



RESEARCH ARTICLE

## Two new black fly species of the *Simulium* (*Simulium*) *rufibasis* subgroup (Diptera: Simuliidae) from Taiwan

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### ABSTRACT

*Simulium* (*Simulium*) *rufibasis* Brunetti originally described from India was once considered a geographic generalist widely distributed in the Oriental Region. In this study, the species previously regarded as *S. (S.) rufibasis* in Taiwan was morphologically re-evaluated and found to be distinguished in the male and pupa from true *S. (S.) rufibasis* from India. This new species is described as *S. (S.) hehuanense* sp. nov. based on a female, a male and their pupal exuviae in Taiwan. This new species is placed in the *S. rufibasis* subgroup of the *S. tuberosum* species-group, and is similar to *S. (S.) yamatoense* Takaoka, Adler & Fukuda from Japan and Korea, but it is barely distinguished by the slenderer forebasitarsi of the female and male. Another new, related species, *S. (S.) xiulinense* sp. nov., is described based on a male and its pupal exuviae. This new species is distinguished from *S. (S.) hehuanense* sp. nov. by the number of male upper-eye (large) facets in 20 or 21 vertical columns and 22 horizontal rows (19 vertical columns and 19 horizontal rows in the latter species), and presence of a pair of dorsolateral shiny spots on male abdominal segment 5 (absence in the latter species). Both new species inhabit streams at high elevations (ca, 2,600 m). They differ from *S. (S.)* sp. (probably *S. (S.) arisanum* Shiraki) from Taiwan, of the same subgroup, which breeds in streams at low elevations (433–685 m), by the pupal head and thorax covered with tubercles (bare in the latter species).

**Keywords:** Biting insects; taxonomy; biodiversity; oriental region.

### INTRODUCTION

*Simulium* (*Simulium*) *rufibasis* Brunetti (Diptera: Simuliidae) was once considered a geographic black fly generalist having a wide distribution in the Oriental Region and parts of the Palearctic Region. It was originally described from northern India (Brunetti, 1911; Puri, 1932), and recorded from Pakistan (Lewis, 1973), Nepal (Shrestha & Takaoka, 2009), Myanmar (Takaoka, 1989), Thailand (Takaoka & Suzuki, 1984), Vietnam (Takaoka *et al.*, 2014, 2015), south China (Chen & An, 2003), Taiwan (Takaoka, 1979), Japan (Bentinck, 1955; Ogata & Sasa, 1955) and Korea (Bentinck, 1955). This species was reported to bite humans in Japan and Thailand (Bentinck, 1955; Ogata, 1955; Chochote *et al.*, 2005) and to be a potential vector of *Onchocerca japonica* Uni, Bain & Takaoka, which is a parasite of wild boar and a causative agent of zoonotic onchocerciasis in Japan (Fukuda *et al.*, 2008).

Recent morphological, molecular and chromosomal studies have shown that *S. (S.) rufibasis* is a complex of multiple, geographically limited species, most of which were thus described as new species, i.e., *S. (S.) fuscicoxae* Takaoka & Ya'cob from Vietnam (Takaoka *et al.*, 2017), *S. (S.) tenebrosum*

Takaoka, Srisuka & Saeung from Thailand (Adler *et al.*, 2019; Takaoka *et al.*, 2019), *S. (S.) yamatoense* Takaoka, Adler & Fukuda from Japan and Korea (Adler *et al.*, 2020), and *S. (S.) langtangense* Takaoka & Shrestha from Nepal (Takaoka *et al.*, 2020).

*Simulium* (*S.*) *rufibasis* is one of 17 members in the *S. rufibasis* subgroup of the *S. (S.) tuberosum* species-group. This subgroup is characterized by the ventral surface of female abdominal segment 7 with a pair of clustered stout hairs (Takaoka, 2017).

Our aim is to morphologically evaluate the species previously recognized as *S. (S.) rufibasis* in Taiwan for clarification of its taxonomic status by reexamining a female, two males, and their pupal exuviae collected from high elevation streams, at Dayuling, Hualien County, Taiwan.

### MATERIAL AND METHODS

The material examined in this study consisted of a female and two males, their associated pupal exuviae and cocoons collected in Taiwan (see Type specimens). All specimens were fixed in 80% ethanol; therefore, all colors are based on specimens in ethanol.

Methods of morphological observation, terms of features, descriptions, and illustrations, followed Takaoka (2003) and partially Adler et al. (2004).

The holotypes and paratype of the new species are deposited in the Entomology Section of the Queen Sirikit Botanic Garden, Chiang Mai, Thailand.

## RESULTS AND DISCUSSION

Our reexamination of adult and pupal specimens shows that the species previously considered *S. (S.) rufibasis* in Taiwan is morphologically different from true *S. (S.) rufibasis* from India, redescribed by Puri (1932). This species is also distinguished from other related known species of the *S. rufibasis* subgroup. For this reason, this species is here described as new to science. In addition, another new species is also described from one male, because it differs from that of the first new species.

