Zootaxa 4895 (3): 381–397
https://www.mapress.com/j/zt/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

https://doi.org/10.11646/zootaxa.4895.3.4
http://zoobank.org/urn:lsid:zoobank.org:pub:EDD13FF7-E045-4D13-A865-55682DC13C61

An Illustrated Key of Pyrgomorphidae (Orthoptera: Caelifera) of the Indian Subcontinent Region

SUNDUS ZAHID[1,2,5], RICARDO MARIÑO-PÉREZ[2,4], SARDAR AZHAR AMEHMOOD[1,6], KUSHI MUHAMMAD[3] & HOJUN SONG[2*]

[1]*Department of Zoology, Hazara University, Mansehra, Pakistan*
[2]*Department of Entomology, Texas A&M University, College Station, TX, USA*
[3]*Department of Genetics, Hazara University, Mansehra, Pakistan*
khushisbs@yahoo.com; https://orcid.org/0000-0003-4425-4742
[4]*Department of Ecology & Evolutionary Biology, University of Michigan, Ann Arbor, MI, USA*
pselliopus@yahoo.com.mx; https://orcid.org/0000-0002-0566-1372
[5] *sundus_zahid@hotmail.com; https://orcid.org/0000-0001-8986-3459*
[6] *banianhu@gmail.com; https://orcid.org/0000-0003-4121-9271*
[*]*Corresponding author.* *hsong@tamu.edu; https://orcid.org/0000-0001-6115-0473*

Abstract

The Indian subcontinent is known to harbor a high level of insect biodiversity and endemism, but the grasshopper fauna in this region is poorly understood, in part due to the lack of appropriate taxonomic resources. Based on detailed examinations of museum specimens and high-resolution digital images, we have produced an illustrated key to 21 Pyrgomorphidae genera known from the Indian subcontinent. This new identification key will become a useful tool for increasing our knowledge on the taxonomy of grasshoppers in this important biogeographic region.

Key words: dichotomous key, gaudy grasshoppers, taxonomy

Introduction

The Indian subcontinent is known to harbor a high level of insect biodiversity and endemism (Ghosh 1996), but is also one of the most poorly studied regions in terms of biodiversity discovery (Song 2010). This region includes Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. In terms of biogeography, this region is extremely interesting because it was part of Gondwana that broke off from East Africa in the Middle Jurassic period, followed by the breakup between India-Seychelles and Madagascar around 88 million years ago (Briggs 2003). The land mass rifted further north and collided with the Eurasian plate about 55 million years ago (van Hinsbergen *et al*. 2012). Thus, the fauna of the Indian subcontinent shares common elements with Africa and Madagascar (Briggs 2003) as well as those coming from Asia. Nevertheless, the Indian subcontinent has received relatively little attention from orthopteran taxonomists over the past 250 years (Song 2010). Other than small regional checklists, there is no major taxonomic synopsis available from this region, except for a review by Chandra *et al*. (2010) on the Orthoptera of India, an annotated checklist of Orthoptera from India by Shishodia *et al*. (2010), which included 1,033 species, and a book on grasshoppers and locusts of Pakistan by Sultana & Wagan (2015). According to the data available from the Orthoptera Species File (OSF, Cigliano *et al*. 2020), 372 orthopteran species were described from this region during 1776–1899, followed by 559 species during 1900–1949, 276 species during 1950–1999, and 188 species during 2000–2020. The total number of orthopteran species described from this region is therefore 1,395, which includes 709 ensiferans and 686 caeliferans. However, this is a serious underestimate of the actual biodiversity, given the uniqueness of the Indian subcontinent and the relative lack of taxonomists who can competently document and describe the biodiversity.

Currently, there is no reliable and comprehensive taxonomic identification tool available for identifying any orthopteran lineage of the Indian subcontinent, although regional keys (Priya & Narendran 2003; Haldhar & Swami-

Accepted by D. Rentz: 18 Nov. 2020; published: 16 Dec. 2020

nathan 2012; Sultana & Wagan 2015; Khan *et al*. 2018) and keys to agricultural pests (Mandal *et al*. 2007) exist. This lack is a major hindrance for advancing the orthopteran taxonomic research for this region. For some groups with numerous species, such as Acrididae, Gryllidae, or Tettigoniidae, developing such a tool is a challenge, but for smaller taxonomic groups, it can be easily implemented, given the current advances in imaging technologies and the availability of electronic resources such as OSF. In this study, we focus on developing a reliable identification key for a caeliferan family Pyrgomorphidae, which is one of the most easily recognizable orthopteran lineages within the region.

Commonly known as gaudy grasshoppers, Pyrgomorphidae is well known for several species that have vibrant body color and eye-catching sculpting patterns on pronotum, often featured in display collections of large and showy insects (Mariño-Pérez & Song 2018). The family can be easily distinguished from other grasshopper families by the presence of a groove in the fastigium (Kevan & Akbar 1964) and distinctive phallic characteristics, such as their cingulum extending around to the ventral side, medially directed endophallic apodemes, and their ejaculatory sac opening to the genital chamber (Eades 2000). Pyrgomorphidae is the sole member of the superfamily Pyrgomorphoidea, which is sister to the superfamily Acridoidea (Song *et al*. 2015), and currently, it includes 31 tribes, 149 genera and 487 valid species (Mariño-Pérez & Song 2018). Many members of this family have uniform color while some of them have bright aposematic coloration (Mariño-Pérez & Song 2018).

Concerning the Indian subcontinent grasshopper fauna, Kirby (1910, 1914) prepared a catalogue for Acrididae (which included Pyrgomorphidae) of the world and a volume of *Fauna of British India*, including the fauna of Pakistan, Bangladesh, Sri Lanka, and Burma. Later, Chopard (1924), Uvarov (1925, 1929), and Ayyar (1940) also studied the Indian species of Pyrgomorphidae. Kevan *et al*. (1970) worked on the taxonomy of the Oriental taxa of Pyrgomorphidae. Kevan (1968), Tandon & Shishodia (1969, 1989), Tandon (1976), Usmani & Shafee (1985), and Schmidt (2004) worked on the taxonomy of various genera and species of Pyrgomorphidae. Priya & Narendran (2003) gave the key and checklist of a few Pyrgomorphidae species from Kerala, India. Haldhar & Swaminathan (2012) produced a key for a few genera of Pyrgomorphidae in southwestern Rajasthan, India. Mandal *et al*. (2007) created the key for the Indian grasshopper pests, but only included 6 Pyrgomorphidae species with poor quality photos. Sultana & Wagan (2015) compiled a book on grasshoppers and locusts of Pakistan, which contained information and keys about families and subfamilies of Pakistani orthopteran fauna.

There are 21 genera of Pyrgomorphidae known from the Indian subcontinent, but currently, there is no reliable identification key available for this region. The main objective of this study is therefore to produce an illustrated key to genera for Pyrgomorphidae of the Indian subcontinent based on high resolution images of external morphology and male phallic structures.

Materials and methods

Taxon sampling

We first reviewed available taxonomic literature on the Pyrgomorphidae of the Indian subcontinent, including Kevan & Singh (1964), Kevan (1968, 1969), Schmidt (2004) and Shishodia *et al*. (2010) to obtain information on taxonomically useful and diagnostic characters for developing a key. To confirm the utility of these characters as well as to search for additional diagnostic characters, we compiled a synoptic collection of the Indian subcontinent Pyrgomorphidae from the specimens borrowed from the following institutions: Natural History Museum, London, U.K. (BMNH); Academy of Natural Sciences of Drexel University, the Philadelphia, PA, U.S.A. (ANSP); the Muséum National d'Histoire Naturelle, and Paris, France (MNHN). These specimens were used for digital imaging and male genitalia dissection. Of the 21 known genera from the Indian subcontinent, we had specimens representing 18 genera. We did not have specimens for *Rakwana*, *Ramakrishnaia*, *Feacris*, and *Plerisca* for which we relied on published taxonomic papers and type photographs for obtaining diagnostic characters.

Dissection of male phallic complex

We used the dissection technique described in Hubbell (1960) and Song & Mariño-Pérez (2013). We relaxed dried specimens by dipping their posterior end of abdomen in boiling water for a few minutes up until they were soft enough to dissect. Male genitalia were dissected by slitting open the membrane between epiproct and subgenital plate. We inserted a tip of forceps under the phallic structure and by gently pulled it out. We placed the dissected phallic structures in 10% KOH solution for 30–120 min to dissolve muscle tissues. For obtaining quicker results we

also placed the vial in boiling water for 5 min to speed up muscle dissolvement. Dissolved muscles were removed in 70% ethanol and the entire structure was cleaned thoroughly. After clearing, epiphallus was separated from the ecto-endophallus complex. Both pieces were placed in genitalia vials with glycerine for long-term preservation, which were pinned under the original specimen.

Digital imaging

The high-resolution digital images of external morphology and male genital structures were taken using the Visionary Digital LK Imaging System available at the Song Laboratory of Insect Systematics and Evolution in the Department of Entomology at Texas A&M University in combination with a Canon EOS 6D camera using 65 and 100-mm lenses to take multiple pictures altering the depths of field. For external morphology, dorsal and lateral views of the whole specimens were taken. For male genitalia, specimens were first taken out of genitalia vials, cleaned in ethanol, and positioned by immersing them in hand sanitizer with 80% ethanol over it. After photographing, Adobe Lightroom v.3.2 was used to import the images and transformed them from RAW files to TIFFs and for stacking the image slices into a single focused image using Zerene stacker (v.1.02). Finally, the focus-staked images were imported to Adobe Photoshop CS5 to adjust light levels, sharpness and background color.

