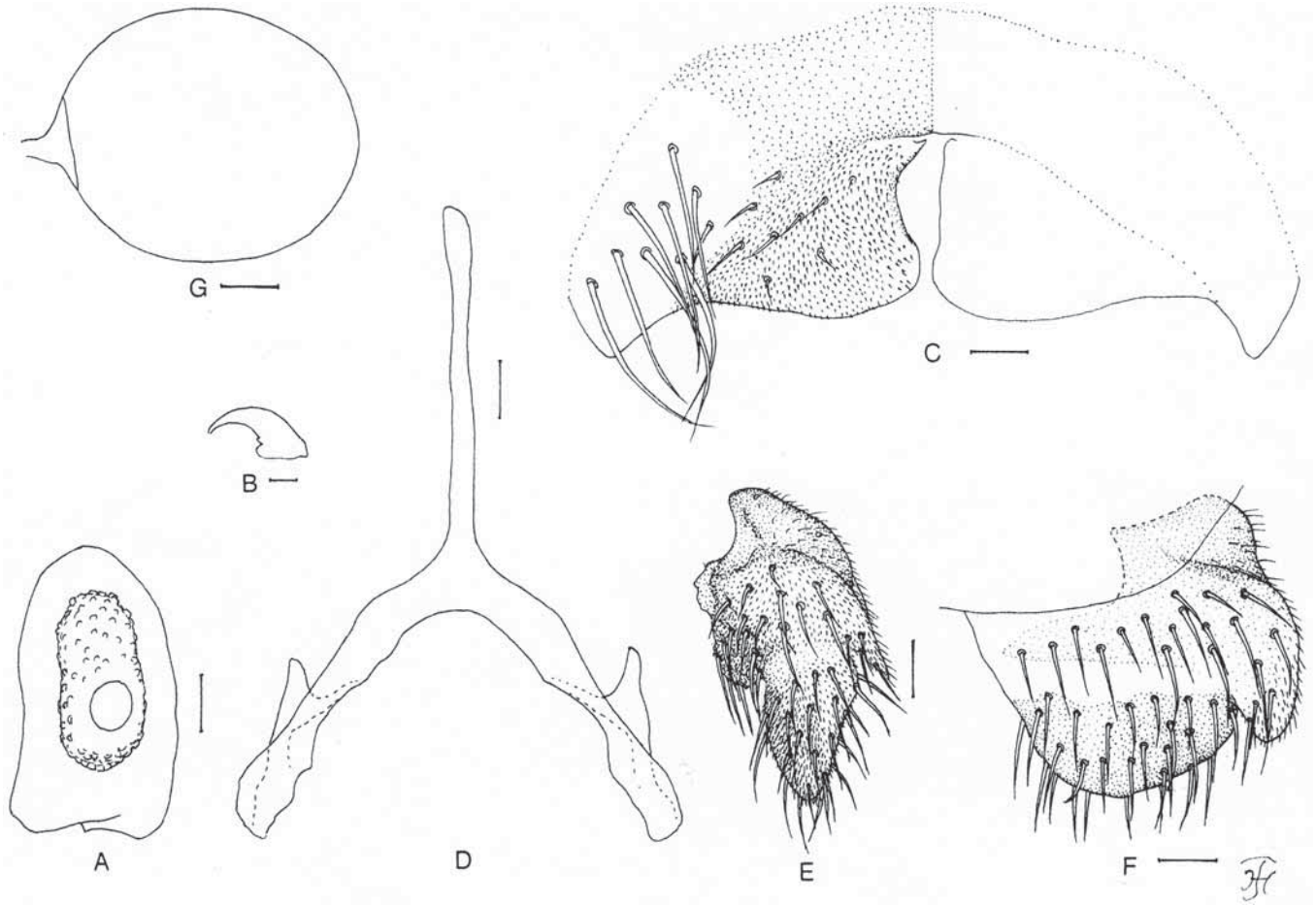

Fig. 1. Female of *Simulium* (*Simulium*) *jasmoni*, new species. A, 3rd segment of left maxillary palp showing elongate sensory vesicle (front view); B, tarsal claw with a minute subbasal projection (lateral view); C, 8th sternite and ovipositor valves (ventral view); D, genital fork (ventral view); E, F, paraprocts and cerci (right side; E, ventral view; F, lateral view); G, spermatheca. Scale bars = 0.02 mm for A, C–G; 0.01 mm for B.

6–8 short fine hairs; right inner margin widely concave but left one nearly straight. Genital fork (Fig. 1D) of inverted-Y form; stem slender and well sclerotized; arms of moderate width, each with strongly-sclerotized projection directed forwardly from lateral ridge. Paraproct in ventral view (Fig. 1E) pointed posteromedially, moderately concave anterolaterally, and with strongly sclerotized anteromedial surface; paraproct in lateral view (Fig. 1F) somewhat produced ventrally and slightly posteriorly, 0.84 times as long as wide, covered with about 20 medium-long stout hairs and numerous microsetae on lateral and ventral surfaces. Cercus in lateral view (Fig. 1F) short, rounded posteriorly, 0.49 times as long as its greatest width, and covered with numerous medium-long and short stout hairs. Spermatheca (Fig. 1G) ovoidal, 1.12 times as long as wide, well sclerotized except duct and narrow area of juncture to duct unsclerotized, without discernible reticulate surface patterns; minute internal setae present.

Male. Body length 2.0 mm. ***Head***. Somewhat wider than thorax. Upper eye medium brown, consisting of 16 vertical columns and 17 horizontal rows of large facets. Face brownish-black to black, greyish-white pruinose and shiny when illuminated at certain angle of light. Clypeus black, whitish pruinose, covered with several dark brown simple longer hairs along each lateral margin. Antenna composed of scape, pedicel and 9 flagellomeres, dark brown except base of 1st flagellomere somewhat dark yellow; 1st flagellomere elongate, 1.56 times as long as 2nd one. Maxillary palp greyish-brown, with 5 segments, proportional lengths of 3rd, 4th, and 5th segments 1.00:1.22:2.33; 3rd segment (Fig. 2A) widened apically; sensory vesicle (Fig. 2A) globular, small (0.22 times as long as 3rd segment), and with small opening. ***Thorax***. Scutum black, with distinct white markings which are shiny when illuminated at certain angle of light: i.e., large spot on each shoulder and large spot on prescutellar area, both of which approaching each other along each lateral margin but do not connect; scutum moderately covered with brassy short hairs mixed with several dark brown long upright hairs on prescutellar area. Scutellum brownish-black to black, with dark brown upright long hairs. Postnotum black and bare. Pleural membrane bare. Katepisternum longer than deep, black and bare. ***Legs***. Foreleg: coxa yellowish-white; trochanter yellow except apical portion light brown; femur medium brown; tibia dark brown to brownish-black

