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Review of the scorpionfly genus *Dicerapanorpa* Zhong & Hua (Mecoptera: Panorpidae), with descriptions of two new species

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Abstract. The current knowledge of the scorpionfly genus *Dicerapanorpa* Zhong & Hua, 2013 is taxonomically reviewed. Two new species of *Dicerapanorpa* are described and illustrated, increasing the species number of this genus to 20. *Dicerapanorpa bifurcata* sp. nov. from the Minshan Mountains, Sichuan Province, is characterized by the absence of the paramere basal branch and the elongated mesal branch in males, and the medigynium having a short basal stalk in females. *Dicerapanorpa zhengkuni* sp. nov. from the Wuling and Miaoling Mountains, Guizhou Province, is distinguishable by the greatly elongated hypovalves, the very short basal branch of the paramere, and the dorsomedially curved lateral branch in males, and the rounded main plate of the medigynium in females. An updated key to species of *Dicerapanorpa* is presented.

Keywords. China, *Dicerapanorpa*, scorpionfly, taxonomy, species diversity.

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Introduction

Panorpidae Latreille, 1805 is the most speciose family of Mecoptera Packard, 1886, with more than 480 species in the world (Penny & Byers 1979; Bicha 2018; Wang & Hua 2019a, 2019b). They are commonly known as scorpionflies, because their enlarged and recurved male genitalia resemble the stinger of scorpions (Byers & Thornhill 1983; Dunford & Somma 2008). Panorpids usually occur in mesic forests in mountainous regions and mainly feed on dead arthropods and vegetative material (Palmer 2010).

Panorpidae currently consists of eight extant genera (Gao & Hua 2019; Hu *et al.* 2019c; Wang & Hua 2019a). *Panorpa* Linnaeus, 1758 (with ca 260 spp.) is distributed in Asia, Europe and North America. *Neopanorpa* van der Weele, 1909 (with ca 170 spp.) is limited to the Oriental Region (Wang & Hua 2017, 2019a, 2019b; Wang & Hua 2018). *Leptopanorpa* MacLachlan, 1875 (with 14 spp.) is restricted to Java and Sumatra of Indonesia (Wang & Hua 2020). The remaining five genera (*Sinopanorpa* Cai &

Hua, 2008, *Furcatopanorpa* Ma & Hua, 2011, *Dicerapanorpa* Zhong & Hua, 2013, *Cerapanorpa* Gao, Ma & Hua, 2016 and *Megapanorpa* Wang & Hua, 2019) are endemic to China (Cai *et al.* 2008; Ma & Hua 2011; Zhong & Hua 2013; Hu *et al.* 2015; Gao *et al.* 2016; Miao *et al.* 2019; Wang & Hua 2019a).

The genus *Dicerapanorpa* Zhong & Hua, 2013, erected for the *Panorpa diceras* group (Cheng 1957), comprises 18 described species to date (Hu & Hua 2019; Hu *et al.* 2019a, 2019c). The monophyly of *Dicerapanorpa* was confirmed by molecular (Hu *et al.* 2015; Miao *et al.* 2019) and morphological studies (Ma *et al.* 2009, 2011, 2012). The genus can be readily recognized by male adults with two finger-like anal horns on the posterior margin of abdominal tergum VI and the trifurcated paramere of genitalia, and females with concealed axis of medigynium (Cheng 1957; Zhong & Hua 2013). Considerable variations within *Dicerapanorpa* were found in the wing pattern (Liu *et al.* 2016), the number of female ovarioles (Hou & Hua 2008) and the male salivary gland tubes (Ma *et al.* 2011). The male adult initiates copulation by grasping the female with a notal organ on the posterior margin of the third abdominal tergum and two anal horns on the posterior margin of the sixth tergum, and prolongs copulation by offering salivary masses as nuptial gifts (Zhong *et al.* 2015). The larvae of *Dicerapanorpa* are eruciform with annulated processes, reflecting the adaptive significance for fossorial and soil-living habits (Ma *et al.* 2014; Jiang *et al.* 2019).

The species of *Dicerapanorpa* are distributed in the Hengduan Mountains and the adjacent Qinling-Bashan Mountains (Fig. 1), and can be categorized into two groups (Hu & Hua 2019; Hu *et al.* 2019a,