Results

We developed a dichotomous key to identify the 21 genera of the Pyrgomorphidae of the Indian subcontinent. For each couplet, we included a figure to clearly show diagnostic characters, whenever we can. We also included a brief morphological guide for Pyrgomorphidae to aid identification (Figs. 1, 2). We carefully selected morphological traits that would be useful regardless of the sex, but to be more comprehensive, we included diagnostic characters from the male phallic complex as well. Below is the key to genera.

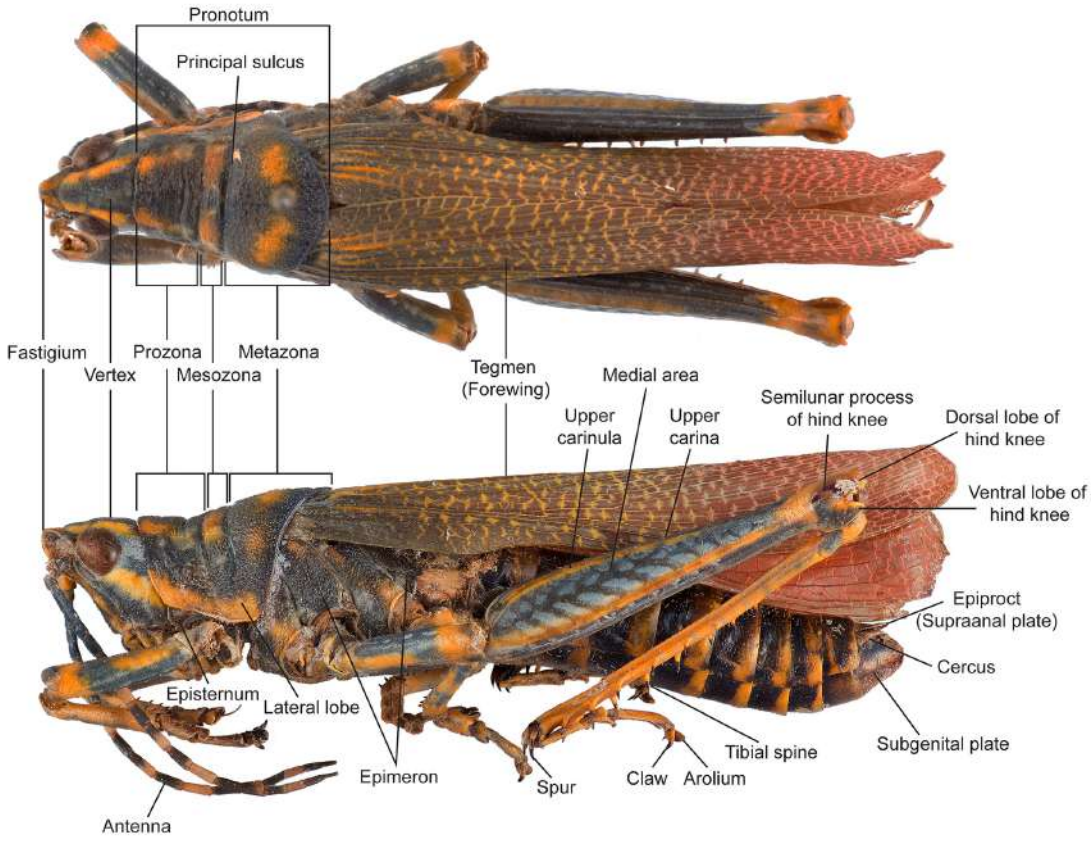

FIGURE 1. External morphology of Pyrgomorphidae. Shown here are dorsal and lateral views of a male specimen of *Poekilocerus pictus* (Fabricius, 1775).

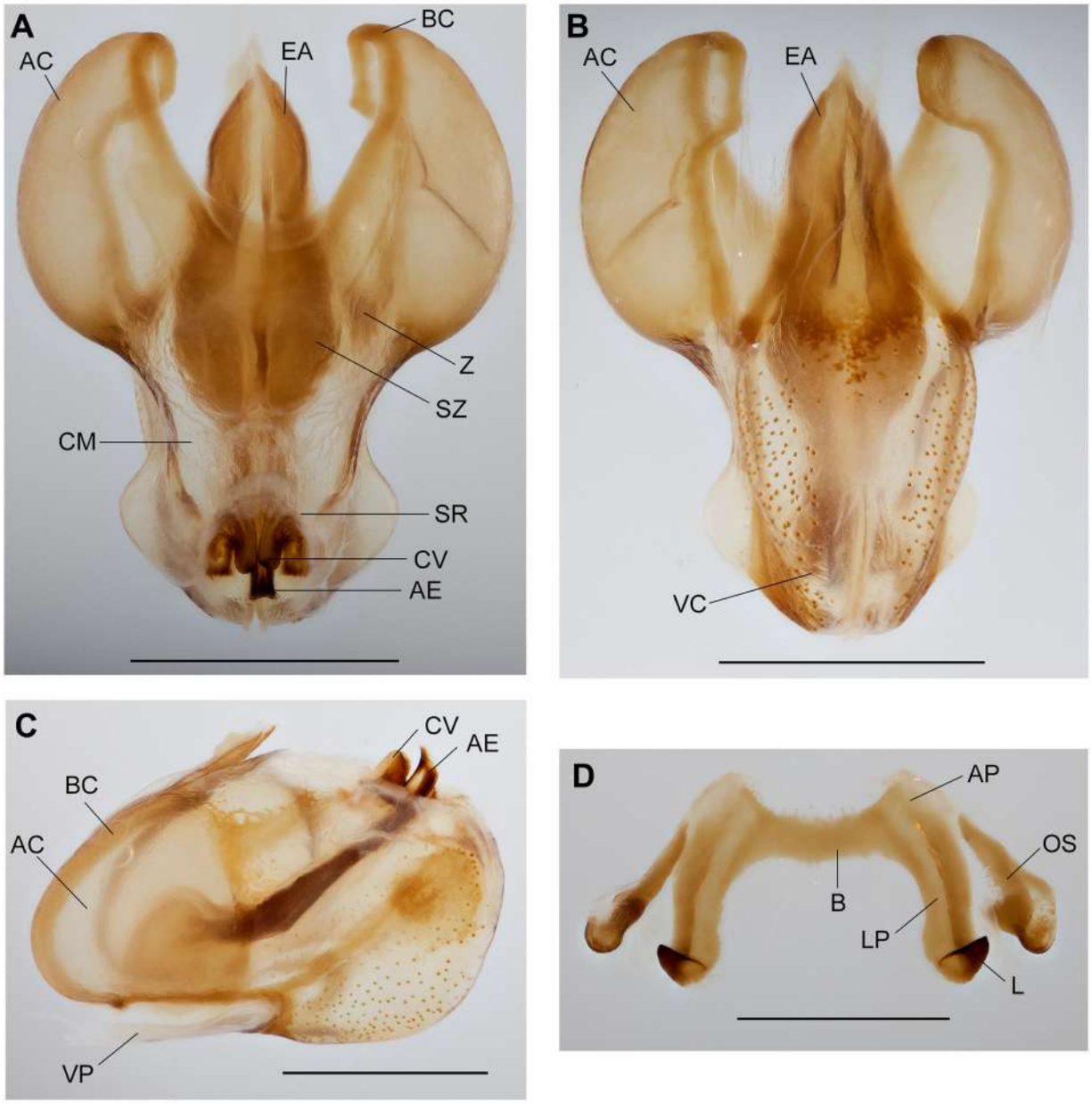

FIGURE 2. Male phallic complex of *Poekilocerus pictus* (Fabricius, 1775). (A) dorsal view of ectophallus and endophallus; (B) ventral view of ectophallus and endophallus; (C) lateral view of ectophallus and endophallus; (D) dorsal view of epiphallus. AC, apodemal plate of cingulum; AE, aedeagus (aedeagal valves); AP, anterior projection of epiphallus; B, bridge of epiphallus; BC, basal thickening of cingulum; CM, central membrane of epiphallus; CV, valve of cingulum; EA, endophallic apodeme; L, lophus of epiphallus; LP, lateral plate of epiphallus; OS, oval sclerites; SR, supraramus of cingulum; SZ, suprazygomal plate of cingulum; VC, ventral cleft of cingulum; VP, ventral process of cingulum; Z, zygoma of cingulum. Scale bar = 1 mm

Key to Pyrgomorphidae Genera of the Indian Subcontinent

1. Anterior margin of prosternum covering the posterior and lower part of the mouth (Fig. 3A, B); pronotum form pentagonoid (Fig. 4A) **2**

1'. Anterior margin of prosternum not covering the posterior and lower part of the mouth. (Fig. 3C, D); pronotum form otherwise (Fig. 4B–E) **3**

2. Frons surface with tubercles (Fig. 3A); lower basal lobe of hind femur longer than the upper one (Fig. 5A); middle femur short, much shorter than head and pronotum together; spurs of hind tibia shorter than the basal tarsal segment (Fig. 5A); lateral plates

of epiphallus elongate and straight (Fig. 6A); overall body dark to light brown also pale (Fig. 20E, G), with dark brown and black spots on thorax, wings and legs; abdomen coloration pattern contrasting. (Present in all Indian Subcontinent) . . . . . ***Chrotogonus* Serville, 1838**