### Descriptions of new species

#### *Simulium (Simulium) hehuanense* Takaoka sp. nov.

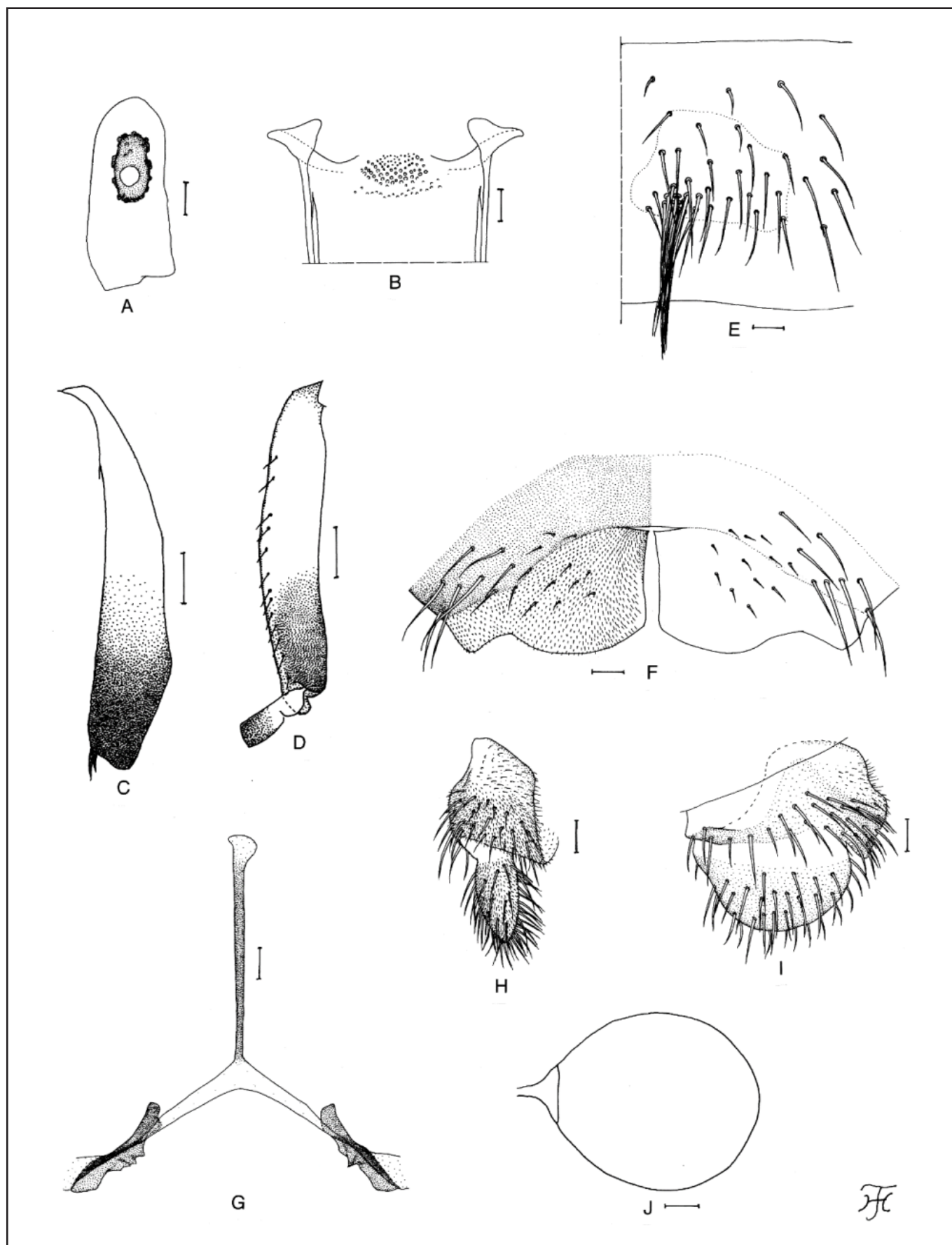
*Simulium (Simulium) rufibasis* (not Brunetti): Takaoka, 1979: 395.

**Diagnosis.** Female: frons nearly as high as its narrowest width, hind tibia yellow on basal half, and dark on rest, and clustered stout hairs on sternite 7 nearly twice as long as other hairs on surrounding area. Male: upper-eye facets in 19 vertical columns and 19 horizontal rows, forebasitarsus 5.52 times as long as its greatest width, and abdominal segments 2, 6 and 7 each with pair of shiny, white-pruinose dorsolateral spots. Pupa: frons moderately covered with tubercles, and gill with six filaments, of which the longest dorsal filament is 2.3–2.5 mm long.

**Female** (n=1). Body length 2.5 mm. **Head.** Slightly narrower than thorax. Frons black, shiny, with several dark stout hairs along lateral margins and few hairs near lower margin; frontal ratio 1.31:1.00:0.98; frons:head ratio 1.0:3.56. Frontocular area well developed, short, directed laterally, and rounded apically. Clypeus black, grayish pruinose, shiny, sparsely covered with dark-brown medium-long hairs along lateral margins and near lower margins and upper half widely bare medially. Labrum 0.70 times length of clypeus. Antenna composed of scape, pedicel and nine flagellomeres, dark brown to brownish black except scape and pedicel yellow and first flagellomere dark yellow. Maxillary palp with five palpomeres medium brown except third segment dark brown; proportional lengths of third, fourth, and fifth palpomeres 1.0:1.0:2.3; third palpomere (Figure 1A) of moderate size, with medium-sized ellipsoidal sensory vesicle (0.33–0.36 times length of third palpomere) having medium-sized opening. Maxillary lacinia with 14 or 15 inner and 17 or 18 outer teeth. Mandible with 35 inner and 14 or 15 outer teeth. Cibarium (Figure 1B) with 99 tiny processes near posterodorsal margin. **Thorax.** Scutum brownish black, shiny, white pruinose when illuminated at certain angles, moderately covered with whitish-yellow short fine hairs interspersed with several dark-brown long upright hairs on prescutellar area. Scutellum dark brown, covered with dark-brown upright long and short hairs. Postnotum brownish black, shiny and white pruinose when illuminated at certain angles, and bare. Pleural membrane bare. Katepisternum longer than deep, brownish black, shiny and white pruinose when illuminated at certain angles, and bare. **Legs.** Foreleg: coxa whitish yellow; trochanter light brown except base whitish yellow; femur medium to dark brown; tibia whitish except apical cap dark brown, with median outer surface widely white and with sheen when illuminated at certain