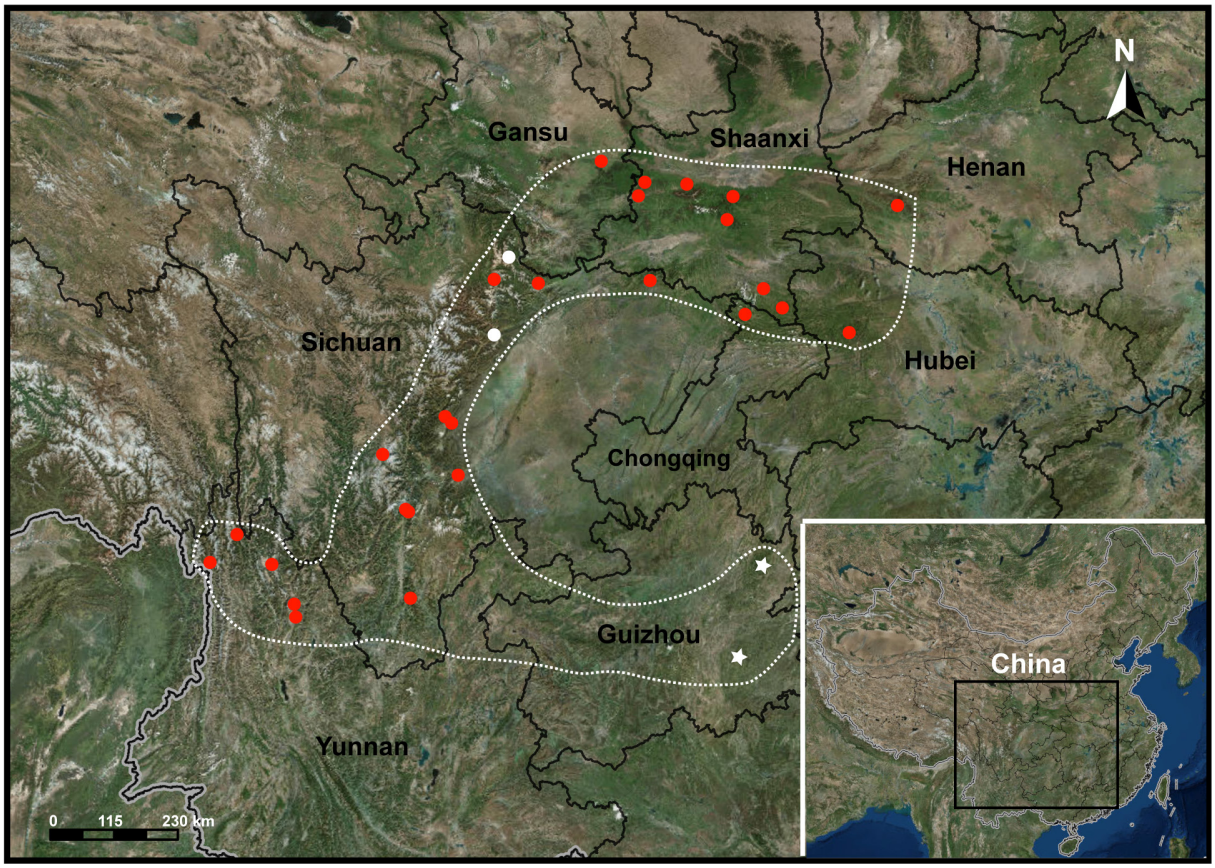

Fig. 1. Geographical distribution of *Dicerapanorpa* Zhong & Hua, 2013. The white dots represent the type locality of *D. bifurcata* sp. nov., the white asterisks indicate the type locality of *D. zhengkuni* sp. nov., and the red dots represent the distribution of the known species of *Dicerapanorpa*.

2019b, 2019c). The *D. magna* group is restricted to the Qinling, Bashan, and Minshan Mountains, and is characterized by the yellowish wing membrane with distinct wing markings and the rostrum without distinct lateral stripes. In contrast, the *D. diceras* group is distributed in the Hengduan Mountains, and is distinguishable by the hyaline wing membrane and the rostrum with two distinct lateral stripes.

In this paper, two new species are described from the Minshan Mountains, Sichuan Province, and the Wuling and Miaoling Mountains, Guizhou Province, China (Fig. 1), respectively, thereby raising the species number of *Dicerapanorpa* to 20. In addition, we updated the key to species of *Dicerapanorpa*.

Material and methods

The specimens were examined using a Nikon SMZ-168 microscope. Female medigynia were macerated in 5% NaOH for 3 min, and rinsed with distilled water. Images of habitus were taken with a Nikon D7000 digital camera. Other photographs were taken using an Auto-montage imaging system AxioCam IC attached to a ZEISS SteREO Discovery.V20 stereo microscope. All the images were further processed and assembled with Adobe Photoshop CS6. The length and width of the left wing were measured with a vernier caliper.

All the specimens examined are preserved in 75% or 100% ethanol in -20°C freezers. All material is deposited in the Entomological Museum, Northwest A&F University, Yangling, China (NWAU).

Abbreviations

A1 = first abdominal segment (and so forth for other segments)
T1 = first tergum (and so forth for other terga)

Abbreviations for morphological terms used in figures

ae = aedeagus
ax = axis
bb = basal branch
bp = basal process
ep = epandrium
gcx = gonocoxite
gs = gonostylus
hv = hypovalve
lb = lateral branch
mb = mesal branch
mp = main plate
mt = median tooth
pa = posterior arm
sgp = subgenital plate

Results

Taxonomic treatments

Class Insecta Linnaeus, 1758
Order Mecoptera Packard, 1886
Family Panorpidae Latreille, 1805
Genus *Dicerapanorpa* Zhong & Hua, 2013

Dicerapanorpa Zhong & Hua, 2013: 1021. Type species: *Panorpa magna* Chou, 1981 [by original designation].