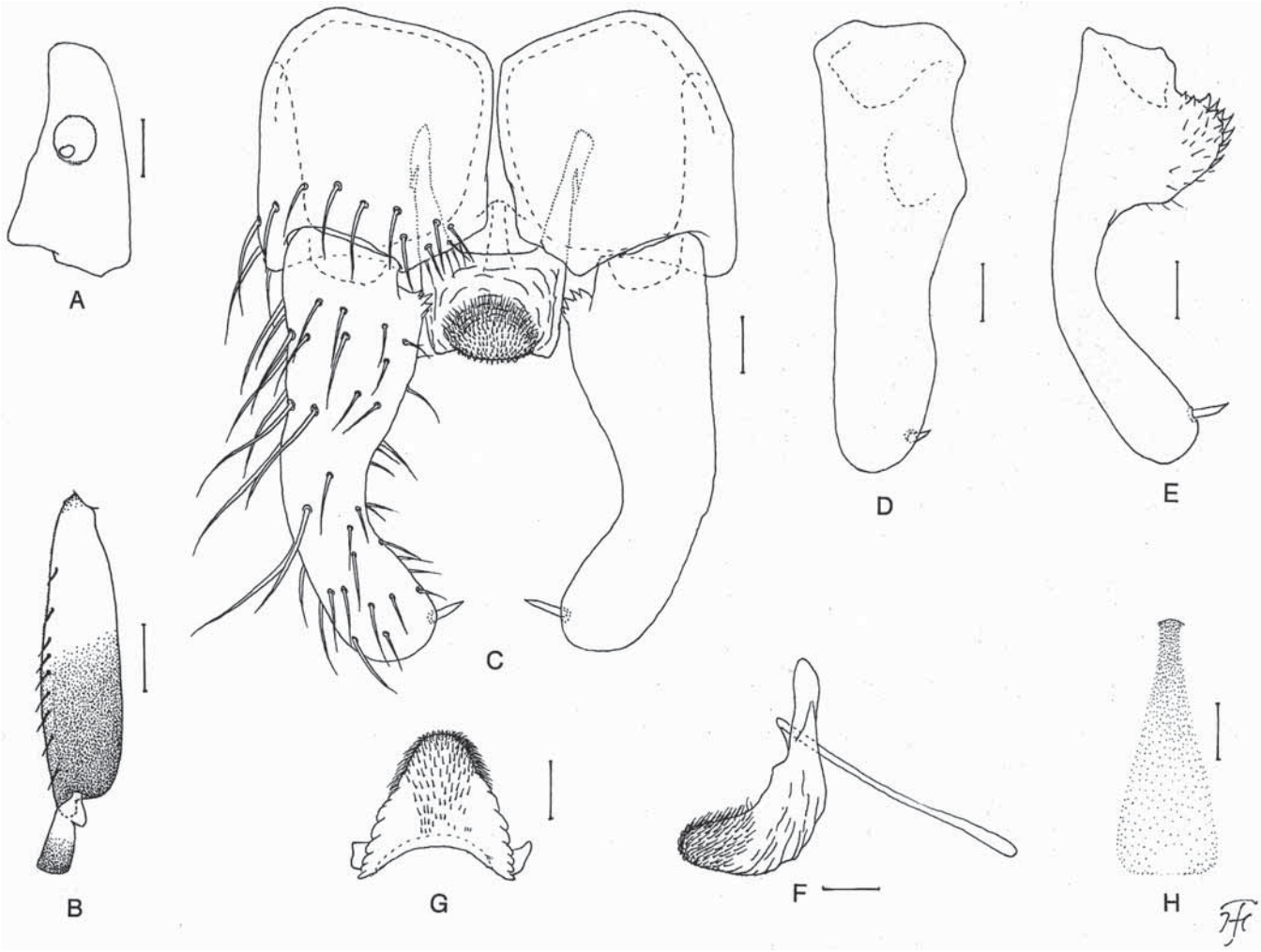

Fig. 2. Male of *Simulium* (*Simulium*) *jasmoni*, new species. A, 3rd segment of left maxillary palp showing small sensory vesicle (frontal view); B, basitarsus and 2nd tarsomere of left hind leg showing calcipala and pedisulcus (outer view); C, coxites, styles, ventral plate and median sclerite (ventral view); D, E, styles (D ventrolateral view; E, medial view); F, ventral plate and median sclerite (lateral view); G, ventral plate (end view); H, median sclerite (ventroposterior view). Scale bars = 0.1 mm for B; 0.02 mm for A, C–H.