angles; tarsus brownish black, with moderate dorsal hair crest; basitarsus moderately dilated, 4.56 times as long as its greatest width. Midleg: coxa dark brown; trochanter medium brown except base yellow; femur medium to dark brown; tibia whitish except apical one-third or little more dark brown, and with whitish sheen on basal three-fourths or little more of posterior surface when illuminated at certain angles; tarsus dark brown except basal half of basitarsus whitish yellow. Hind leg: coxa dark brown; trochanter dark yellow; femur dark brown except extreme base dark yellow or light brown and apical cap brownish black; tibia (Figure 1C) yellowish white on little more than basal half and dark brown to brownish black on rest (though basal two-thirds on posterior surface yellowish white), and with whitish fine hairs and sheen on basal two-thirds or little more of lateral and posterior surfaces when illuminated at certain angles; tarsus dark brown except basal three-fifths of basitarsus (though base light brown) yellowish white and little less than basal half of second tarsomere dark yellow or light brown; basitarsus (Figure 1D) nearly parallel-sided, 5.47 times as long as wide, and 0.77 and 0.71 times as wide as greatest widths of hind tibia and femur, respectively; calcipala (Figure 1D) moderately developed, slightly shorter than wide, and 0.41 times as wide as greatest width of basitarsus; pedisulcus (Figure 1D) well developed; claw simple, without tooth. **Wing.** Length 2.2 mm. Costa with dark spinules and hairs; subcosta haired except apical one-fourth bare; basal section of radius bare; R<sub>1</sub> with dark spinules and hairs; R<sub>2</sub> with dark hairs; hair tuft on base of radius dark brown; basal cell absent. **Halter.** White except base darkened. **Abdomen.** Basal scale medium to dark brown, with fringe of whitish fine hairs. Dorsal surface of abdomen dark brown to brownish black, with light to dark brown short hairs; tergite 2 and 6–9 shiny when illuminated at certain angles. Ventral surface medium to dark brown; segment 7 with pair of submedian sternal plates each bearing 27–30 long stout hairs, of which dozen of hairs arising in cluster (longest hairs twice or slightly more times as long as other hairs on sternal plate) (Figure 1E). **Terminalia.** Sternite 8 (Figure 1F) bare medially, covered with eight long and medium-long stout hairs and four or five short fine hairs on each side. Ovipositor valves (Figure 1F) nearly tongue-like, rounded posteromedially, membranous except inner margins weakly sclerotized, densely covered with microsetae together with nine short fine hairs; inner margin slightly sinuous. Genital fork (Figure 1G) of inverted-Y form; stem slender and well sclerotized, with widened apex 3.0 times as wide as middle of stem; arms of moderate width, each with moderately sclerotized projection directed forwardly from lateral ridge. Paraproct in ventral view (Figure 1H) pointed posteromedially, moderately concave anterolaterally, and with strongly sclerotized anteromedial surface bearing five or six sensilla; paraproct in lateral view (Figure 1I) somewhat produced ventrally, 0.6 times as long as wide, covered with 32 or 33 short to medium-long hairs and numerous microsetae on lateral and ventral surfaces. Cercus in lateral view (Figure 1I) short, rounded posteriorly, 0.46 times as long as its greatest width, and covered with medium-long and short hairs. Spermatheca (Figure 1J) ovoidal, 1.14 times as long as wide, moderately sclerotized and pigmented except duct and narrow area of juncture with duct unpigmented, without discernible reticulate surface patterns; minute internal setae present; accessory ducts unpigmented, subequal in thickness to each other and slightly thicker than main duct.

**Male** (n=1). Body length 2.6 mm. **Head.** Slightly wider than thorax. Upper eye medium brown, with large facets in 19 vertical columns and 19 horizontal rows. Clypeus brownish



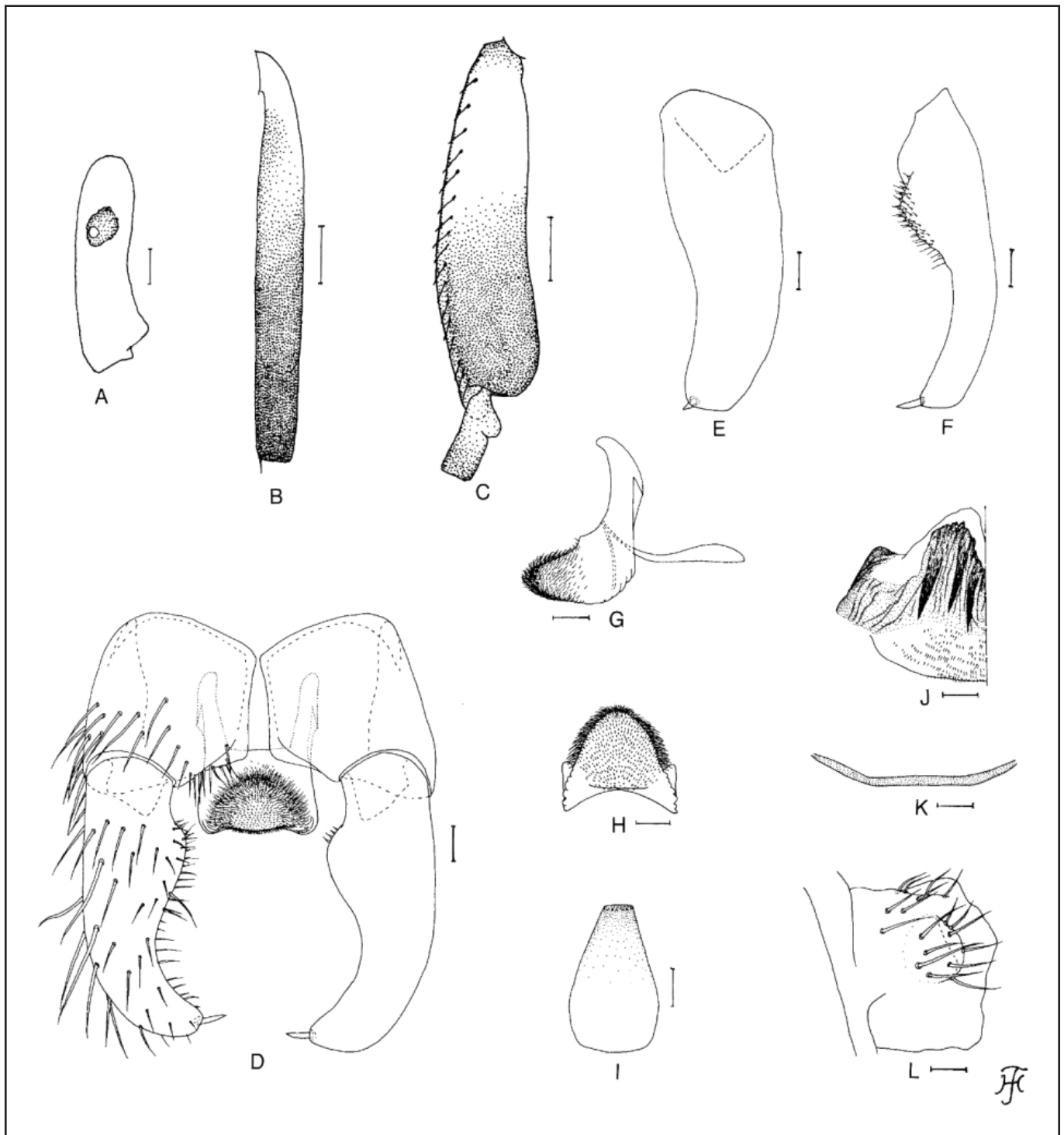
**Figure 1.** Female of *S. (S.) hehuanense* sp. nov. (A) Third palpomere with sensory vesicle (right side; front view). (B) Cibarium (front view). (C) Hind tibia (left side; outer view). (D) Hind basitarsus and second tarsomere (left side; outer view). (E) Median part of abdominal segment 7 with clustered stout hairs on sternite (ventral view; left half). (F) Sternite 8 and ovipositor valves (ventral view). (G) Genital fork (ventral view). (H) and (I) Paraprocts and cerci (right side; H, ventral view; I, lateral view). (J) Spermatheca. Scale bars = 0.1 mm for C and D; 0.02 mm for A, B and E-J.