Dicerapanorpa bifurcata Hu & Hua sp. nov.
urn:lsid:zoobank.org:act:E02C50F8-920B-4A40-B7BD-EA4666930497
Figs 2–3

Diagnosis

This species can be readily recognized by the following characters: basal branch of male paramere absent; mesal branches elongated, convergent distally, and extending to the median tooth of gonostylus; lateral branch curved semicircularly at base and convergent at apex, exceeding basal process of gonostylus (Figs 2D, 3A–B); and female medigynium strongly folded ventrally on each side, bearing a short basal stalk, with rounded main plate beneath the basal stalk (Figs 2F, 3C).

Etymology

The specific epithet refers to the bifurcated paramere of the male genitalia.

Type material

Holotype

CHINA – **Sichuan Province** • ♂; Pingwu County, Wanglang Nature Reserve; 32.92° N, 104.16° E; 2500 m a.s.l.; 2 Jun. 2018; Kai Gao leg.; NWAU.

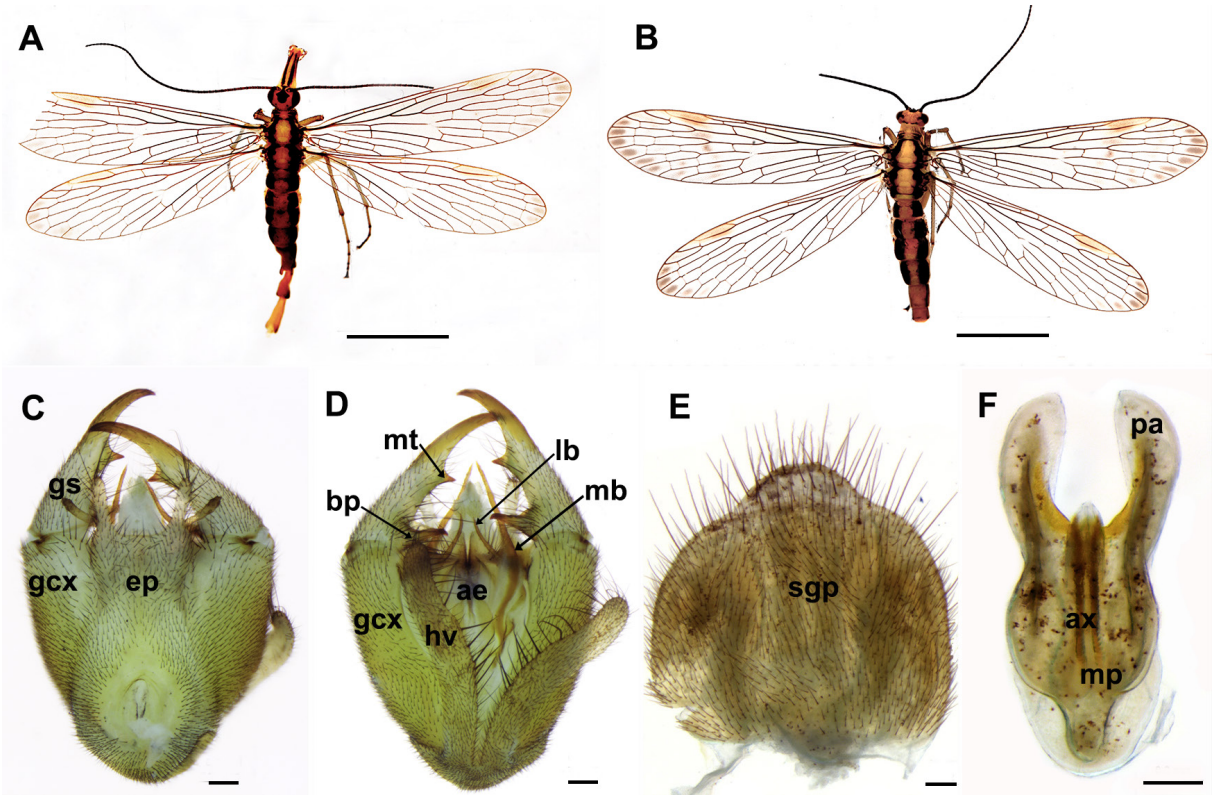

Fig. 2. *Dicerapanorpa bifurcata* sp. nov. **A**. ♂, holotype, dorsal view, NWAU. **B**. ♀, paratype, dorsal view, NWAU. **C**–**D**. ♂, genital bulb in dorsal and ventral views, respectively. **E**. ♀, subgenital plate, ventral view. **F**. ♀, medigynium, ventral view. Scale bars: A–B = 5.0 mm; C–F = 0.2 mm.