except median large portion of outer surface white, and with median large white sheen when illuminated at certain angle of light; tarsus brownish-black to black with moderate hair crest; basitarsus moderately dilated, 6.43 times as long as its greatest width. Midleg: coxa brownish-black; trochanter medium brown except base dark yellow; femur dark brown to brownish-black; tibia brownish-black except base yellowish-white; tarsus light brown except basal 3/4 of basitarsus and basal tip of 2nd tarsomere yellowish-white. Hind leg: coxa brownish-black; trochanter yellow; femur dark brown with apical cap brownish-black and base yellow; tibia brownish-black to black except basal tip yellow; tarsus (Fig. 2B) medium brown except little less than basal 1/2 of basitarsus and little more than basal 1/2 of 2nd tarsomere yellowish-white; basitarsus (Fig. 2B) enlarged, wedge-shaped, 3.86 times as long as wide, and 0.83 and 0.73 times as wide as greatest width of tibia and femur, respectively; calcipala (Fig. 2B) nearly as long as wide, and 0.27 times as wide as greatest width of basitarsus. Pedisulcus (Fig. 2B) well defined. ***Wing***. Length 1.5 mm. Costa with dark brown spinules as well as pale hairs. Subcosta bare. Hair tuft on stem vein dark brown. Basal portion of radius bare; R_1 with dark spinules and few pale hairs; R_2 with hairs only. Basal cell absent. ***Haltere***. White except basal stem darkened. ***Abdomen***. Basal scale dark brown, with fringe of light to medium brown hairs. Dorsal surface of abdomen medium black, covered with dark brown short to long hairs; segments 2 and 5–7 each with pair of white dorsolateral or lateral patches which are brilliantly shiny when illuminated at certain angle of light; ventral surface brownish-black to black. ***Genitalia***. Coxite in ventral view (Fig. 2C) nearly quadrate, 1.15 times as long as its greatest width, and covered with stout hairs along posterior margin. Style in ventral view (Fig. 2C) 1.67 times as long as coxite, slightly divergent and moderately tapered from base toward apical 2/5, then convergent and very slightly widened to round apex, and with apical spine; style in ventrolateral view (Fig. 2D) with outer margin nearly straight and inner margin sinuous, somewhat produced outward at basal 1/3 and slightly so at apical 1/4; style in medial view (Fig. 2E) gently curved dorsally, with short basal protuberance furnished with 8–10 distinct cone-like spines. Ventral plate in ventral view (Fig. 2C) with body quadrate, though very slightly narrowed posteriorly, with anterior and posterior margins nearly straight, and basal arms of moderate length, directed forward and slightly divergent; ventral plate in lateral view (Fig. 2F) with ventrally produced hairy process; ventral plate in end view (Fig. 2G) rounded ventrally, with lateral margins weakly toothed on basal 2/3, and moderately covered with microsetae on posterior surface except lateral areas of basal 2/3 widely bare. Median sclerite (Fig. 2H) gradually widened from base to apex, plate-like, and well sclerotized basally; base of median sclerite located apart from anterior margin of ventral plate (Fig. 2C, F). Paramere wide basally, with several distinct long and stout hooks. Aedeagal membrane moderately setose; dorsal plate well defined in form of horizontal bar. Abdominal segment 10 with 3 or 4 hairs on each posterolateral surface. Cercus small, rounded, with 8 or 9 hairs.

Pupa. Body length 2.2 mm. ***Head***. Integument ochreous to yellowish-brown, moderately or sparsely covered with small round tubercles on frons (Fig. 3A) but almost bare on ventral surface and sparsely covered with smaller tubercles on both lateral surfaces; antennal sheath without tubercles; frons with 2 pairs of simple medium-long trichomes with uncoiled apices (Fig. 3B) (on left side of 1 pupal exuviae, 2 frontal trichomes are short and 1 of them bifid — Fig. 3C); face with pair of simple medium-long trichomes with uncoiled apices (Fig. 3D), nearly as long as or longer than frontal trichomes. ***Thorax***. Integument ochreous to yellowish-brown, moderately covered with round tubercles on anterior 2/5 of dorsal and dorsolateral surfaces but rather sparsely covered with smaller round and cone-shaped tubercles on posterior 3/5 of dorsal surface, with 1 simple medium-long trichome with uncoiled apex anterodorsally (Fig. 3E), 1 similar trichome mediodorsally, 2 simple trichomes with uncoiled apices (1 medium-long and 1 short) anterolaterally (Fig. 3F), 1 simple or bifid short trichome with uncoiled apex posterolaterally (Fig. 3G), and 3 simple trichomes with uncoiled apices (2 medium-long and 1 short; or 1 medium-long and 2 short) ventrolaterally (Fig. 3H) on each side. Gill (Fig. 3I) composed of 6 slender thread-like filaments, arranged in 2+2+2 filaments from dorsal to ventral, with very short common basal stalk having transparent organ ventrally; common basal stalk hidden below produced cuticle of thoracic integument when gill is viewed dorsally; all pairs with very short or short stalk; dorsal and ventral filaments lying at angle of 90 degrees or little more when their basal portions are viewed laterally; all filaments ochreous or light brown, gradually tapered toward apex, subequal in length (0.8–1.0 mm long including their own stalks and basal common stalk) but differing in relative thickness, i.e., relative thickness of 6 filaments from dorsal to ventral 1.00:0.82:0.97:0.80:0.89:0.69; cuticle of all filaments with annular ridges and furrows though becoming less marked apically, and densely covered with minute tubercles. ***Abdomen***. Dorsally, segments 1 and 2 not pigmented and without tubercles; segment 1 with 1 simple slender short hair-like seta on each side; segment 2 with 1 simple slender short hair-like seta and 5 very short somewhat spinous setae submedially on each side; segments 3 and 4 each with 4 hooked spines and 1 very short somewhat spinous seta on each side; segments 5 and 6 lacking spine-combs; segments 7–9 each with spine-combs in transverse row (though those on segments 7 and 9 slightly smaller than those on segment 8) and comb-like groups of minute spines on each side; segment 9 with pair of small round terminal hooks (Fig. 3J). Ventrally, segment 4 with 1 simple hook and few simple slender very short setae on each side; segment 5 with pair of bifid hooks submedially and few very short simple slender setae on each side; segments 6 and 7 each with pair of bifid inner and simple outer hooks somewhat spaced from each other and few very short simple slender setae on each side; segments 4–8 with comb-like groups of minute spines. Each side of segment 9 without grapnel-shaped hooklets. ***Cocoon***. Wall-pocket-shaped, thinly woven, not extended ventrolaterally; anterior margin somewhat thickly woven, posterior 1/2 with floor roughly or moderately woven; individual threads slightly visible; 2.2–2.9 mm long by 1.0–1.2 mm wide.

Mature larva. Body length 3.9–4.2 mm. Thorax and abdomen blackish-brown except each intersegmental area from thoracic segment 3 to abdominal segment 5 whitish in dorsal view, and whitish in ventral view except blackish-brown transverse band connected to that on dorsal surface of thoracic segment 1, large blackish spot on each of thoracic segments 2 and 3, blackish-brown transverse band connected to that on dorsal surface on each of abdominal segments 1–4, blackish-brown transverse band on each of abdominal segments 6 and 7and light blackish-brown mediolongitudinal line from abdominal segment 1 to abdominal segment 6. Cephalic apotome whitish-yellow to yellowish-brown, with medial area along posterior margin somewhat darkened; head spots faintly positive except posterolateral spots often indistinct and anterior or posterior spot of mediolongitudinal spots sometimes indistinct. Lateral surface of head capsule