black, white pruinose, shiny when illuminated at certain angles, sparsely covered with dark hairs medially, though densely with dark hairs along lateral margins. Antenna composed of scape, pedicel and nine flagellomeres, brownish black except base of first flagellomere yellow; first flagellomere elongate, 1.94 times as long as second one. Maxillary palp grayish to medium brown, composed of five palpomeres with proportional lengths of third, fourth, and fifth palpomeres 1.0:1.1:2.7; third palpomere (Figure 2A) of moderate size; sensory vesicle (Figure 2A) small, ellipsoidal (0.18–0.21 times as long as third palpomere), and with small opening. **Thorax.** Scutum brownish black, with white pruinose pattern, i.e., anterior pair of crescent spots on shoulders extended posteriorly along lateral margins and narrowly disconnected near base of wings to large transverse posterior spot entirely covering prescutellar area; these pruinose areas silvery when illuminated at certain angles; scutum uniformly and moderately covered with yellow recumbent short hairs mixed with brassy short hairs anteriorly and interspersed with dark brown longer upright hairs on prescutellar area. Scutellum brownish black, with several dark brown longer upright hairs and short hairs. Postnotum brownish black, white-pruinose when illuminated at certain angles and bare. Pleural membrane bare. Katepisternum longer than deep, brownish black, white-pruinose when illuminated at certain angles, and bare. **Legs.** Foreleg: coxa yellow; trochanter medium brown; femur medium to dark brown; tibia medium to dark brown except median large portion widely white on outer surface, and with sheen widely on outer surface when illuminated at certain angles; tarsus brownish black, with moderate dorsal hair crest; basitarsus greatly dilated, 5.52 times as long as its greatest width. Midleg: coxa brownish black; trochanter dark brown except base yellow; femur dark brown; tibia (Figure 2B) dark brown except basal one-third of posterior surface whitish yellow; tarsus dark brown except basal one-third of basitarsus dark yellow to light brown. Hind leg: coxa dark brown; trochanter dark yellow; femur dark brown except apical cap brownish black; tibia brownish black except basal tip yellowish white; tarsus dark brown except basal two-fifths of basitarsus or little more yellow (though extreme base somewhat darkened) and little less than basal half of second tarsomere light brown; basitarsus (Figure 2C) much enlarged, 3.75 times as long as its greatest width, and 0.96 and 1.09 times as wide as greatest widths of hind tibia and femur, respectively; calcipala (Figure 2C) small, slightly shorter than wide, 0.26 times as wide as greatest width of basitarsus; pedisulcus (Figure 2C) well developed. **Halter.** White except basal portion darkened. **Wing.** Length 2.2 mm. Other characteristics as in female except subcosta bare. **Abdomen.** Basal scale brownish black, with fringe of dark long hairs. Dorsal surface of abdomen dark brown to brownish black, with dark short hairs; segments 2, 6 and 7 each with pair of silvery spots dorsolaterally, those on segment 2 broadly connected in middle to each other. **Genitalia.** Coxites, styles and ventral plate in ventral view as in Figure 2D. Coxite in ventral view nearly quadrate. Style in ventrolateral view (Figure 2E) elongate, 1.6 times as long as coxite, 2.9 times as long as its greatest width, nearly parallel-sided from base to basal one-third, then gradually tapered to apex. Style in medial view (Figure 2F) somewhat produced dorsally near basal one-third forming low protuberance having many small cone-like spines on its dorsal surface. Ventral plate in ventral view (Figure 2D) well sclerotized, with body subquadrate, 0.7 times as long as wide, posterior margin somewhat concave, and with round projection directed ventrally, which is covered with many minute setae; arms

slightly divergent from each other, and distance between their tips subequal to greatest width of body of ventral plate; ventral plate in lateral view (Figure 2G) with posterior margin serrated along little less than basal half, and with arms gently curved ventrally; ventral plate in end view (Figure 2H) triangular, with rounded ventral apex, with lateral margins serrated along basal half, with numerous setae on posterior surface except each side of basal portion bare; body of ventral plate 0.9 times as high as its width. Median sclerite in lateral view (Figure 2G) arising just anterior to ventral plate, directed dorsally; median sclerite in caudal view (Figure 2I) plate-like, gradually widened from base to apical one-third, then narrowed to apex, with round apex. Paramere in caudal view (Figure 2J) with three distinct hooks. Aedeagal membrane (Figure 2J) sparsely to moderately covered with minute setae, and with moderately sclerotized dorsal plate in form of horizontal bar (Figure 2K). Abdominal segment 10 (Figure 2L) with four to six hairs on ventral and lateral surfaces on each side. Cercus (Figure 2L) small, rounded, with seven to 10–13 distinct hairs.