(4 species known: *C. brachypterus*, *C. homalodemus*, *C. oxypterus*, *C. trachypterus*)

2'. Frons surface texture relatively smooth with small pits (Fig. 3B); lower basal lobe of hind femur shorter than the upper one (Fig. 5B); middle femur thin and strongly elongated, as long as or longer than head and pronotum together; spurs of hind tibia longer than the basal tarsal segment (Fig. 5B); lateral plates of epiphallus strongly bent outward (Fig. 6B); light brown, also touch of cadmium yellow in body (Fig. 20A, C); white spots upon dorsal portion and legs (Pakistan, India, Rajasthan) . . . . . ***Tenuitarsus* Bolívar, 1904**

(1 species known: *T. orientalis*)

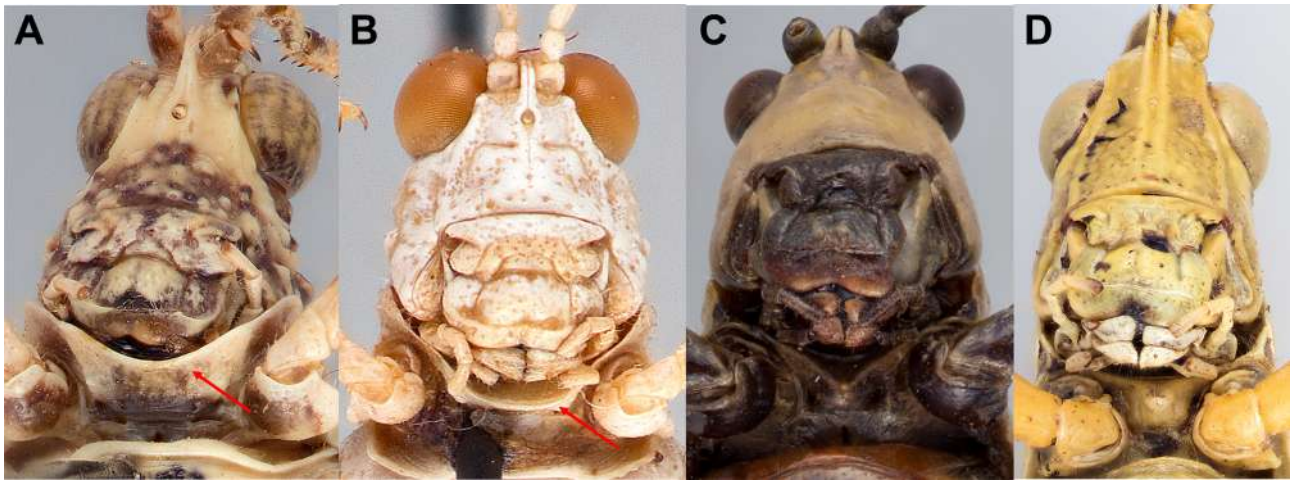

FIGURE 3. Ventral views of head from various Pyrgomorphidae genera. (A) *Chrotogonus*; (B) *Tenuitarsus*; (C) *Aularches*; (D) *Chlorizeina*.

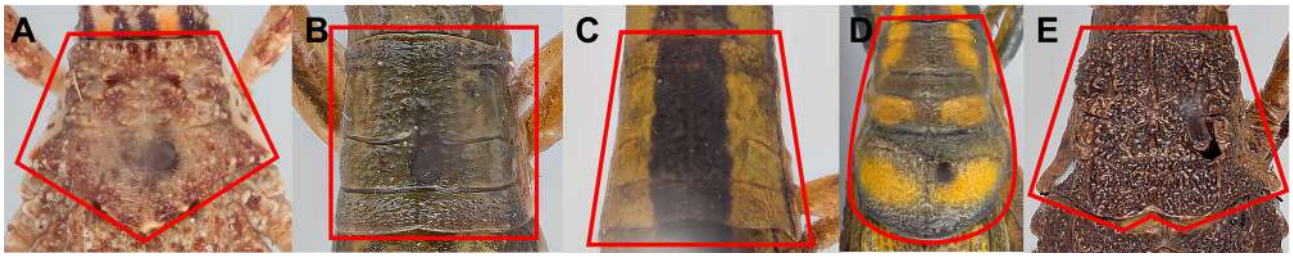

FIGURE 4. Dorsal views of pronotum from various Pyrgomorphidae genera. (A) *Chrotogonus*; (B) *Orthacris*; (C) *Nilgiracris*; (D) *Poekilocerus*; (E) *Mekongiella*

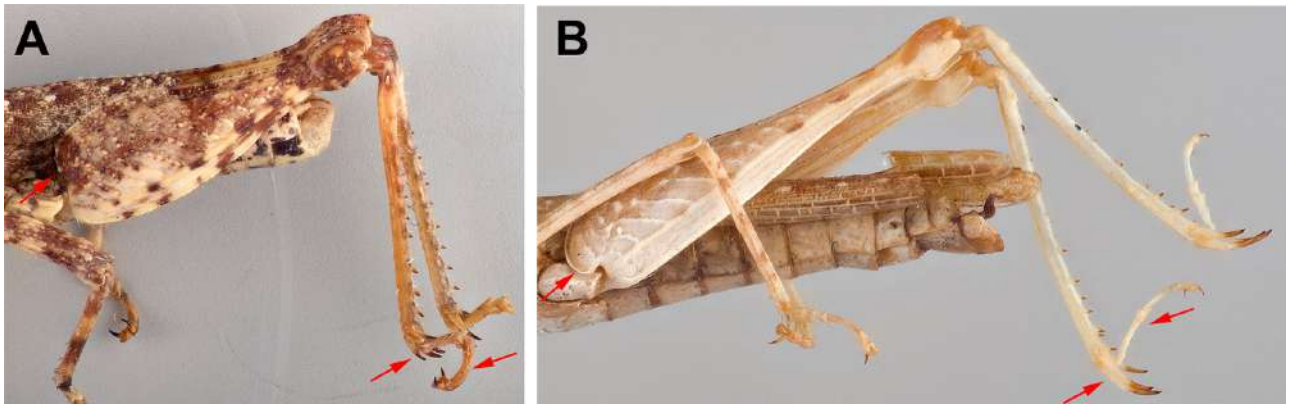

FIGURE 5. Comparison of hind legs between (A) *Chrotogonus* and (B) *Tenuitarsus*.

3. Completely apterous (Fig. 7A–C) **4**

3'. Micropterous (Fig. 7D), brachypterous (Fig. 7E), or macropterous (Fig. 7F) **9**

4. Very prominent spherical eyes; hind leg, third tarsomere slender and longer than first tarsomere (Fig. 8A). Light green and orange body with red from head to abdomen along lateral sides (Fig. 20F, H); black markings on lateral abdomen with tinge of black (Sri Lanka) . . . . . ***Rakwana* Henry, 1933**

(1 species known: *R. ornata*)

4'. Eyes normal and not particularly prominent; hind leg, third tarsomere not slender, and as long as first tarsomere (Fig. 8B); color otherwise **5**

5. Overall body form robust; dorsal and lateral pronotum texture tuberculate (Fig. 7C); pronotum form notched trapezoid (Fig. 4E); lateral carina of pronotum present as tubercles (Fig. 7C); dark brown, brunt umber with touch of brownish orange legs (Fig. 20B, D) (Arunachal Pradesh) . . . . . ***Mekongiella* Kevan, 1966**
(1 species known: *M. wardi*)

5. Overall body form slender, cylindrical or subfusiform; dorsal and lateral pronotum texture smooth or only slightly wrinkled (Fig. 7A, B); pronotum form variable but without a distinct notch in the middle of the hind margin of pronotum (Fig. 4B, C); lateral carina of pronotum absent or faint (Fig. 7A, B); color otherwise **6**

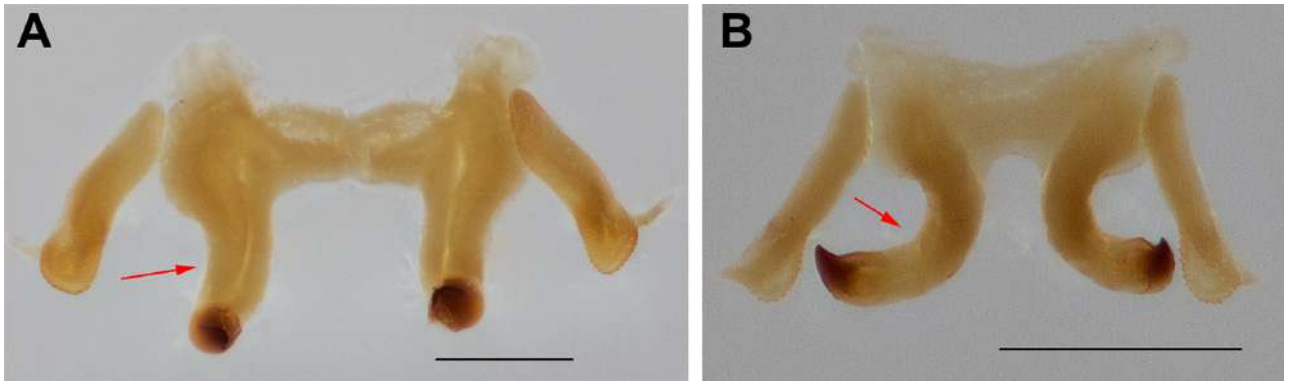

FIGURE 6. Comparison of epiphallus between (A) *Chrotogonus* and (B) *Tenuitarsus.* Scale bar = 0.5mm.