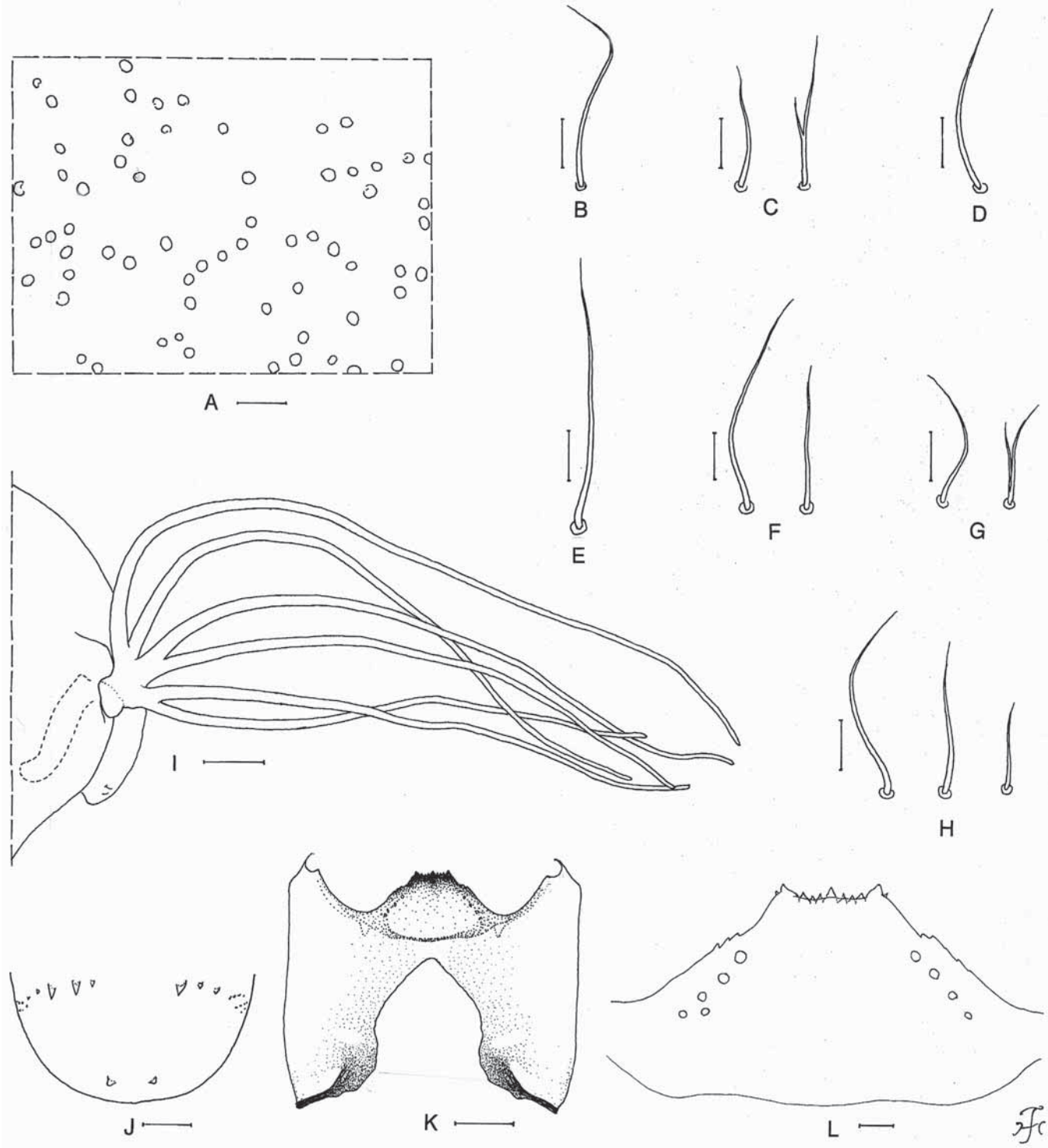

Fig. 3. Pupa and larva of *Simulium* (*Simulium*) *jasmoni*, new species. A–J pupa; K, L larva. A, tubercles on frons; B, and C, frontal trichomes (B, simple medium-long; C, simple short and bifid short); D, facial trichome; E–H, thoracic trichomes (E, anterodorsal; F, anterolateral; G, posterolateral (simple and bifid); H, ventrolateral); I, right gill filaments (outer view); J, spine-combs, groups of minute spines and terminal hooks on 9th abdominal segment (dorsal view); K, head capsule showing mitre-shaped postgenal cleft (ventral view); L, hypostoma (ventral view). Scale bars = 0.1 mm for I, K; 0.04 mm for J; 0.02 mm for A–H, L.

yellow or somewhat dark yellow except eye-spot region whitish; eyebrow distinctly defined; spots below and posterior to eye-spot region indistinct. Ventral surface of head capsule (Fig. 3K) medium to dark yellow except wide area along each lateral margin of postgenal cleft yellowish-brown to light brown; transverse spot on each side of postgenal cleft indistinct or negative; basal area on each side of postgenal cleft dark brown as usual. Cervical sclerite composed of 4 slender pieces (anterior piece dark brown and long, posterior one light brown and short, on each side), not fused to occiput, moderately separated medially from each other. Antenna composed of 3 segments and apical sensillum, much longer than stem of labral fan; proportional lengths of 1st, 2nd, and 3rd segments 1.00:1.10–1.19:0.78–0.87. Labral fan with 40–42 main rays. Mandible with mandibular serrations composed of 2 teeth; major and longer tooth at obtuse angle to mandible on apical side; comb-teeth decreasing in length from 1st tooth to 3rd one. Hypostoma (Fig. 3L) with 9 anterior teeth (though 1 tiny tooth is present on outer side of corner tooth on each side in 1 larva, as shown in Fig. 3L); median tooth and each corner tooth prominent, nearly subequal in length to each other, followed by outer and inner teeth of 3 intermediate teeth, and middle tooth of 3 intermediate teeth shortest of all; lateral margins moderately serrate subapically; 4–6 hypostomal bristles divergent posteriorly from lateral border on each side. Postgenal cleft (Fig. 3K) arrow-head shaped, deep (5.80–6.25 times as long as postgenal bridge), relatively wide (greatest width in middle 0.91 times as long as postgenal cleft and 0.36–0.40 times as wide as head capsule), very slightly widened from base to middle, with somewhat pointed or rounded apex. Thoracic cuticle almost bare. Abdominal cuticle almost bare except each side of anal sclerite and each lateral bulge moderately covered with short colorless setae. Rectal scales appearing to be absent. Rectal organ compound, each lobe with 7 or 8 finger-like secondary lobules. Anal sclerite X-shaped, with broadened anterior arms 0.7 times as long as posterior ones, with wide thinly-sclerotized extension between anterior arms; basal juncture area without unscleotized median incision opening posteriorly; 4–8 sensilla posterior to posterior arms. Last abdominal segment on each side with large bulge laterally and small one ventrolaterally, appearing to be small ventral papillae when viewed laterally. Posterior circlet with 70–82 rows of hooklets with up to 16 hooklets per row.