**Pupa** (n=2). Body length 3.0 mm. **Head.** Integument yellow to dark yellow and moderately covered with round tubercles except antennal sheaths bare; frons with two long unbranched trichomes (subequal in length, or one trichome somewhat longer than another) (Figure 3A) on each side; face with one unbranched medium-long trichome (Figure 3B) on each side. **Thorax.** Integument yellow to dark yellow moderately covered with round tubercles; thorax with two long anterodorsal trichomes (Figure 3C), two anterolateral trichomes (anterior trichome medium-long, posterior one long) (Figure 3D), one medium-long mediolateral trichome (Figure 3E), and three ventrolateral trichomes (one short, two medium-long) (Figure 3F), on each side; all trichomes unbranched. Gill (Figure 3G) with six slender thread-like filaments in three pairs (one dorsal, one middle and one ventral) arising from short common basal stalk; basal fenestra small; all pairs short-stalked; stalks of dorsal and ventral pairs lying at angle of 80–90 degrees when viewed laterally; filaments decreasing in length and thickness from dorsal to ventral, with longest filament 2.3 mm in female pupa and 2.5 mm in male pupa and shortest filament 1.2 mm in female pupa and 1.5 mm in male pupa; relative thickness of each filament from dorsal to ventral when measured basally 1.50–1.86:1.50–1.57:1.25–1.43:1.13–1.29:1.00–1.14:1.00; all filaments ochreous, gradually tapered toward apices, though almost same width along basal half, with distinct annular ridges and furrows forming definite reticulate surface patterns, and densely covered with minute tubercles. **Abdomen.** Dorsally, all segments unpigmented except segment 1 light yellow; segment 1 with one unbranched medium-long seta (Figure 3H) on each side; segment 2 with one unbranched short seta and five spinous minute setae (Figure 3I) on each side; segments 3 and 4 each with four distinct hooked spines and one unbranched spinous minute seta on each side; segment 5 lacking spine-combs and comb-like groups of microspines; segment 6 lacking spine-combs but with comb-like groups of microspines on each side; segments 7–9 each with spine-combs in transverse row (though those on segment 7 much smaller in size and number than those on segment 8 and absent in some pupae) and comb-like groups of microspines (though segment 7 in female pupa lacking spine-combs) on each side; segment 9 lacking terminal hooks. Ventrally, segments 3–8 each with comb-like groups of microspines; segment 4 with one unbranched or bifid stout hook and few slender minute setae on each side; segment 5 with pair of bifid stout hooks





**Figure 2.** Male of *S. (S.) hehuanense* sp. nov. (A) Sensory vesicle (right side; front view). (B) Mid tibia (left side; outer view). (C) Hind basitarsus and second tarsomere (left side; outer view). (D) Coxites, styles and ventral plate (ventral view). (E) and (F) Styles (left side; E, ventrolateral view; F, medial view). (G) Ventral plate and median sclerite (lateral view). (H) Ventral plate (caudal view). (I) Median sclerite (caudal view). (J) Paramere and aedeagal membrane (right half; caudal view). (K) Dorsal plate (ventral view). (L) Abdominal segment 10 and cercus (lateral view). Scale bars = 0.1 mm for B and C; 0.02 mm for A and D-L.

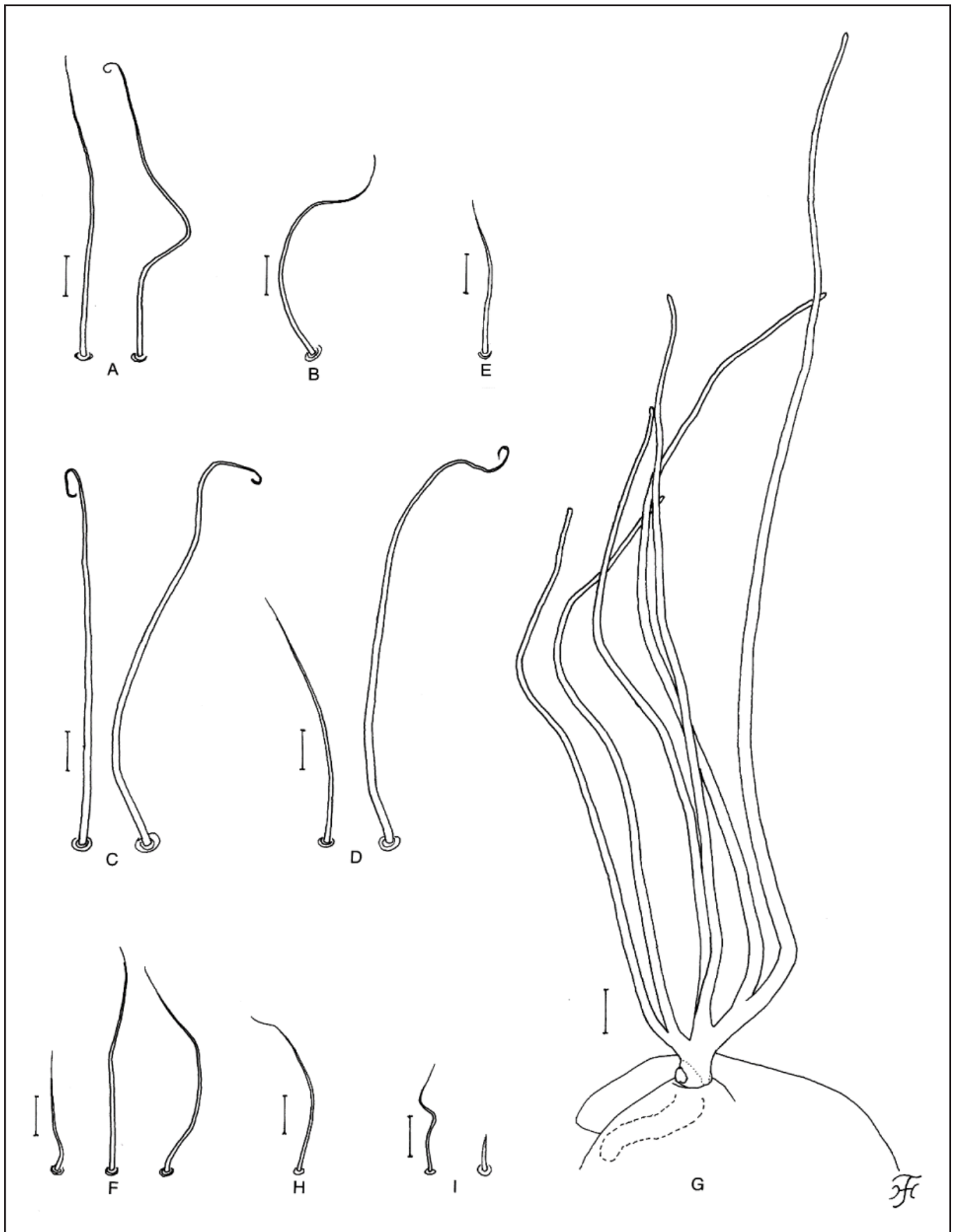
submedially and few unbranched short setae on each side; segments 6 and 7 each with pair of bifid inner and unbranched outer stout hooks somewhat separated from each other, and few unbranched short setae on each side.