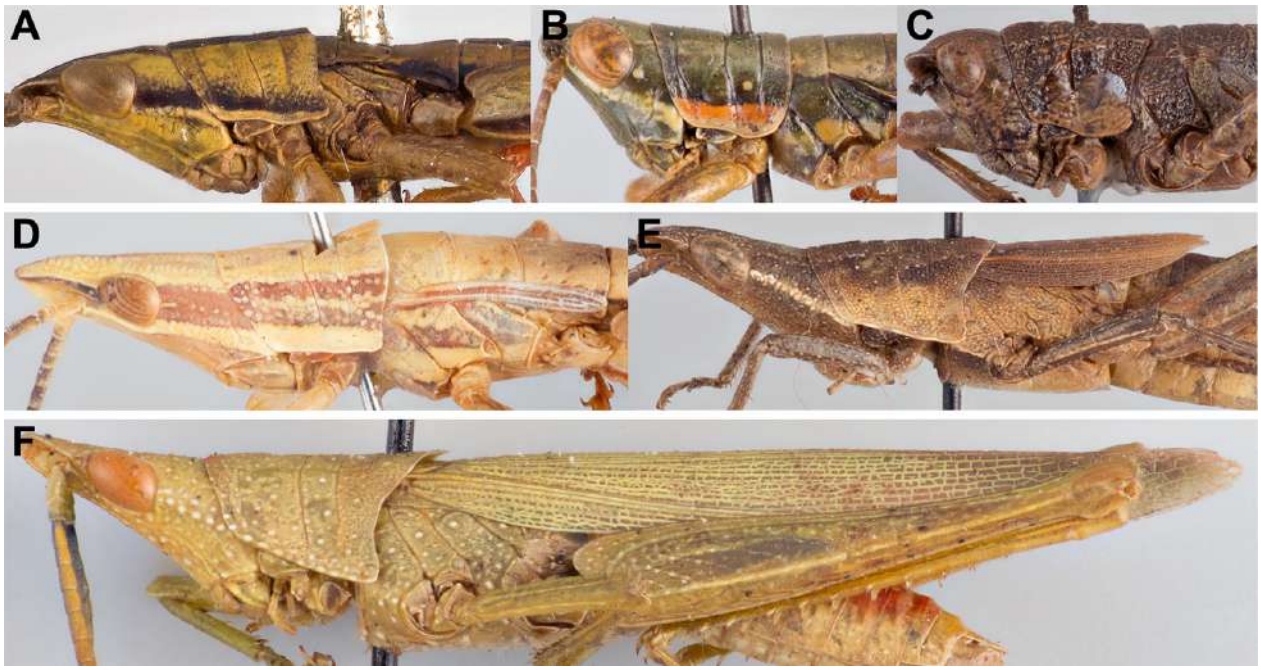

FIGURE 7. Wing length variation in Pyrgomorphidae. Apterous: (A) *Nilgiracris*, (B) *Orthacris*, (C) *Mekongiella*; Micropterous: (D) *Colemania*; Brachypterous: (E) *Zarytes*; Macropterous: (F) *Atractomorpha*.

6. Space between eye and anterior margin of pronotum in lateral view with a row of tubercles (Fig. 9A); head length from fastigium to mouthpart much longer than the length of pronotum (Fig. 1A); head in lateral profile slightly incurved; pronotum texture rugose; lophi of epiphallus broadly projecting outward (Fig. 10A); light ochre brown body with cream-colored line extending from eye up to the lower half of the lateral pronotum (Fig. 21A, C) (Tamil Nadu) . . . . . ***Anarchita* Bolívar, 1904**
(1 species known: *A. aptera*)

6'. Space between eye and anterior margin of pronotum in lateral view without a row of tubercles (Fig. 9B–D); head length from fastigium to mouthpart as long as, or only slightly longer than the length of pronotum (Fig. 9B–D); head in lateral profile slanted, but not incurved; lophi shape otherwise (Fig. 10B–D); color otherwise **7**

7. Antennae length much shorter than the length head and pronotum together (Fig. 9B); sap green color with a thick black line running from fastigium to end of abdomen in dorsal view (Fig. 21E, G); black line under eye extending laterally to the end of pronotum; hind tibia bright orange (Tamil Nadu) . . . . . ***Nilgiracris* Kevan, 1964**
(1 species known: *N. raoi*)

7'. Antennae longer than head and pronotum together (Fig. 9C–D); color otherwise **8**

8. Body cylindrical; head slightly longer than its width; fastigium broadly projecting (Fig. 11A, C); a pair of carinate ridges present dorsally on the head between the eyes (Fig. 11C); extremely elongate, whip-like aedeagal sclerites (Fig. 10G); moss green with cream and black on lateral pronotum and dorsal sides (Fig. 21B, D) (Andhra Pradesh, Tamil Nadu, Kerala) . . . . . ***Neorthacris*** **Kevan & Singh, 1964**
(5 species known: *N. acuticeps*, *N. longicercata*, *N. malabarensis*, *N. palnensis*, *N. simulans*)

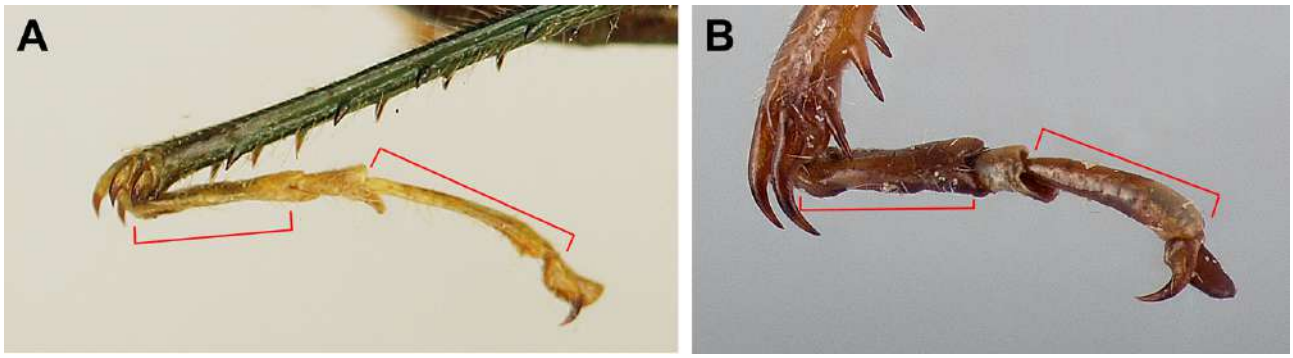

FIGURE 8. Hind tarsus. (A) *Rakwana*; (B) *Mekongiella*.

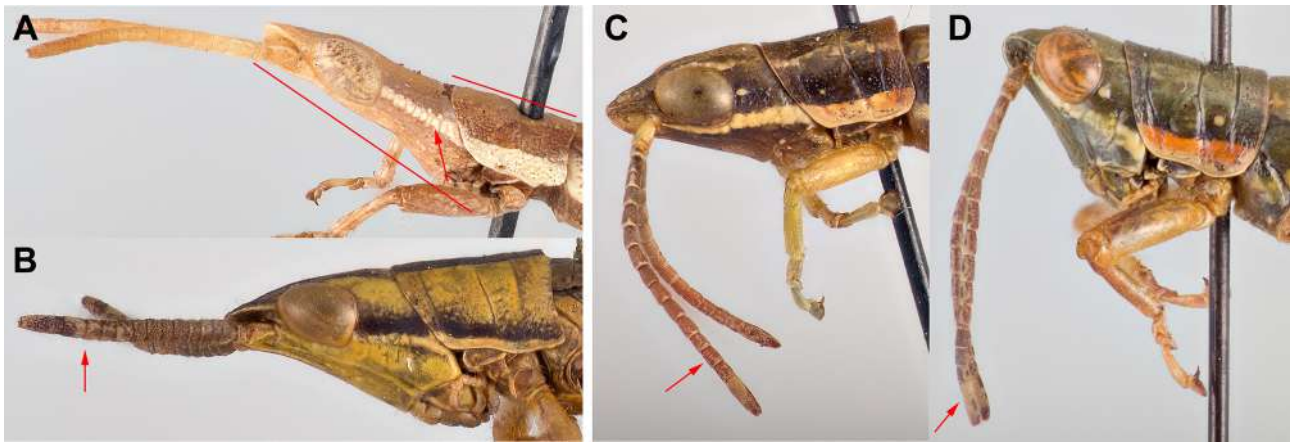

FIGURE 9. Antenna length variation and head shape in some apterous Pyrgomorphidae. (A) *Anarchita*; (B) *Nilgiracris*; (C) *Neorthacris*; (D) *Orthacris*.