Biological notes. — The pupae and larvae of this new species were collected from stalks and leaves of grasses trailing in the water. Associated species were *S.* (*S.*) *tiomanense*, new species, and *S.* (*G.*) sp.

Etymology. — The species name *jasmoni* is in honour of Tan Sri Prof. Dr. Ghauth Jasmon, Vice Chancellor, University of Malaya, who kindly invited HT to University of Malaya for studies of black flies in Malaysia.

Remarks. — *Simulium* (*S.*) *jasmoni*, new species, is characterised by the female tarsal claw with a minute subbasal projection (Fig. 1B), which departs from the original definition (i.e., the tarsal claw is simple) of the *tuberosum* species-group of the subgenus *Simulium* by Rubtsov (1956). However, this new species is assigned to the *tuberosum* species-group because it agrees with the diagnostic characteristics such as the bare basal portion of the radial vein in both female and male, the unpatterned scutum in the female, the scutum with shiny pruinose pattern, the style with a short basal protuberance bearing spines, and the ventral plate quadrate when viewed ventrally and with toothed posterolateral margins in the male, and the gill with six slender filaments and the simple cocoon in the pupa, as defined by Rubtsov (1956).

This new species is very similar in the adults to *S.* (*S.*) *tani* originally described from Peninsular Malaysia (Takaoka & Davies, 1995), recorded from Thailand (Takaoka & Saito, 1996), Sumatra (Takaoka et al., 2000), China and Vietnam (Adler & Crosskey, 2011), and *S.* (*S.*) *rangjungense* Takaoka & Somboon, 2008 described from Bhutan (Takaoka & Somboon, 2008) in many morphological characteristics including the elongate female sensory vesicle (Fig. 1A), the female tarsal claws each with a minute subbasal projection (Fig. 1B), and the numbers of the vertical columns (16) and horizontal rows (17) of enlarged male upper-eye facets, but differs in the pupa from the latter two known species by having the medium-long mediodorsal trichome on the thoracic integument (similar to anterodorsal trichome — Fig. 3E) and the gill filaments divergent at an angle of 90 degrees or slightly more (Fig. 3I) (the mediodorsal trichomes in *S.* (*S.*) *tani* and *S.* (*S.*) *rangjungense* are short and very short, respectively, and the gill filaments are moderately divergent at an angle of 45–60 degrees in both known species).

The female of this new species is also similar to that of *S.* (*S.*) *keningauense* from Sarawak and Sabah (Takaoka, 2008b) in sharing the tarsal claw with a minute subbasal projection but is distinguished from the latter species by the elongate sensory vesicle (the sensory vesicle is 0.42–0.48 times as long as the third maxillary palpal segment in *S.* (*S.*) *keningauense*). The pupa of *S.* (*S.*) *jasmoni*, new species, is easily distinguished from that of *S.* (*S.*) *keningauense* by the round tubercles on the thoracic integument (most tubercles are cone-shaped and with pointed apices in *S.* (*S.*) *keningauense*).

Simulium (*Simulium*) *tiomanense*, new species

(Figs. 4A–L, 5A–P)

Material examined. — Holotype: pharate male (with associated pupal exuviae and cocoon) (preserved in 80% ethanol), collected from a small stream (Sungai Tedau, width 0.5–2.0 m, water temperature 25.0°C, shaded) moderately flowing in a forest, Tioman Island, Malaysia, coll. D.M. Belabut, 3–7 Apr.2011.

Paratypes: 1 mature larva and 1 immature larva (preserved in 80% ethanol), same data as those of holotype.

Description. — **Pharate male** (dissected out of pupa). Body length 2.4 mm. Nearly as in male of *S.* (*S.*) *jasmoni*, new species, except following characteristics. ***Head***. Dichoptic. Frons (Fig. 4A) present, though very narrow, and covered with dark short hairs. Upper eye consisting of 16 vertical columns and 16 or 17 horizontal rows of large facets, which are slightly

separated from one another leaving distinct interspaces (usually closely spaced, leaving no interspaces) and nearly round (usually hexagonal) (Fig. 4B). Antenna composed of scape, pedicel and 9 flagellomeres, dark brown except scape and pedicel dark yellow; 1st flagellomere elongate, 1.8 times as long as 2nd one. Proportional lengths of 3rd, 4th, and 5th segments of maxillary palp 1.00:1.10:2.43; 3rd segment (Fig. 4C, D) with widened apical portion; sensory vesicle (Fig. 4C, D) ellipsoidal, 0.24 times as long as 3rd segment and with medium-sized or large opening. ***Legs***. Foreleg: coxa yellow; trochanter light brown; femur light brown except apical cap dark brown; tibia dark brown (though median portion of inner surface light brown) except median large portion of outer surface white and with white sheen when illuminated at certain angle of light; tarsus brownish-black to black with relatively thick hair crest; basitarsus greatly dilated, 4.27 times as long as its greatest width. Midleg: coxa brownish-black; trochanter light brown; femur light brown except apical cap dark brown; tibia medium to dark brown except posterior surface of basal 1/3 narrowly white and with white sheen when illuminated at certain angle of light; tarsus light brown except basal 3/4 of basitarsus and basal 1/2 of 2nd tarsomere yellowish-white. Hind leg: coxa dark brown; trochanter light brown; femur light brown with apical cap dark brown and base yellow; tibia medium to dark brown except posterior surface of basal 1/4 white, and with white sheen when illuminated at certain angle of light; tarsus (Fig. 4E) medium to dark brown except little more than basal 1/2 of basitarsus yellowish-white and 2/3 of 2nd tarsomere yellowish-white; basitarsus (Fig. 4E) enlarged, possibly wedge-shaped; calcipala (Fig. 4E) nearly as long as wide. Pedisulcus (Fig. 4E) well developed. ***Abdomen***. Segments 2, 6, and 7 each with pair of white dorsolateral patches which are brilliantly shiny when illuminated at certain angle of light. ***Genitalia***. Coxite in ventral view (Fig. 4F) nearly quadrate, nearly as long as wide. Style in ventral view (Fig. 4F) gently bent inward, widened from base toward basal 1/3, then gradually tapered to apex and with subapical spine; style in ventrolateral view (Fig. 4G) widened from base to basal 1/3, then gradually tapered to apex, with subapical spine, and 2.21 times as long as its greatest width at basal 1/3; style in medial view (Fig. 4H) 1.55 times as long as coxite, with short basal protuberance bearing about 16 stout cone-like spines, gradually tapered to little more than apical 1/3, then nearly parallel-sided to apex, and with subapical spine. Ventral plate in ventral view (Fig. 4I) with body quadrate, though very slightly widened posteriorly, 0.55 times as long as wide, with anterior margin very slightly produced and posterior margins nearly straight, and basal arms of moderate length, directed forward and moderately divergent; ventral plate in lateral view (Fig. 4J) with ventrally produced hairy process; ventral plate in end view (Fig. 4K) rounded ventrally, with lateral margins weakly toothed on basal 1/2, and moderately covered with microsetae on posterior surface except lateral areas of basal 1/2 widely bare. Median sclerite (Fig. 4L) gradually widened from base to middle, then nearly parallel-sided to near apex, plate-like, and well sclerotized basally; base of median sclerite located apart from anterior margin of ventral plate (Fig. 4J). Abdominal segment 10 with 5 or 6 fine short hairs on each posterolateral surface. Cercus small, rounded, with 7 or 8 fine short hairs.