**Cocoon.** Wall-pocket shaped, thickly woven, brownish, and not extended ventrolaterally; individual threads visible; 3.0 mm long by 1.4 mm wide.

**Mature larva.** Unknown.

**Type specimens.** Holotype. Male with its pupal exuviae, collected from a stream (elevation ca. 2,600 m; 24°10'50.7"N 121°18'36.1"E) at Dayuling, Xiulin Township, Hualien County, Taiwan, 16-VII-1976, by H. Takaoka. Paratype. One female with its pupal exuviae, same data as in the holotype.

**Etymology.** The species name, *hehuanense*, refers to the formerly name, Hehuan, of Dayuling where this new species was collected.



**Figure 3.** Pupa of *S. (S.) hehuanense* sp. nov. (A) Frontal trichomes. (B) Facial trichome. (C)–(F) Thoracic trichomes (C, mediodorsal; D, anterolateral; E, mediolateral; F, ventrolateral). (G) Gill filaments (left side; outer view). (H) Hair-like seta on dorsum of abdominal segment 1. (I) Hair-like seta and minute seta on dorsum of abdominal segment 2. Scale bars = 0.1 mm for G; 0.02 mm for A–F, H and I.

**Remarks.** This new species is distinguished from *S. (S.) rufibasis* from India (Puri, 1932) by the following characteristics (those of *S. (S.) rufibasis* in parentheses): the female hind basitarsus yellowish white on the basal three-fifths (yellow on the basal half to one-third), absence of a pair of shiny dorso-lateral spots on male abdominal segment 5 (presence), and absence of pupal terminal hooks (presence).

This new species is similar to *S. (S.) yamatoense* Takaoka, Adler & Fukuda from Japan and Korea (Adler et al., 2020) in many characteristics including the number of male upper-eye facets, but it is barely distinguished from the latter species by the length ratios of the forebasitarsi against their greatest widths in the female and male, which are 4.56 and 5.52, respectively, in this new species but 5.3–5.6 and 6.8–6.9, respectively, in *S. (S.) yamatoense*.

***Simulium (Simulium) xiulinense* Takaoka sp. nov.**

**Diagnosis.** Male: upper-eye (large) facets in 20 or 21 vertical columns and 22 horizontal rows, and fore basitarsus 6.64 times as long as its greatest width, and abdominal segments 2, 5, 6 and 7 each with pair of shiny, white-pruinose dorso-lateral spots. Pupa: gill with six filaments of which the longest dorsal filament is about 3.0 mm long.

**Male** (n=1). Similar to that of *S. (S.) hehuanense* sp. nov. except following characteristics. Body length 2.8 mm. **Head.** Upper-eye (large) facets in 20 or 21 vertical columns and 22 horizontal rows. Antenna: first flagellomere elongate, 1.91 times as long as second. Clypeus densely covered with dark hairs along lateral margins and medial portion widely bare. Maxillary palpus: proportional length of third, fourth and fifth palpomeres 1.0:1.0:2.4; sensory vesicle ellipsoidal, 0.21–0.23 times as long as third palpomere. **Legs.** Foreleg: coxa yellow, though anterior surface somewhat darkened; basitarsus 6.64 times as long as its greatest width. Midleg: tibia (Figure 4A) dark brown except base dark yellow (though basal one-fifth of outer surface yellow). Hind leg: basitarsus (Figure 4B) dark brown except basal two-fifths yellow; basitarsus (Figure 4B) 3.80 times as long as its greatest width, and 1.02 and 1.18 times as wide as greatest widths of hind tibia and femur, respectively. **Wing.** Length 2.6 mm. **Abdomen.** Segments 2 and 5–7 each with pair of large shiny, white-pruinose spots dorsolaterally. **Genitalia.** Style in ventrolateral view (Figure 4C) with outer margin somewhat sinuous; style in medial view (Figure 4D) with low protuberance subbasally; style in dorsal view (Figure 4E) with about 20 cone-like spines each with seta on its apex. Ventral plate in ventral view (Figure 4F) with arms divergent apically, distance between their tips 1.2 times as long as greatest width of body of ventral plate; ventral plate in lateral view (Figure 4G) with posterior margin serrated on basal half, and arms nearly straightly directed forward; ventral plate in caudal view (Figure 4H) with body as high as its greatest width. Paramere with five distinct hooks. Abdominal segment 10 with eight hairs on ventral and lateral surfaces on each side. Cercus with 11–13 distinct hairs.

**Pupa** (n=1). Nearly as in that of *S. (S.) hehuanense* sp. nov. except following characteristics. Body length 3.5 mm. **Thorax.** Three ventrolateral trichomes (Figure 4I) nearly subequal in length to one another. Gill (Figure 4J) with six filaments, of which longest dorsal filament (though its tip lost) probably 3.0 mm or little longer, and shortest ventral filament (though its tip lost) probably 1.9 mm long; relative thickness of six filaments from dorsal to ventral when compared basally 2.00:1.63:1.38:1.25:1.25:1.00. **Abdomen.** Dorsum of segment 3

with two hooks and three short setae on each side (usually segments 3 and 4 each with four hooks and one short seta on each side, so reduced number of hooks appearing abnormal); segments 6 and 7 each with comb-like groups of minute spines but lacking spine-combs; segments 8 and 9 each with spine-combs and comb-like groups of minute spines on each side. **Cocoon.** 3.5 mm long by 1.6 mm wide.

**Female and larva.** Unknown.

**Type specimen.** Holotype. Male with its pupal exuviae and cocoon, collected from a stream (near the stream where *S. (S.) hehuanense* sp. nov. was collected), Dayuling, Xiulin Township, Hualien County, Taiwan, 1-III-2006, by H. Takaoka.