8'. Body varying from cylindrical to rather robust, subfusiform; head variable in form but frequently not longer than its width or shorter; fastigium normal and only slight projecting (Fig. 11B,D); carinate ridges on the head absent (Fig. 11D); aedeagal sclerites normal (Fig. 10H); dark to light green with yellowish orange legs (Fig. 21F, H); black and orange line covering lateral side of pronotum, yellow line under eyes (Tamil Nadu, Sri Lanka) . . . . . ***Orthacris*** **Bolívar, 1884**
(13 species known: *O. ceylonica*, *O. comorensis*, *O. curvicerca*, *O. elongata*, *O. filiformis*, *O. gracilis*, *O. maindroni*, *O. major*, *O. elegans*, *O. incongruens*, *O. ramakrishnai. O. robusta*, *O. ruficornis*)

9. Micropterous (Fig. 7D) 10

9'. Brachypterous (Fig. 7E), or macropterous (Fig. 7F) 11

10. Eye size small compared to head (1/4 of total length of head in lateral view) (Fig. 12A); vertex of the head shallowly divided without a median carina (Fig. 12C); pronotum texture rugose; abdomen coloration pattern uniform (Fig. 22F, H) (Andhra Pradesh, Karnataka, Tamil Nadu, Maharashtra) . . . . . ***Colemania*** **Bolívar, 1910**
(1 species known: *C. sphenarioides*)

10'. Eye size about 1/3 of total length of head in lateral view (Fig. 12B); vertex of the head with a median carina (Fig. 12D); pronotum texture foveolate; abdomen coloration pattern contrasting; yellowish green body with tinge of orange on legs; black line under eye up to lateral pronotum (Fig. 22A, C) (Karnataka) . . . . . ***Ramakrishnaia*** **Bolívar, 1917**
(2 species known: *R. gracilis*, *R. notabilis*)

11. Brachypterous, with tegmina much shorter than the length of abdomen (Fig. 7E) **12**

11'. Macropterous, with tegmina as long as or longer than the length of abdomen (Fig. 7F) **15**

12. A row of tubercles absent in the lateral side of the head behind eyes (Fig. 13A); pronotum without tubercles (Fig. 13A); tegmina and hind wings variously reduced but extending beyond the bases of the hind femora; bridge of epiphallus broad (Fig. 14A); oval sclerite sickle-shaped (Fig. 14A); light green color with orangish yellow legs; yellow line under eye extending up to lateral pronotum; abdomen coloration pattern uniform (Fig. 22B, D) (Assam, Tripura, Sri Lanka, Manipur) . . . . . ***Chlorizeina*** **Brunner von Wattenwyl, 1893**
(1 species known: *C. unicolor*)

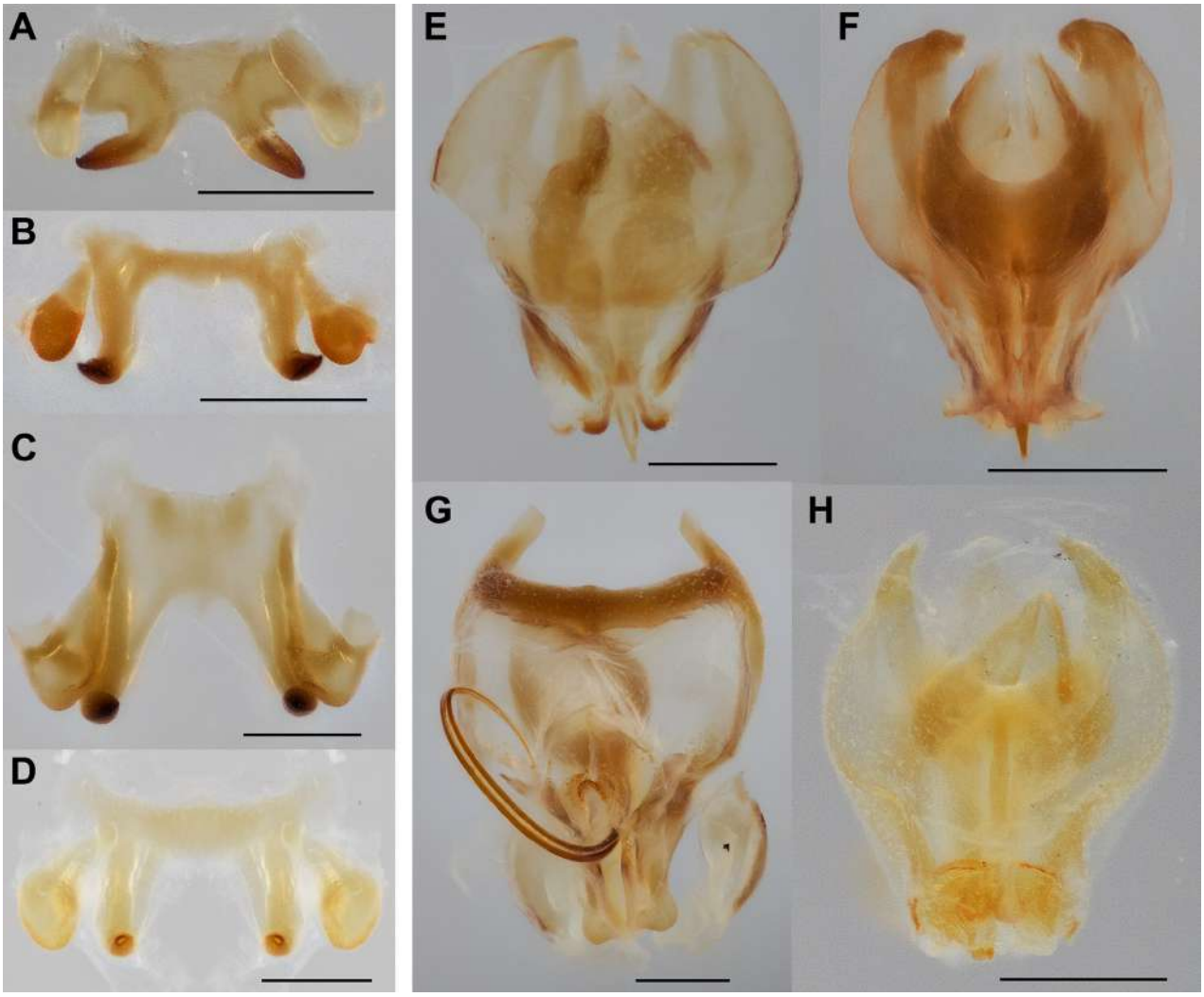

FIGURE 10. Epiphallus and dorsal view of phallic complex of some apterous Pyrgomorphidae. (A, E) *Anarchita*; (B, F) *Nilgiracris*; (C, G) *Neorthacris*; (D, H) *Orthacris*. Scale bar = 0.5mm.

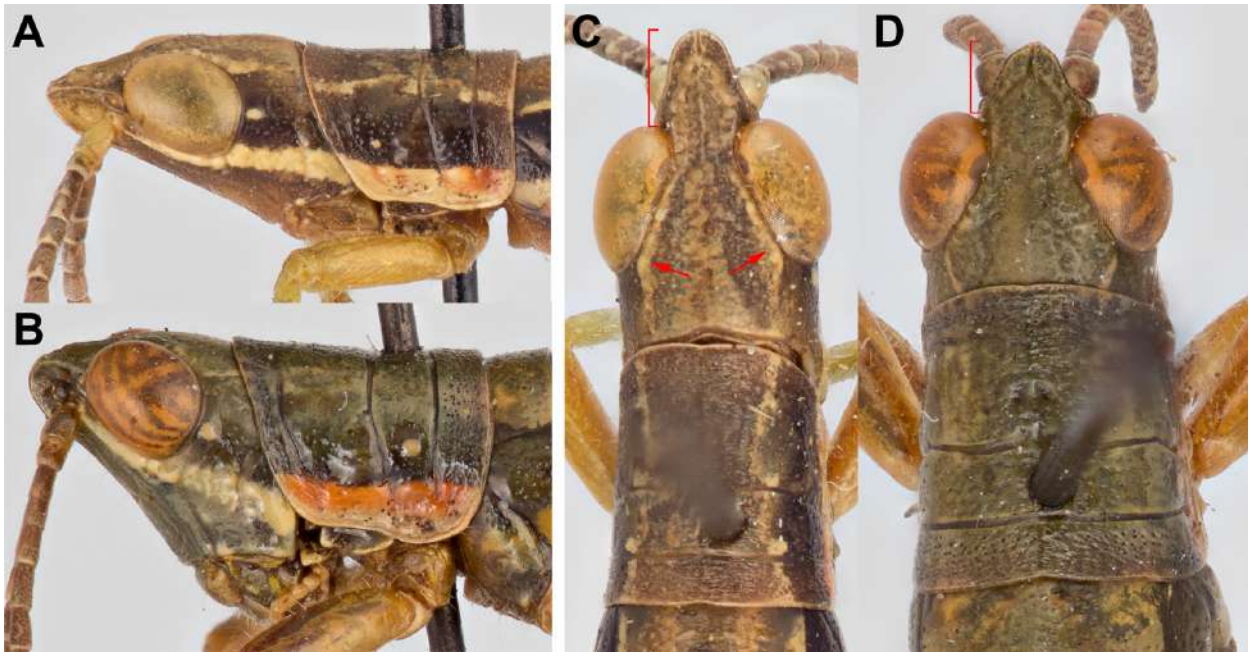

FIGURE 11. Lateral and dorsal views of the head for (A, C) *Neorthacris*; (B, D) *Orthacris*.