Pupa. Body length 2.5 mm. ***Head***. Integument yellowish-brown, moderately covered with round relatively large tubercles (Fig. 5A) on frons and on upper part of lateral surfaces; antennal sheath with low protuberances and sparsely or moderately covered with round smaller tubercles; frons with 2 pairs of trichomes with uncoiled apices (1 simple and medium-long, 1 simple or bifid and short) (Fig. 5B, C); face with pair of simple medium-long trichomes with uncoiled apices (Fig. 5D). ***Thorax***. Integument yellow to yellowish-brown, moderately covered with round relatively large tubercles, with small pit-like organ near base of gill on each side (Fig. 5E), and with 1 simple short trichome with uncoiled apex anterodorsally (Fig. 5F), 1 simple short trichome with uncoiled apex (Fig. 5G) mediodorsally, 2 simple trichomes with uncoiled apices (1 medium-long and 1 short) anterolaterally (Fig. 5H), and 2 simple short trichomes with uncoiled apices ventrolaterally (Fig. 5I) on each side; mediolateral trichome and 1 of 3 ventrolateral trichomes lost on each side. Gill (Fig. 5J) composed of 6 slender thread-like filaments, arranged in 2+1+1+2 filaments from dorsal to ventral, with no common basal stalk; dorsal paired filaments with very short stalk, ventral pair with very short stalk or almost sessile, and 2 filaments in middle unpaired and each arising individually though lying side by side very closely at base; all filaments light brown except uppermost filament dark brown; uppermost filament thick basally, then gradually tapered toward apex, other filaments nearly same in thickness for most of their lengths though slightly tapered near apex; relative thickness of 6 filaments from dorsal to ventral when basal portions are compared 1.00:0.60:0.45 (outer middle filament):0.56 (inner middle filament):0.45 (outer ventral filament):0.50 (inner ventral filament); relative length of 6 filaments not available due to loss of apical portions of all filaments; all filaments with well-defined annular ridges and furrows though becoming less marked apically, densely covered with minute tubercles. ***Abdomen***. Nearly as in *S.* (*S.*) *jasmoni*, new species, except following characteristics: segments 7–9 each with spine-combs in transverse row (though those on segments 7 and 9 much smaller than those on segment 8) (Fig. 5K–M); segment 9 without terminal hooks. Ventrally, segment 5 with pair of simple or bifid hooks submedially and few very short simple slender setae on each side; segments 6 and 7 each with pair of simple or bifid inner and simple outer hooks somewhat spaced from each other and few very short simple slender setae on each side. ***Cocoon***. Wall-pocket shaped, tightly woven, not extended ventrolaterally; anterior margin thickly woven; posterior 1/2 with floor roughly or moderately woven; individual threads invisible; 2.8 mm long by 2.1 mm wide.

Mature larva. Body length 5.1 mm. Body almost uniformly dark gray to greyish-brown when viewed dorsally. Cephalic apotome yellowish-white on anterior 1/2 and light to medium brown on posterior 1/2, with medial area along posterior margin dark brown; anterior spot of 2 mediolongitudinal spots medium brown, well defined on yellowish-white

background, posterior spot of 2 mediolongitudinal spots medium brown, not well defined, merged into medium brown background, lateral spots dark brown on anterior 1/2 and medium brown on posterior 1/2, and thus anterior part appearing positive and posterior part negative on medium to dark brown background, posterolateral spots light brown, appearing negative on medium brown background. Lateral surface of head capsule medium brown except eye-spot region whitish on dorsal 1/2 and yellowish except areas along ventral and posterior margins medium brown; eyebrow distinctly defined; spots below and posterior to eye-spot region indistinct. Ventral surface of head capsule (Fig. 5N) yellow except wide area along each lateral margin of postgenal cleft and near posterior margin medium brown; transverse spot on each side of postgenal cleft indistinct or faintly negative; basal area on each side of postgenal cleft dark brown as usual. Cervical sclerite composed of pair of yellow small oblong pieces, not fused to occiput, moderately separated medially from each other. Antenna composed of 3 segments and apical sensillum, much longer than stem of labral fan; proportional lengths of 1st, 2nd, and 3rd segments 1.00:1.05:0.64. Labral fan with 40 main rays. Mandible with mandibular serration composed of 2 teeth; major and longer tooth at obtuse angle to mandible on apical side; comb-teeth