Paratypes

CHINA – **Sichuan Province•** 2 ♂♂, 14 ♀♀; same data as for the holotype; Kai Gao and Yu-Ru Yang leg.; NWAU • 1 ♂; Maoxian County, Tudiling; 31.71° N, 103.92° E; 2500 m a.s.l.; 21 May 2018; Kai Gao leg.; NWAU.

Description

Male

Head. Head mostly yellow. Rostrum faint yellow, with pair of blackish longitudinal stripes laterally. Maxillary and labial palps yellowish brown, distal segment dark brown. Antenna black brown. Ocellar triangle black (Fig. 2A).

Thorax. Pronotum yellow, with short black setae along anterior margin and two black longitudinal stripes laterally. Meso- and metanotum pale yellow with black longitudinal stripe on each side. Pleura and sterna yellow. Legs pale brown, distal tarsi dark brown (Fig. 2A).

Wing. Forewing length 13.4 mm, width 3.4 mm; membrane hyaline; apical and pterostigmal bands reduced to discontinuous spots, other markings absent. Hindwing length 12.5 mm, width 3.3 mm, similar to forewing in coloration and pattern (Fig. 2A).

Abdomen. T1–T5 yellow, with two black longitudinal stripes laterally. Notal organ on T3 slightly developed, semicircular, bearing numerous stout setae posteriorly. Post-notal organ on T4 pointed, projecting forward. Sterna and pleura yellowish. A6 yellowish brown, bearing two short digitate anal horns on posterior margin. A7 yellowish, elongated, constricted basally, abruptly dilated distally. A8 yellow, evenly broadening toward apex (Fig. 2A).

Genitalia. Genital bulb ovoid, yellowish brown. Epandrium (tergum IX) broad basally, constricted at distal third, terminating with deep trapezoidal emargination between two parallel setose lobes (Fig. 2C). Hypovalves broad, divergent apically, covered with long black bristles along inner margin, reaching apex of gonocoxite. Gonostylus shorter than gonocoxite, smoothly curved convergently; basal process gradually narrowing toward acute tip; median tooth subtriangular (Figs 2D, 3A). Basal branches

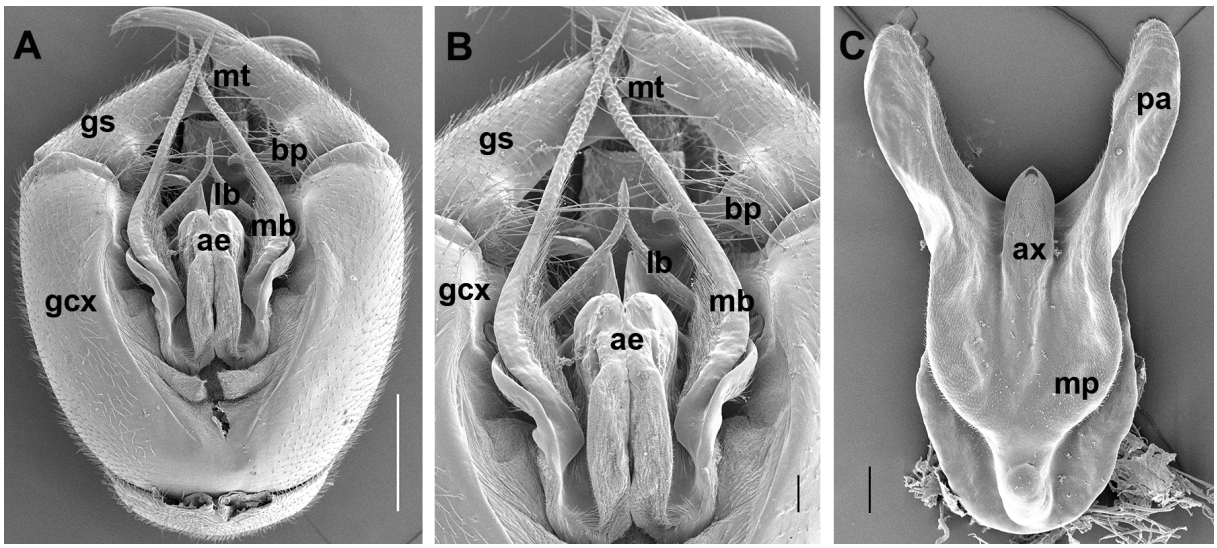

Fig. 3. Scanning electron micrographs of genitalia of *Dicerapanorpa bifurcata* sp. nov. **A**. ♂, genitalia in ventral view, with hypandrium removed. **B**. Magnification of A. **C**. ♀, medigynium, ventral view. Scale bars: A = 0.5 mm; B–C = 0.1 mm.

of parameres absent; mesal branches elongated, curved convergently, extending to median tooth of gonostylus; lateral branch curved semicircularly near base and convergent at apex, slightly exceeding basal process of gonostylus (Fig. 3B). Ventral valves of aedeagus short and slender; dorsal valves separated apically, greatly elongated, reaching apex of gonocoxite (Fig. 3B).