12'. A row of tubercles present in the lateral side of the head behind eyes (Fig. 13B); body form variable; head variable; epiphallus variable; color otherwise **13**

13. Body distinctly fusiform; head distinctly conical; head length from a dorsal view shorter than the length of pronotum; tegmina and hind wings greatly reduced, barely reaching the bases of the hind femora; overall light olive with duller, suffused areas (Karnataka, Goa, Maharashtra) . . . . . ***Feacris*** **Kevan, 1969**
(2 species known: *F. malabarensis*, *F. reducta*)

13'. Body cylindrical to subfusiform; head somewhat dorsoventrally flattened (Fig. 13B); head length from a dorsal view as long as the length of pronotum (Fig. 13B, D); tegmina length variable **14**

14. Tegmina reaching one third of hind femur from the base; lophi of epiphallus broad and projecting outward (Fig. 14B); light to dark brown with few black spots. (Fig. 22E, G) (India) . . . . . ***Zarytes*** **Bolívar, 1904**
(1 species known: *Z. squalinus*)

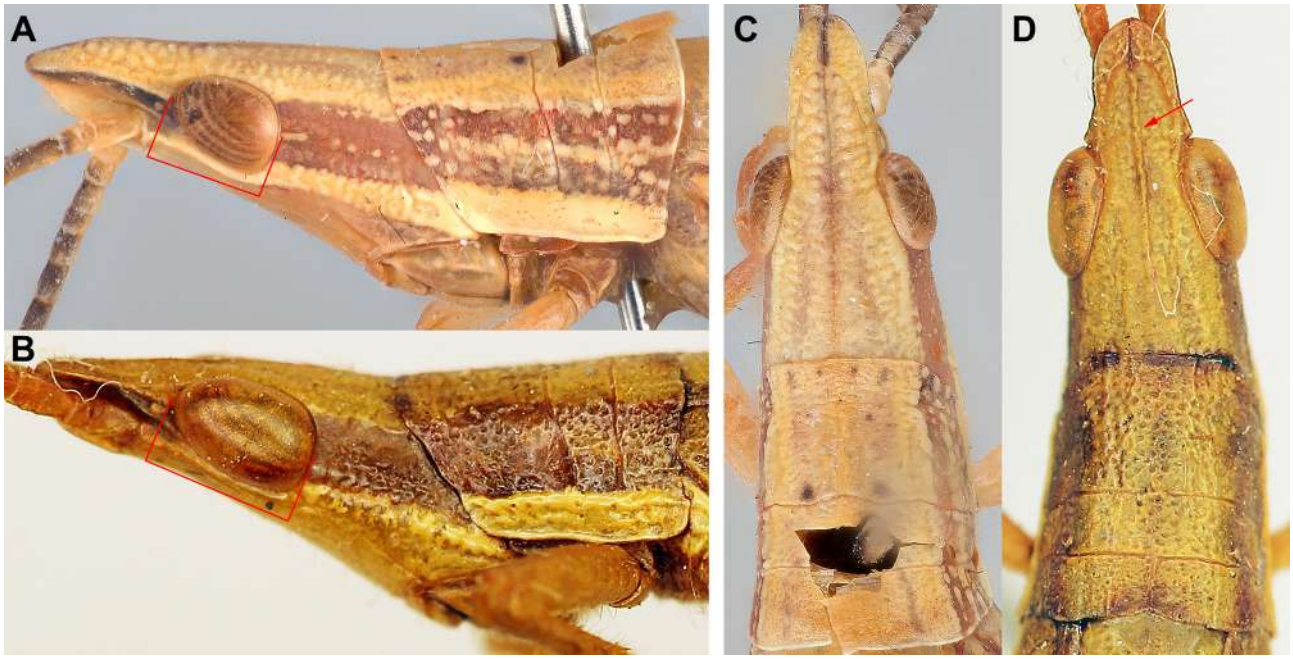

FIGURE 12. Lateral and dorsal views of the head for (A, C) *Colemania*; (B, D) *Ramakrishnaia.*

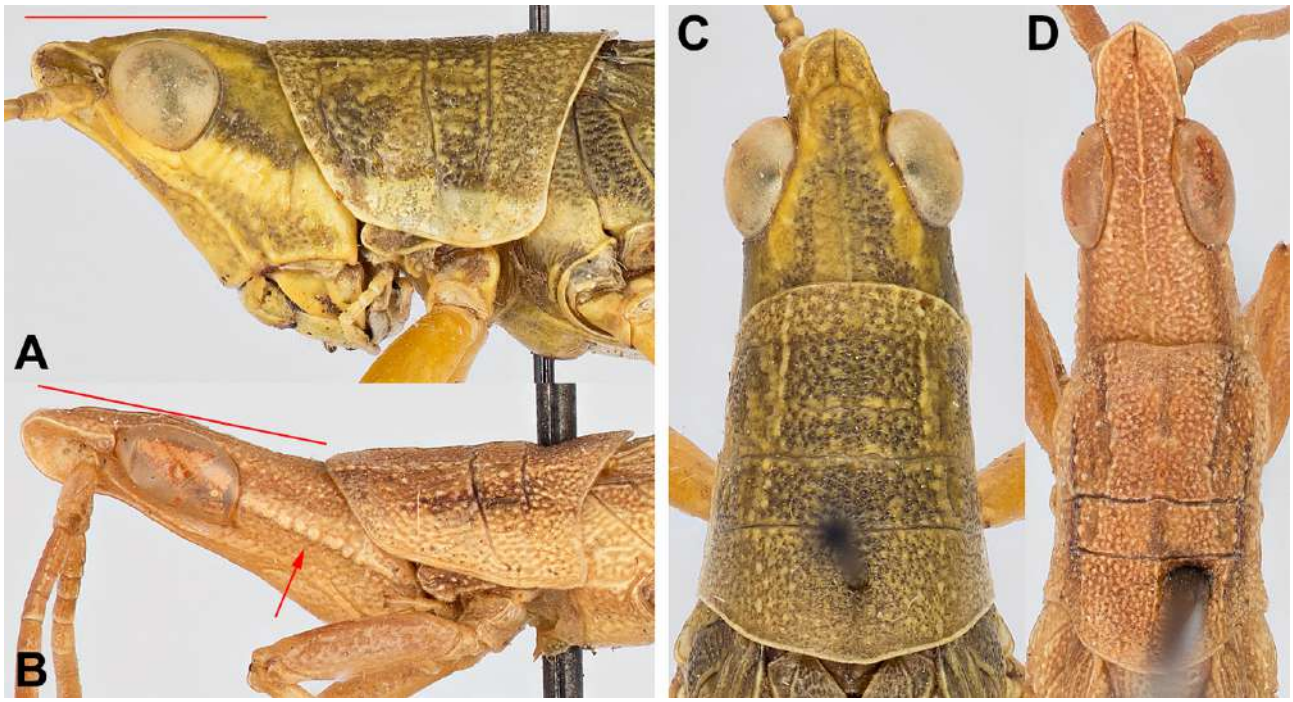

FIGURE 13. Lateral and dorsal views of the head for (A, C) *Chlorizeina*; (B, D) *Zarytes.*

14'. Tegmina barely reaching hind femur; gray-brown colored, irregularly covered with very small partly white granules (Tamil Nadu) . . . . . ***Plerisca* Bolívar, 1904**
(1 species known only from female specimens: *P. sudindica*)

15. Pronotum with a bilobed tubercle and spines in prozona (Fig. 15E); large insect with unmistakable spines, tubercles, and contrasting color; dark and light green body; pronotum with red, orange and yellow sometimes black also present; tegmina green with yellow dots (Fig. 23A, C) (Pakistan, Sri Lanka, Bangladesh, India, Nepal) . . . . . ***Aularches* Stål, 1873**
(1 species known: *A. miliaris*)

15'. Pronotum unarmed without a bilobed tubercle nor spines in prozona; body size variable; color patterns otherwise (Fig. 15A–D) **16**

16. A row of tubercles present in the lateral side of the head behind eyes (Fig. 15A, B); head in lateral view highly slanted (Fig. 15A, B) **17**

16'. A row of tubercles absent in the lateral side of the head behind eyes (Fig. 15C–E); head in lateral view oval (Fig. 15D, E) or only slightly slanted (Fig. 15C) **20**

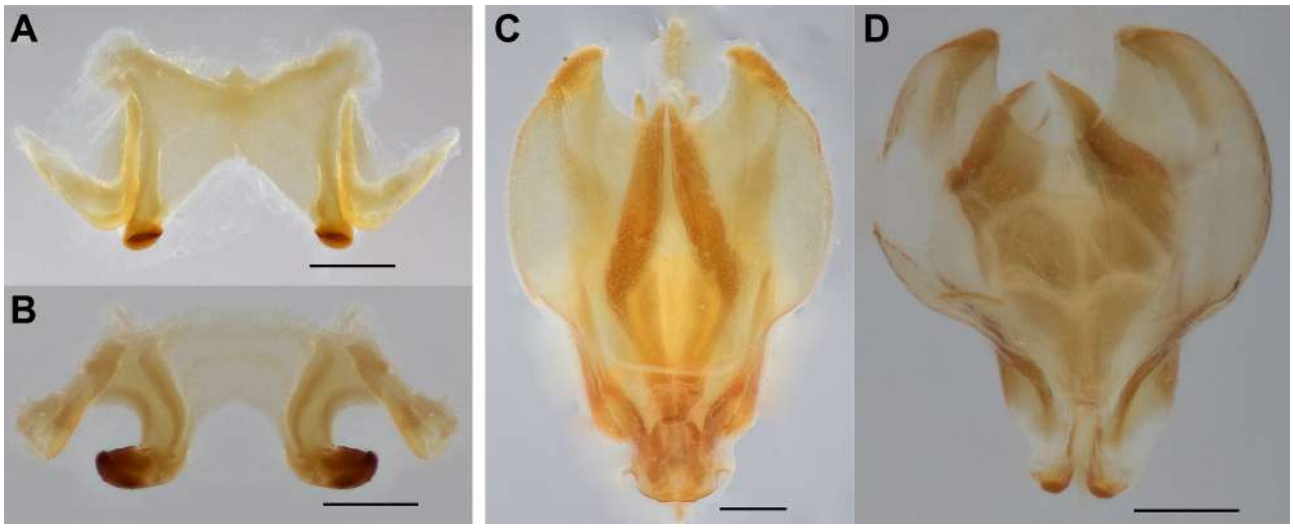

FIGURE 14. Epiphallus and dorsal view of phallic complex of (A, C) *Chlorizeina*; (B, D) *Zarytes.* Scale bar = 0.5mm.