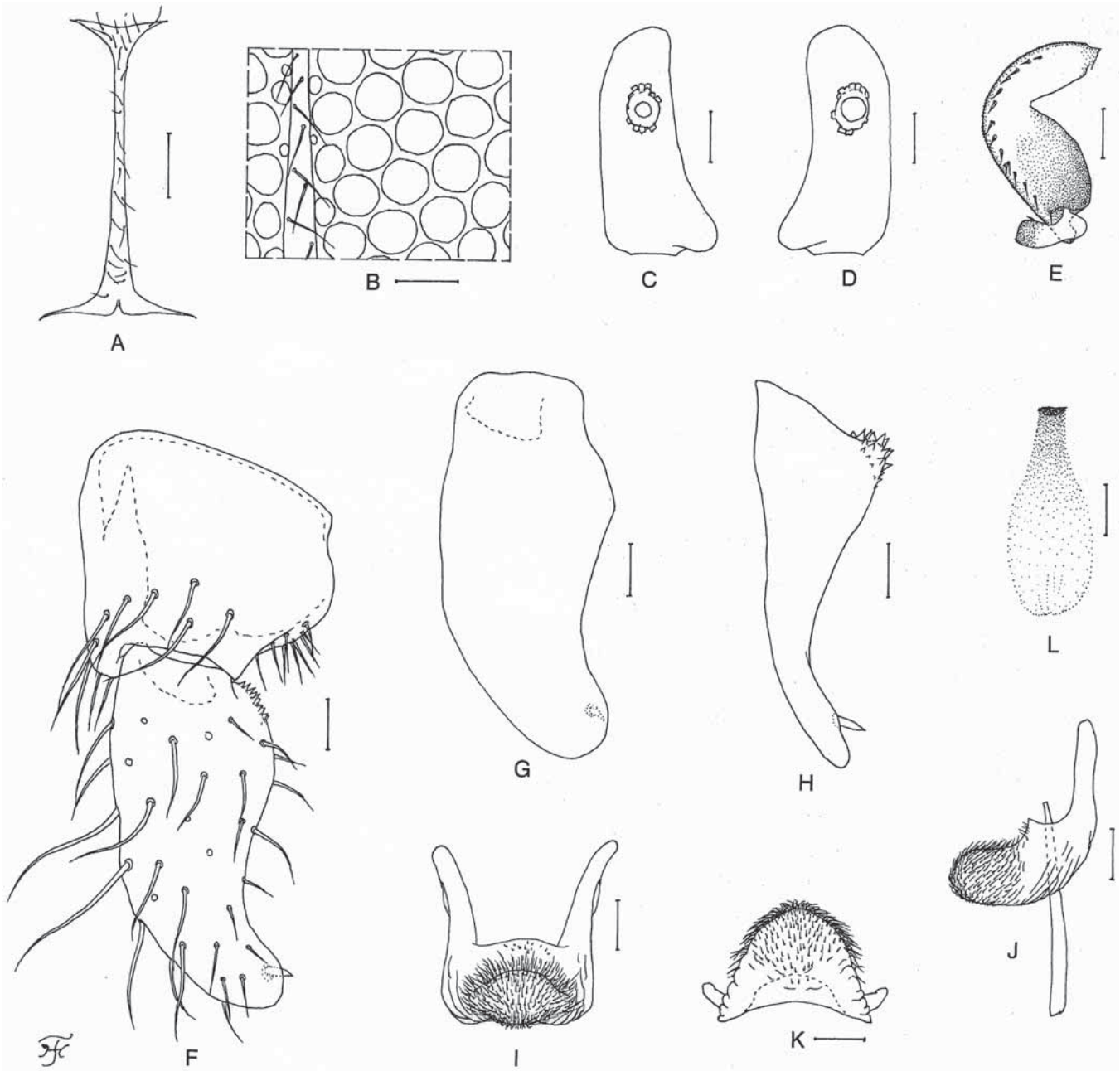

Fig. 4. Male of *Simulium* (*Simulium*) *tiomanense*, new species. A, frons; B, enlarged facets near frons; C, 3rd segment of right maxillary palp with sensory vesicle having opening of moderate size (front view); D, 3rd segment of left maxillary palp with sensory vesicle having large opening (front view); E, basitarsus and 2nd tarsomere of left hind leg (outer view); F, coxa and style (ventral view); G, style (ventrolateral view); H, style showing basal protuberance covered with many spines (medial view); I, ventral plate (ventral view); J, ventral plate and median sclerite (lateral view); K, ventral plate (end view); L, median sclerite (dorsal view). Scale bars = 0.1mm for A, E; 0.05 mm for B; 0.02 mm for C, D, F–L.