**Etymology.** The species name, *xiulinense*, refers to the township, Xiulin, where this new species was collected.

**Remarks.** *Simulium (S.) xiulinense* sp. nov. is placed in the *S. tuberosum* species-group by having the subquadrate body of the ventral plate (when viewed ventrally) and the style with many microspines on a basal protuberance. It is further placed in the *S. rufibasis* subgroup in having the style with a low protuberance (Figure 4D).

This new species is similar to *S. (S.) dailekhense* Takaoka & Shrestha, *S. (S.) ramosum* Puri and *S. (S.) rufibasis* in sharing male abdominal segments 2 and 5–7 each with a pair of shiny, white-pruinose dorsolateral spots. However, this new species is distinguished from *S. (S.) dailekhense* and *S. (S.) rufibasis* by the male forecoxa yellow (light to median brown in the latter two species), and from *S. (S.) dailekhense* and *S. (S.) ramosum* by the unbranched trichomes on the pupal frons and thorax (branched trichomes in the latter two species).

This new species is distinguished from *S. (S.) hehuanense* sp. nov. in the male by abdominal segment 5 with a pair of shiny, white-pruinose dorsolateral spots, and length ratio of the forebasitarsus against its greatest width, which is 6.64 in this new species but 5.52 in *S. (S.) hehuanense* sp. nov., and in the pupa by the longest dorsal filament, which is about 3.0 mm in this new species but 2.3–2.5 mm in *S. (S.) hehuanense* sp. nov.

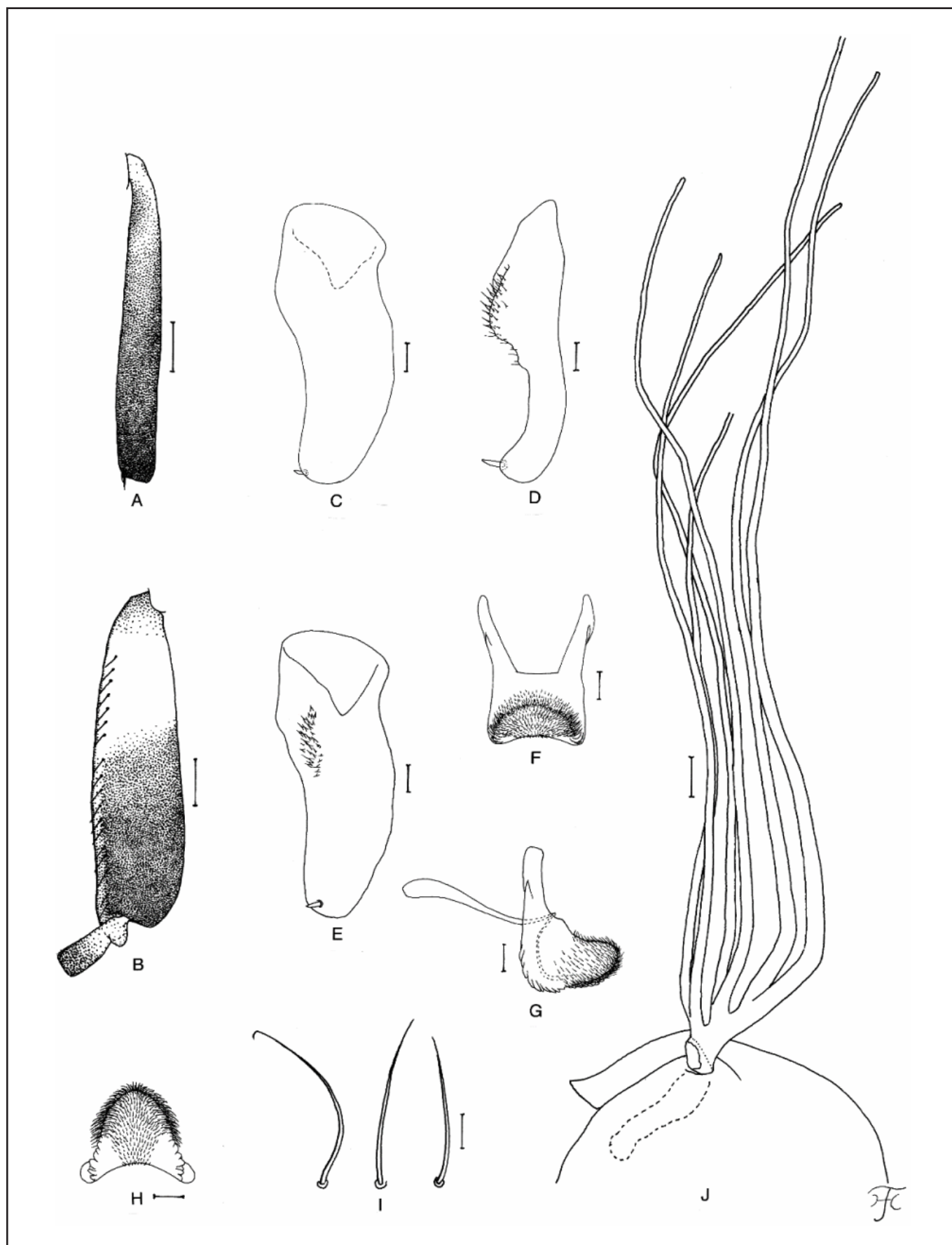
*Simulium (S.)* sp. collected from lowland streams (elevation 433–685 m) in Taiwan was placed in the *S. rufibasis* subgroup and tentatively identified as *S. arisanum* Shiraki by Low et al. (2018). This species is distinguished from the two new species described in this study by the pupal head and thorax lacking tubercles.

Thus, the *S. rufibasis* subgroup in Taiwan is at present represented by three species.

**Keys to 18 species of the *S. rufibasis* subgroup of the *S. tuberosum* species-group**

**Females\***

1. Claw with a small subbasal tooth.....*S. neorufibasis*  
Claw simple, without a basal or subbasal tooth.....2
2. Fore coxa dark yellow to light brown. Clustered stout hairs on sternite 7 nearly as long as those on surrounding area.....3  
Fore coxa yellowish white to yellow. Clustered stout hairs on sternite 7 longer than those on surrounding area....4
3. Sensory vesicle short, 0.3 times length of third maxillary palpomere, and with large opening. Hind tibia white on basal two-fifths and dark on rest.....*S. fuscicoxae*  
Sensory vesicle medium-long, 0.39–0.49 length of third maxillary palpomere, and with medium-sized opening. Hind tibia whitish yellow on basal one-third and dark on rest .....*S. setsukoa*



**Figure 4.** Male and pupa of *S. (S.) xiulinense* sp. nov. (A)–(H), male; (I) and (J), pupa. (A) Mid tibia (left side; outer view). (B) Hind basitarsus and second tarsomere (left side; outer view). (C)–(E) Styles (C and D, left side; C, ventrolateral view; D, medial view; E, right side; dorsal view). (F) and (H) Ventral plates (F, ventral view; H, caudal view). (G) Ventral plate and median sclerite (lateral view). (I) Ventrolateral trichomes on thorax. (J) Gill filaments (left side; outer view). Scale bars = 0.1 mm for A, B and J; 0.02 mm for C–I.