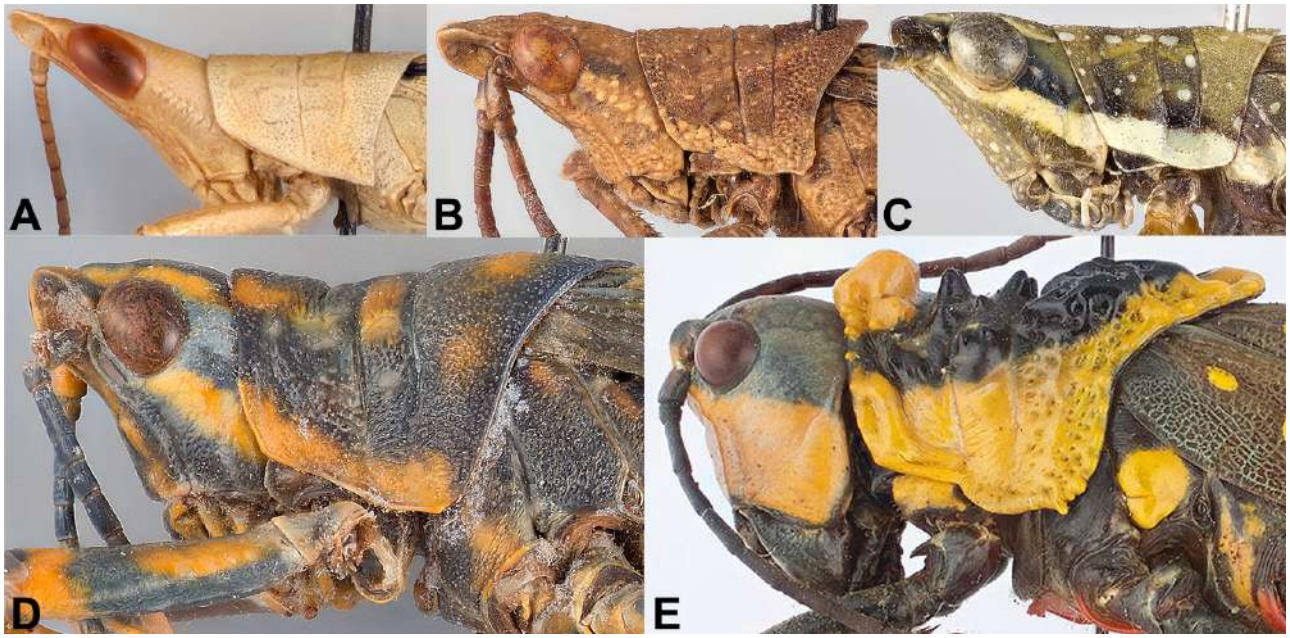

FIGURE 15. Lateral view of head and pronotum. (A) *Pseudomorphacris*; (B) *Pyrgomorpha*; (C) *Pterorthacris*; (D) *Poekilocerus;* (E) *Aularches*.

17. A row of tubercles present in the lateral side of the head behind eyes continuing on to pronotum (Fig. 16A, C); hind margin of pronotum in dorsal view, with a distinct notch in each side (Fig. 16E, G) **18**

17'. Pronotum without a row of tubercles continuing from the head (Fig. 16B, D); hind margin of pronotum in dorsal view, without a distinct notch in each side (Fig. 16F, H) **19**

18. Eyes oval and bulging (Fig. 16A); lateral profile of the head slightly incurved (Fig. 16A); vertex of head in dorsal view duck-

bill-shaped (Fig. 16E); tubercles on head and pronotum prominent; sulcus on pronotum distinct (Fig. 16A); hind margin of pronotum round (Fig. 16E); lophi of epiphallus projecting outward (Fig. 17A); general body brown or green (Fig. 24E, F) (All Indian Subcontinent) . . . . . ***Pyrgomorpha*** **Serville, 1838**
(3 species known: *P. bispinosa*, *P. conica*, *P. inaequalipennis*)

18'. Eyes elliptical and normal (Fig. 16C); lateral profile of the head straight (Fig. 16C); vertex of head in dorsal view broadly projecting and narrowing toward apex (Fig. 16G); tubercles on head and pronotum small; sulcus on pronotum shallow (Fig. 16C); hind margin of pronotum broadly angular (Fig. 16G); epiphallus bridge joined (Fig. 17C); light green body with cream ray of tubercles under eye up to lateral pronotum (Fig. 23B, D) (All Indian Subcontinent) . . . . . ***Atractomorpha*** **Saussure, 1862**
(7 species known: *A. acutipennis*, *A. angusta*, *A. burri*, *A. crenulata*, *A. himalayica*, *A. psittacina*, *A. sinensis*)

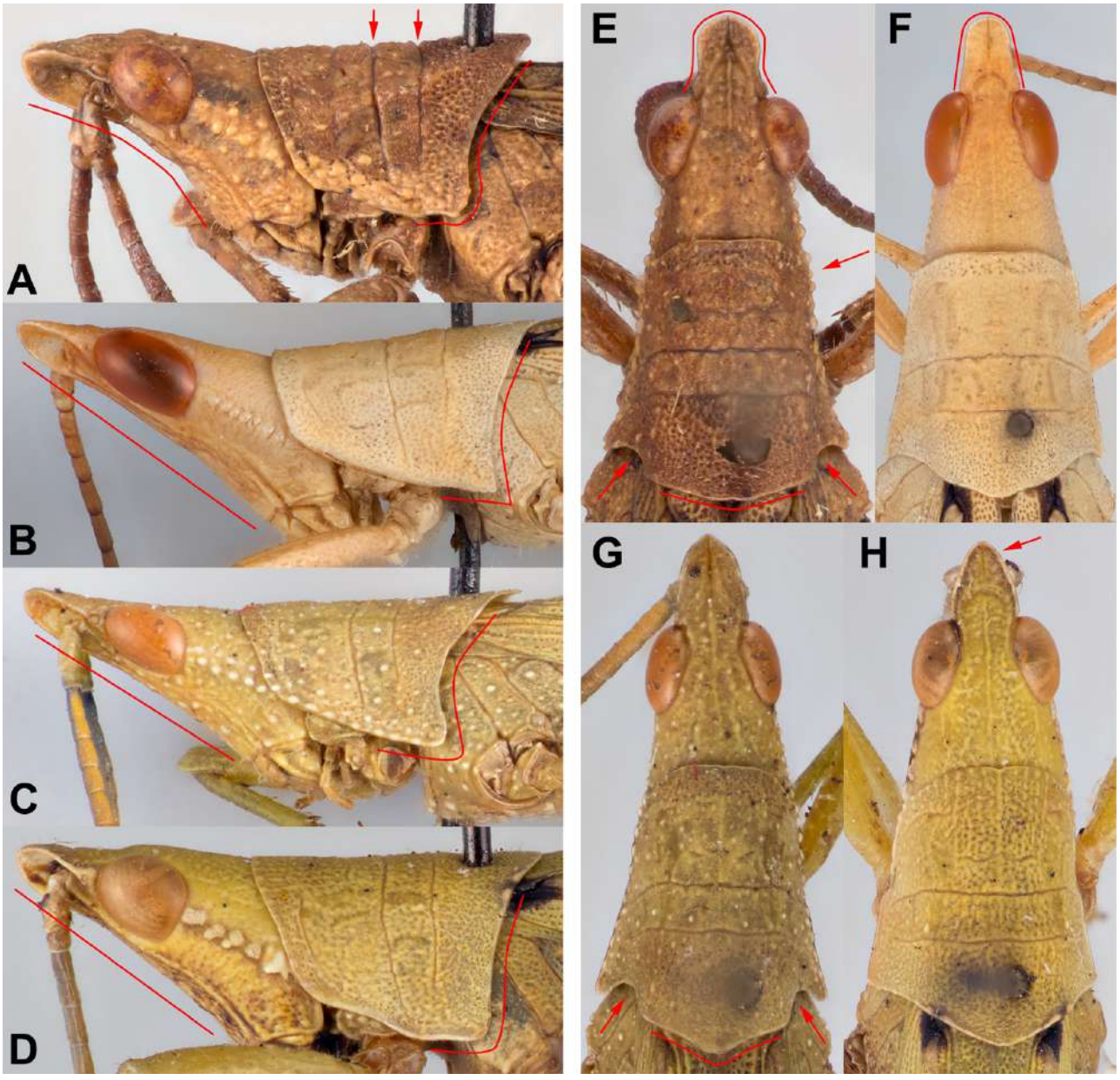

FIGURE 16. Lateral and dorsal views of the head for (A, E) *Pyrgomorpha*; (B, F) *Pseudomorphacris*; (C, G) *Atractomorpha*; (D, H) *Tagasta.*