Female

Head, thorax and abdomen. Similar to males in general appearance (Fig. 2B). Forewing length 14.5–15.8 mm, width 3.9–4.1 mm; hindwing length 13.3–14.4 mm, width 3.9–4.1 mm.

Genitalia. Subgenital plate trapezoidal, terminating in ligulate process, covered with long bristles caudally (Fig. 2E). Medigynium strongly folded ventrally on each side, bearing short stalk at base, with round main plate beneath basal stalk. Posterior arm stout, nearly half as long as main plate. Axis concealed in main plate, slightly protruding apically (Figs 2F, 3C).

Distribution

Minshan Mountains, Sichuan Province, China (Fig. 1).

Dicerapanorpa zhengkuni Hu & Hua sp. nov.
urn:lsid:zoobank.org:act:D002EF64-9B01-4A06-B46A-0514533684CF
Figs 4–5

Diagnosis

This new species can be readily differentiated from its congeners by the following features: wings dusky hyaline, pterostigmal band with broad basal branch, gradually narrowing toward posterior margin, apical band greatly reduced (Fig. 4A–B); male hypovalve greatly elongated, extending far beyond basal process of gonostylus (Fig. 4H); basal branches of male paramere extremely short, mesal branches semi-circular basally and convergent apically, lateral branches curved to dorsal side basally (Fig. 5A–B); and main plate of female medigynium rounded, folded ventrally into a circular plate (Fig. 5C).

Etymology

The specific name is dedicated to Mr. Zheng-Kun Hu for his generous help to this study.

Type material

Holotype

CHINA – **Guizhou Province** • ♂; Jiangkou County, Fanjinshan Nature Reserve; 27.91° N, 108.65° E; 2200 m a.s.l.; 5 Jun. 2018; Gui-Lin Hu leg.; NWAU.

Paratypes

CHINA – **Guizhou Province** • 13 ♂♂, 65 ♀♀; same data as for the holotype; Gui-Lin Hu & Ning Li leg.; NWAU • 2 ♂♂, 1 ♀; Leishan County, Leigongshan Nature Reserve; 26.37° N, 108.17° E; 1600 m a.s.l.; 28 May 2018; Gui-Lin Hu and Ning Li leg.; NWAU.

Description

Male

Head. Head mostly yellow. Rostrum yellow with pair of blackish lateral longitudinal stripes. Maxillary and labial palps yellowish brown, distal segment dark brown. Antenna black. Ocellar triangle black (Fig. 4A, C).

Thorax. Pronotum yellow with several stout setae along anterior margin and two black longitudinal stripes on lateral sides. Meso- and metanotum yellow, with black longitudinal stripe along each side. Pleura pale yellow. Legs brown with tarsomere darkening toward apex (Fig. 4A).

Wings. Forewing length 15.0 mm, width 4.0 mm. Wing dusky hyaline with markings greatly reduced. Hindwing length 13.9 mm, width 3.9 mm, similar to forewing in color and pattern (Fig. 4A).

Abdomen. T1–T5 yellowish with two black longitudinal stripes laterally. Sterna and pleura yellow. Notal organ on T3 semicircular, prominent, bearing numerous setae posteriorly. Post-notal organ on T4