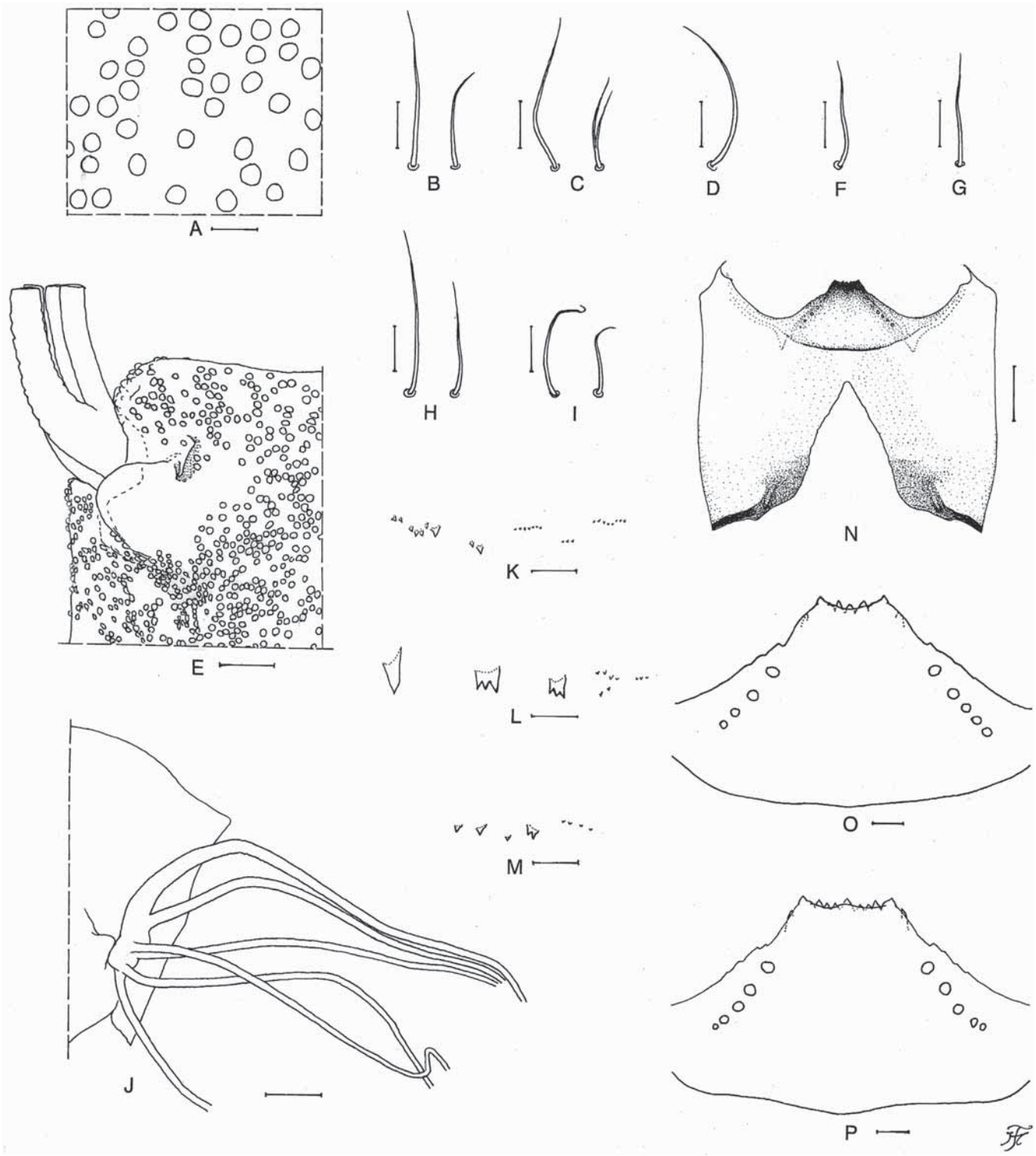

Fig. 5. Pupa and larva of *Simulium* (*Simulium*) *tiomanense*, new species. A–M, pupa; N–P, larva. A relatively large tubercles on frons, which are round and lack secondary projections on their surfaces; B, left frontal trichomes; C, right frontal trichomes; D, facial trichome; E, anterior part of left thoracic integument showing pit-like organ adjacent to the base of gill; F–I, thoracic trichomes (F, anterodorsal; G, mediodorsal; H, anterolateral; I, ventrolateral); J, right gill filaments (apical portions of all filaments lost) (lateral view); K–M, spine-combs and groups of minute spines on dorsal surface of abdomen (K, 7th segment; L, 8th segment; M, 9th segment); N, head capsule showing triangular postgenal cleft (ventral view); O, hypostoma with fewer anterior teeth (ventral view); P, hypostoma with normal 9 anterior teeth (ventral view). Scale bars = 0.1 mm for J, N; 0.05 mm for E; 0.02 mm for A–D, F–I, K–M, O, P.

decreasing in length from 1st tooth to 3rd one though 2nd tooth very slightly longer than 3rd one; supernumerary serrations absent. Hypostoma (Fig. 5O) with 5 anterior teeth consisting of 1 median tooth, 2 submedian teeth and 2 corner teeth (the reduced number of anterior teeth in this unique mature larva might be abnormal, because an immature larva of the same species has a hypostoma with 9 anterior teeth — Fig. 5P); each corner tooth prominent and median tooth shortest; lateral margins weakly serrate apically; 4 or 5 hypostomal bristles divergent posteriorly from lateral border on each side. Postgenal cleft (Fig. 5N) narrow, triangular, deep (4.37 times as long as postgenal bridge), with pointed apex. Thoracic cuticle almost bare. Abdominal cuticle almost bare except each side of anal sclerite and each lateral bulge moderately covered with short colourless setae. Rectal scales present. Rectal organ not observable because it was withdrawn. Anal sclerite X-shaped, with broadened anterior arms 0.71 times as long as posterior ones, with wide thinly-sclerotized extension between anterior arms; basal juncture area with very narrow median incision opening posteriorly; 9 sensilla posterior to posterior arms. Last abdominal segment on each side with moderately developed bulge laterally and small one ventrolaterally, appearing to be small ventral papillae when viewed ventrolaterally. Posterior circlet with 84 rows of hooklets with up to 14 hooklets per row.

Female. Unknown.

Biological notes. — The pupa and larvae of this new species were collected from stalks of grasses trailing in the water. Associated species were *S.* (*S.*) *jasmoni*, new species and *S.* (*G.*) sp.

Etymology. — The species name *tiomanense* refers to the name of the island, Tioman, where this new species was collected.

Remarks. — *Simulium* (*S.*) *tiomanense*, new species, is assigned to the *tuberosum* species-group of the subgenus *Simulium* on the basis of the male genitalia (Fig. 4F–L) and the pupal gill with 6 filaments (Fig. 5J).

The male of this new species is striking in having the dichoptic head (in place of the usual holoptic head), which is divided by a very narrow frons (Fig. 4A), as well as the round enlarged facets (in place of the usual hexagonal facets), these characteristics being very rarely recorded in the family Simuliidae. However, future studies are needed to confirm whether these rare head characteristics seen in the holotype male are also commonly found in other male specimens of *S.* (*S.*) *tiomanense*, new species.

This new species is also remarkable in having the pit-like organ adjacent to the base of the pupal gill (Fig. 5E). The pit-like organ is a diagnostic characteristic of the *clathrinum* species-group, one of the six species-groups of the subgenus *Simulium* (*Morops*) Enderlein in the Australasian Region (Takaoka, 2003). This has been also reported in four species of the *tuberosum* species-group of the subgenus *Simulium*: *S.* (*S.*) *brevipar* from Peninsular Malaysia (Takaoka & Davies, 1995), Sumatra (Takaoka et al., 2000) and southern Thailand (Takaoka et al., 2009), *S.* (*S.*) *sigiti* Takaoka & Hadi, 1991 from Java (Takaoka & Hadi, 1991), *S.* (*S.*) *tianchi* Chen, Zhang & Yang, 2003 from Hainan, China (Chen et al., 2003), and *S.* (*S.*) *yuphae* Takaoka & Choochote, 2005 from northern Thailand (Takaoka & Choochote, 2005). This new species is easily distinguished from all these four known species by the small pit-like organ (Fig. 5E) and the relatively large tubercles without secondary projections on the frons and thorax (Fig. 5A) (the pit-like organs are medium-sized and prominent, and the relatively large tubercles bear secondary minute projections in all the four known species) and also from *S.* (*S.*) *sigiti* and *S.* (*S.*) *tianchi* by the different relative thickness of the six gill filaments (Fig. 5J) (all six gill filaments are equal in thickness to one another in the latter two known species).

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