4. Hind tibia dark brown to brownish black with base yellow .....*S. weiji*  
Hind tibia dark brown to brownish black except basal one-third to little more than basal half white to whitish yellow .....5
5. Fine short hairs on scutum brassy.....6  
Fine short hairs on scutum yellow.....8
6. Hind basitarsus yellow on basal one-third to half .....*S. rufibasis* & *S. ramosum*  
Hind basitarsus yellow on basal three-fifths.....7
7. Fore basitarsus 5.0 times as long as its greatest width .....*S. manooni*  
Fore basitarsus 6.1–6.6 times as long as its greatest width.....*S. tenebrosum* complex
8. Fore basitarsus 5.9–7.2 times as long as its greatest width.....*S. nakanoi*, *S. rosliramlii* & *S. giayense*  
Fore basitarsus 4.6–5.6 times as long as its greatest width .....9
9. Fore basitarsus 5.3–5.6 times as long as its greatest width.....*S. pradyai* & *S. yamatoense*  
Fore basitarsus 4.6–5.1 times as long as its greatest width .....10
10. Height of frons 0.98 times as long as its narrowest width.....*S. hehuanense* sp. nov.  
Height of frons 1.3 times as long as its narrowest width .....*S. dailekhense*, *S. doipuiense* complex & *S. langtangense*

## Males\*\*

1. Abdominal segments 2 and 5–7 each with pair of shiny dorsolateral spots.....2  
Abdominal segments 2, 6 and 7 each with pair of shiny dorsolateral spots.....4
2. Fore coxa light brown to black.....*S. dailekhense* & *S. rufibasis*  
Fore coxa yellow to dark yellow.....3
3. Hind basitarsus yellow on basal half and dark on rest .....*S. ramosum*  
Hind basitarsus yellow on basal two-fifths, and dark on rest.....*S. xiulinense* sp. nov.
4. Hind tibia yellowish white on basal half or little less and dark on rest.....*S. nakanoi*  
Hind tibia darkened except base yellow.....5
5. Fore coxa darkened.....6  
Fore coxa yellow.....9
6. Fore basitarsus 5.5–5.8 times as long as its greatest width .....*S. langtangense*  
Fore basitarsus 6.6–8.5 times as long as its greatest width .....7
7. Fore basitarsus 6.6 times as long as its greatest width .....*S. manooni*  
Fore basitarsus 7.2–8.5 times as long as its greatest width .....8
8. Upper-eye (large facets) in 18 vertical columns and 19 horizontal rows.....*S. tenebrosum* complex  
Upper-eye (large) facets in 20–22 vertical columns and 21 or 22 horizontal rows.....*S. giayense* & *S. rosliramlii*
9. Upper-eye (large facets) in 16 or 17 vertical columns and 17 horizontal rows.....10  
Upper-eye (large facets) in 18 or 19 vertical columns and 19 or 20 horizontal rows.....11
10. Fore basitarsus 5.9–6.1 times as long as its greatest width .....*S. doipuiense* complex  
Fore basitarsus 4.5 times as long as its greatest width .....*S. weiji*
11. Fore basitarsus 5.5 times as long as its greatest width .....*S. hehuanense* sp. nov.  
Fore basitarsus 6.8–6.9 times as long as its greatest width .....*S. yamatoense*

## Pupae\*\*\*

1. Frons and most of thorax bare, without tubercles.....2  
Frons and most of thorax moderately or densely with tubercles.....4
2. Terminal hooks absent.....*S. nakanoi*  
Terminal hook present, though weakly developed.....3
3. Stalk of ventral pair of gill filaments much longer than that of dorsal pair.....*S. pradyai*  
Stalk of ventral pair of gill filaments somewhat shorter than that of dorsal pair.....*S. rosliramlii*
4. Frons densely covered with tubercles.....5  
Frons moderately covered with tubercles.....6
5. Frontal trichomes slightly longer than facial trichome. Longest dorsal gill filament 2.4 mm. All three pairs of gill filaments short-stalked.....*S. giayense*  
Frontal trichomes 0.4–0.6 times as long as facial trichome. Longest dorsal gill filament 1.5–1.7 mm. All three pairs of gill filaments sessile.....*S. weiji*
6. Most of trichomes on head and thorax branched .....*S. dailekhense* & *S. ramosum*  
Most of trichomes on head and thorax unbranched.....7
7. Terminal hooks present, though weakly developed .....*S. rufibasis*  
Terminal hooks absent.....8  
Cocoon thickly and compactly woven, without open spaces .....9
9. Longest dorsal gill filament 2.3–3.0 mm.....*S. xiulinense* sp. nov., *S. hehuanense* sp. nov., *S. tenebrosum* complex & *S. yamatoense*  
Longest dorsal gill filament 1.5–1.9 mm.....10
10. Facial trichome longer than frontal trichomes.....*S. manooni*  
Facial trichome shorter than frontal trichomes.....*S. doipuiense* complex & *S. langtangense*

\* *Simulium xiulinense* sp. nov. is not included because its female is unknown. *Simulium* sp. (= *S. arisanum*) is not included because of lack of detailed description.

\*\* *Simulium fuscicoxae*, *S. pradyai* and *S. setsukoae* are not included because their males are unknown. *Simulium neorufibasis* and *S. sp.* (= *S. arisanum*) are not included because of lack of detailed description.

\*\*\**Simulium neorufibasis*, *S. setsukoae* and *S. sp.* (= *S. arisanum*) are not included because of lack of detailed description.

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## Conflict of interest

We have no conflict of interest to declare.

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