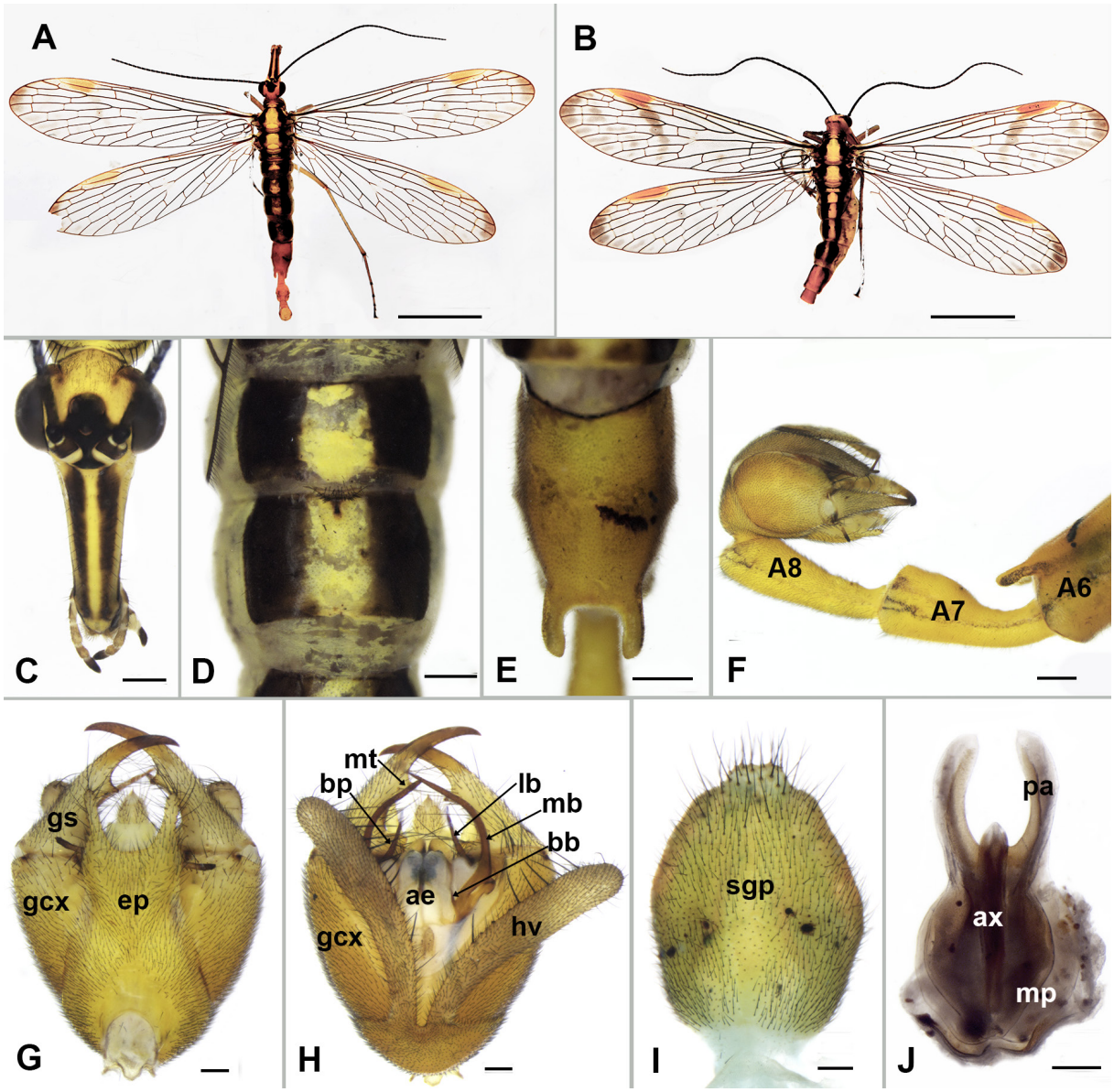

Fig. 4. *Dicerapanorpa zhengkuni* sp. nov. **A**. ♂, holotype, dorsal view, NWAU. **B**. ♀, paratype, dorsal view, NWAU. **C**. Head, frontal view. **D**. ♂, abdominal segments III and IV, showing the notal organ, dorsal view. **E**. Anal horns, dorsal view. **F**. ♂, A6–A8, lateral view. **G–H**. ♂, genital bulb in dorsal and ventral views, respectively. **I**. ♀, subgenital plate, ventral view. **J**. ♀, medigynium, ventral view. Scale bars: A–B = 5.0 mm; C–F = 0.5 mm; G–J = 0.2 mm.

short, hook-shaped, protruding forward (Fig. 4D). A6 uniformly yellowish brown, with pair of parallel finger-like anal horns on posterior margin (Fig. 4E). A7 elongated, constricted at basal half and abruptly dilated at distal half. A8 similar to A7, but gradually broadened distally (Fig. 4F).

Genitalia. Genital bulb ovoid, yellowish brown. Epandrium broad basally, tapering toward apex, with deep broad U-shaped terminal emargination between two parallel digital processes, almost reaching median tooth of gonostylus (Fig. 4G). Hypovalve greatly elongated, broad, with long bristles along inner margin, extending far beyond basal process of gonostylus (Fig. 4H). Gonostylus shorter than gonocoxite, bearing well-developed basal process and subtriangular median tooth (Figs 4H, 5A). Paramere trifurcated: basal branches very short, pointed; mesal branches elongated, curved convergently at apex, extending to median tooth of gonostylus; lateral branches sinuated to dorsal side basally, parallel apically, exceeding basal process of gonostylus. Aedeagus with paired ventral and dorsal valves: ventral valves short, narrow; dorsal valves sclerotized, separated distally, nearly reaching basal process of gonostylus (Figs 4H, 5B).

Female

Head, thorax and abdomen. Similar to males in general appearance. Wing dusky hyaline, pterostigmal band with broad basal branch and reduced distal branch, extending to vein M_4; apical band grayish brown, greatly reduced, discontinuous. Forewing length 15.8–16.9 mm, width 3.9–4.5 mm; hindwing length 14.5–15.2 mm, width 3.9–4.3 mm (Fig. 4B).

Genitalia. Subgenital plate ovoid, gradually tapering toward apex, terminating in truncated ligulate process, covered with long bristles caudally (Fig. 4I). Medigynium with main plate strongly sclerotized and ovoid, folded ventrally into round plate. Posterior arms smoothly curved inward, shorter than main plate. Axis almost entirely concealed in main plate, slightly pointed apically (Figs 4J, 5C).

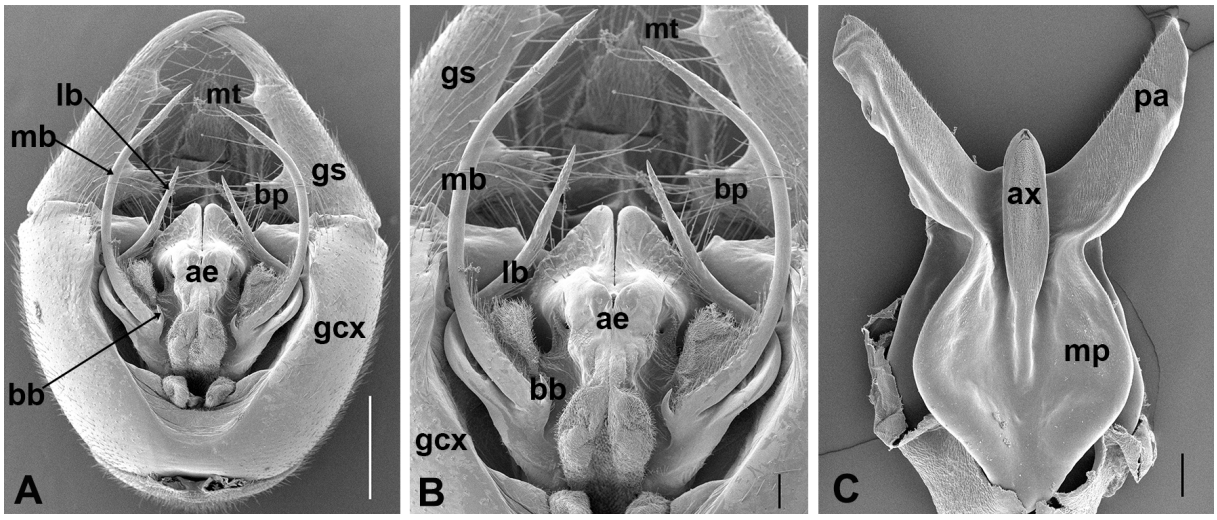

Fig. 5. Scanning electron micrographs of genitalia of *Dicerapanorpa zhengkuni* sp. nov. **A**. ♂, genitalia in ventral view, with hypandrium removed. **B**. Magnification of A. **C**. ♀, medigynium, ventral view. Scale bars: A = 0.5 mm; B–C = 0.1 mm.

Distribution

Wuling and Miaoling Mountains, Guizhou Province, China (Fig. 1).

Key to species of Dicerapanorpa *(males)*

(updated from Hu *et al*. 2019c)

1. Wings yellowish with distinct dark brown markings, apical band broad, enclosing a large hyaline window; pterostigmal band complete, with a broad basal branch and a separated narrow distal branch; basal band complete, across the wing or slightly reduced; rostrum with indistinct black longitudinal stripes 2
– Wings hyaline with indistinct markings, apical, pterostigmal and basal bands extremely reduced; rostrum with two distinct black longitudinal stripes 6

2. Basal branch of paramere not reaching apex of ventral valve of aedeagus; mesal branch short, not reaching median tooth of gonostylus 3
– Basal branch of paramere nearly reaching apex of ventral valve of aedeagus; mesal branch slender and elongated, extending to median tooth of gonostylus ..... ***D. baiyunshana*** Zhong & Hua, 2013

3. Mesal branches of paramere curved convergently, more than twice the length of basal branches 4
– Mesal branches of paramere parallel, nearly twice the length of basal branches .... ***D. shennongensis*** Zhong & Hua, 2013

4. Basal branch of paramere shorter, less than half the length of lateral branch; ventral valve of aedeagus broad and short 5
– Basal branch of paramere longer, more than half the length of lateral branch; ventral valve of aedeagus narrow and long ..... ***D. hualongshana*** Hu & Hua, 2019

5. Genital bulb narrow and elliptical; basal branch of paramere straight or curved nearly perpendicularly ..... ***D. magna*** (Chou, 1981)
– Genital bulb broad and spherical; basal branch of paramere hook-shaped .... ***D. minshana*** Hu & Hua, 2019

6. Hypovalve narrow basally and greatly broadened distally 7
– Hypovalve not markedly broadened distally 12

7. Hypovalve round apically 8
– Hypovalve truncated apically ..... ***D. stotzneri*** (Esben-Petersen, 1934)

8. Basal process of gonostylus broadened and thickened 9
– Basal process of gonostylus narrow and long, pointed distally 11

9. Hypovalve not curved inward at apex 10
– Hypovalve curved inward at apex; all branches of paramere exceeding apex of gonocoxite; basal branch straight, mesal and lateral branches greatly curved inward .... ***D. tenuis*** Hu, Wang & Hua, 2019

10. Genital bulb slender and elliptical; all branches of paramere broadened basally and narrowed distally, reaching or exceeding basal process of gonostylus; lateral branch slightly curved inward; aedeagus narrow ..... ***D. diceras*** (MacLachlan, 1894)
– Genital bulb broad and spherical; basal branch of paramere very short; mesal branch tapering toward apex, reaching median tooth of gonostylus; lateral branches curved perpendicularly, convergent

at basal two-thirds and parallel at apical one-third, extending over median tooth of gonostylus, aedeagus broad .....***D. tanae*** Hu, Wang & Hua, 2019

11. Dorsal valves of aedeagus narrow and sharply angular at apex; lateral branch of paramere convergent apically, reaching basal process of gonostylus ..... ***D. luojishana*** Hu & Hua, 2019
– Dorsal valves of aedeagus broad and rounded at apex; lateral branch of paramere curved semi-circularly at basal two-thirds, nearly parallel at distal one-third, extending far beyond basal process of gonostylus .....***D. lativalva*** Hu & Hua, 2019

12. Paramere trifurcated with basal branch short or long 13
– Paramere bifurcated with basal branch absent; mesal branches convergent distally, reaching median tooth of gonostylus; lateral branch conspicuously sinuated toward dorsal side, intersected apically; dorsal valves of aedeagus divergent apically, reaching apex of gonocoxite ..... ***D. bifurcata*** sp. nov.

13. Basal branch of paramere extremely short, less than one-third the length of mesal branch, straight or hooked 14
– Basal branch of paramere more than one-third the length of mesal branch, straight or curved 15

14. Wings hyaline without markings; hypovalve not exceeding basal process of gonostylus; basal branch of paramere hooked, mesal branches slightly curved basally and nearly parallel distally; lateral branches curved semi-circularly .....***D. kimminsi*** (Carpenter, 1948)
– Wings hyaline with incomplete black pterostigma and apical bands; hypovalve elongated, extending beyond basal process of gonostylus; basal branches of paramere straight, mesal branches curved semi-circularly basally and convergent apically, lateral branches sinuated toward dorsal side ....***D. zhengkuni*** sp. nov.

15. Ventral valve of aedeagus not extending to apex of gonocoxite. 16
– Ventral valve of aedeagus reaching apex of gonocoxite 18

16. Hypovalve extending to apex of gonocoxite 17
– Hypovalve not reaching apex of gonocoxite; basal branches of paramere parallel; mesal branches convergent apically, extending to basal process of gonostylus; lateral branches slightly curved ....***D. triclada*** (Qian & Zhou, 2001)

17. Basal branch of paramere elongated, exceeding basal process of gonostylus; mesal branches straight and parallel, reaching median tooth of gonostylus; lateral branch straight, not reaching apex of gonocoxite .....***D. macula*** Hu, Wang & Hua, 2019
– Basal branch of paramere not reaching basal process of gonostylus; mesal branches straight, intersected distally, exceeding median tooth of gonostylus; lateral branches convergent distally, reaching basal process of gonostylus ..... ***D. zhongdianensis*** Hu, Wang & Hua, 2019

18. Lateral branch of paramere not bifurcated 19
– Lateral branch of paramere bifurcated distally; basal branch nearly reaching apex of gonocoxite; mesal branches slightly curved basally and parallel distally, exceeding median tooth of gonostylus .....***D. tjederi*** (Carpenter, 1938)

19. Terminal emargination of epandrium shallow and rounded; basal branch of paramere nearly as long as lateral branch, reaching apex of gonocoxite; mesal branch elongated, extending to median tooth of gonostylus .....***D. deqenensis*** Hu, Wang & Hua, 2019

– Terminal emargination of epandrium deep and trapezoidal; basal branch of paramere curved inward basally and parallel distally, not reaching apex of gonocoxite; mesal and lateral branches convergent apically, reaching basal process of gonostylus .....***D. yijunae*** Hu & Hua, 2019

Discussion

In this study, we reviewed the descriptions of all the known species of *Dicerapanorpa*, and found that the so-called *D. stotzneri* (Esben-Petersen, 1934) in Zhong & Hua (2013) was very likely a misidentification, because the female medigynium differs from the original descriptions (Esben-Petersen 1934; Tjederi 1936; Cheng 1957). In fact, the figures of the female medigynium of *D. stotzneri* by Zhong & Hua (2013: fig. 12B–D) are more similar to those of *D. yijunae* Hu & Hua, 2019 (Hu & Hua 2019: fig. 3D).

The genus *Dicerapanorpa* was previously known to be restricted to the Hengduan and Qinling-Bashan Mountains. The distribution of *D. zhengkuni* sp. nov. in the Guizhou Plateau is likely an important biogeographical event. In this case, the genus *Dicerapanorpa* exhibits an intriguing circular distribution pattern around the Sichuan Basin. The mechanisms of this distribution pattern and associated species diversification in *Dicerapanorpa* should be an interesting topic to study in the future.

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