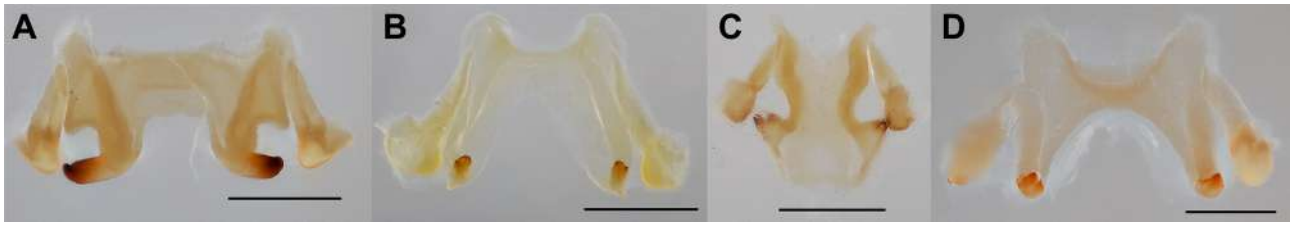

FIGURE 17. Epiphalli of (A) *Pyrgomorpha*; (B) *Pseudomorphacris*; (C) *Atractomorpha*; (D) *Tagasta.* Scale bar = 0.5mm.

19. A row of tubercle in the lateral side of the head regular (Fig. 16B); vertex of head in dorsal view broadly projecting and round (Fig. 16F); eyes prominent and elongated (Fig. 16B); lateral hind margin of pronotum sharply angular (Fig. 16B); marginal area of hind femur expanded, as wide as medial area (Fig. 18A); male cerci narrow and sharply bent up (Fig. 18C); light green with tinge of orange in legs and antennae (Fig. 23E, G) (India, Bangladesh) . . . . . ***Pseudomorphacris*** **Carl, 1916** (1 species known: *P. notata*)

FIGURE 18. Hind femur and male cerci of (A, C) *Pseudomorphacris*; and (B, D) *Tagasta*.

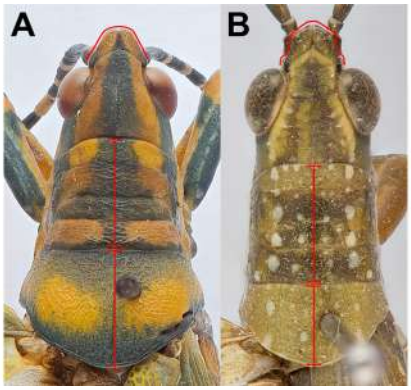

FIGURE 19. Dorsal view of head and pronotum of (A) *Poekilocerus* and (B) *Pterorthacris*.

19'. A row of tubercle in the lateral side of the head large and irregular (Fig. 16D); vertex of head in dorsal view broadly projecting and narrowing toward apex (Fig. 16H); eyes oval (Fig. 16D); lateral hind margin of pronotum broadly round (Fig. 16D); marginal area of hind femur narrow and normal (Fig. 18B); male cerci triangular (Fig. 18D); light to dark green body with tinge of orange in it (Fig. 23F, H); cream colored tubercles under eye (India, Bangladesh). . . . . ***Tagasta*** **Bolívar, 1905** (3 species known: *T. indica*, *T. longipenne*, *T. marginella*)

20. Large body; fastigium in dorsal view broadly projecting (Fig. 19A); the width of prozona in dorsal view narrower than the width of metazona; length of prozona in dorsal view as long as the length of metazona (Fig. 19A); pronotum texture foveolate; green color with patches of yellow or orange on head, thorax, abdomen and legs, tegmina green with yellow markings and ting of pink on back (Figs. 1, 24A, C); (Pakistan, Nepal, India) . . . . . ***Poekilocerus*** **Serville, 1831** (2 species known: *P. geniplanus*, *P. pictus*)

20'. Medium body; fastigium in dorsal view, broadly triangular at the apex with parallel sides basally (Fig. 19B); the width of prozona in dorsal view as wide as the width of metazona; length of prozona in dorsal view longer than the length of metazona (Fig. 19B); dorsum of pronotum covered with white tubercles; dark to light green with white spots upon whole pronotum with tinge of black on lateral side; legs orange to brown, antennomeres green ending in yellows; creamy yellow line below eyes extending up to lateral pronotum; abdomen coloration pattern contrasting (Fig. 24B, D) (Bihar) . . . . . ***Pterorthacris*** **Uvarov, 1921** (1 species known: *P. subcallosa*)

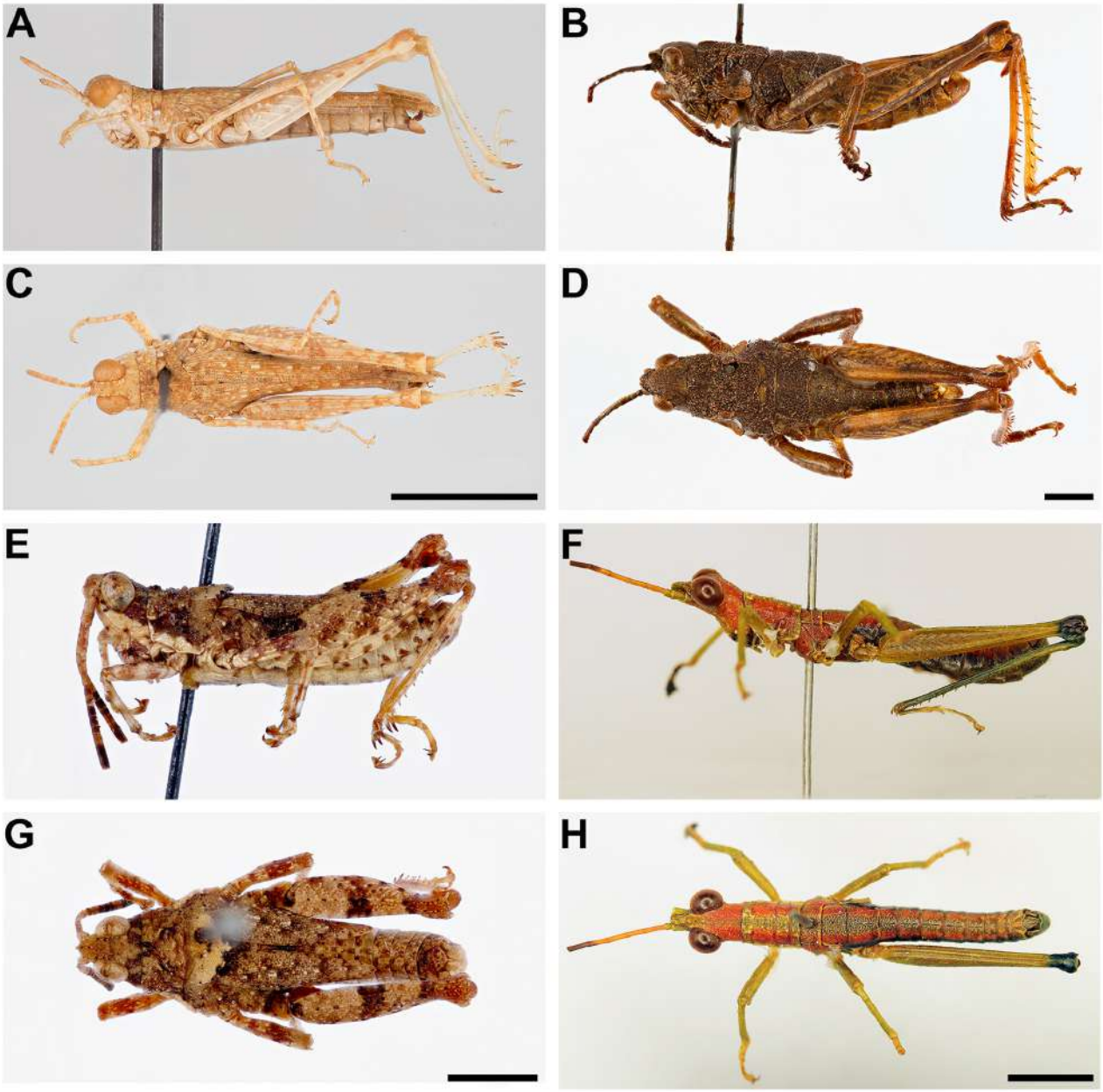

FIGURE 20. Lateral and dorsal views of Pyrgomorphidae species occurring in Indian subcontinent. (A, C) *Tenuitarsus angustus*; (B, D) *Mekongiella kingdoni*; (E, G) *Chrotogonus trachypterus*; (F, H) *Rakwana ornata.* Scale bar = 5mm.

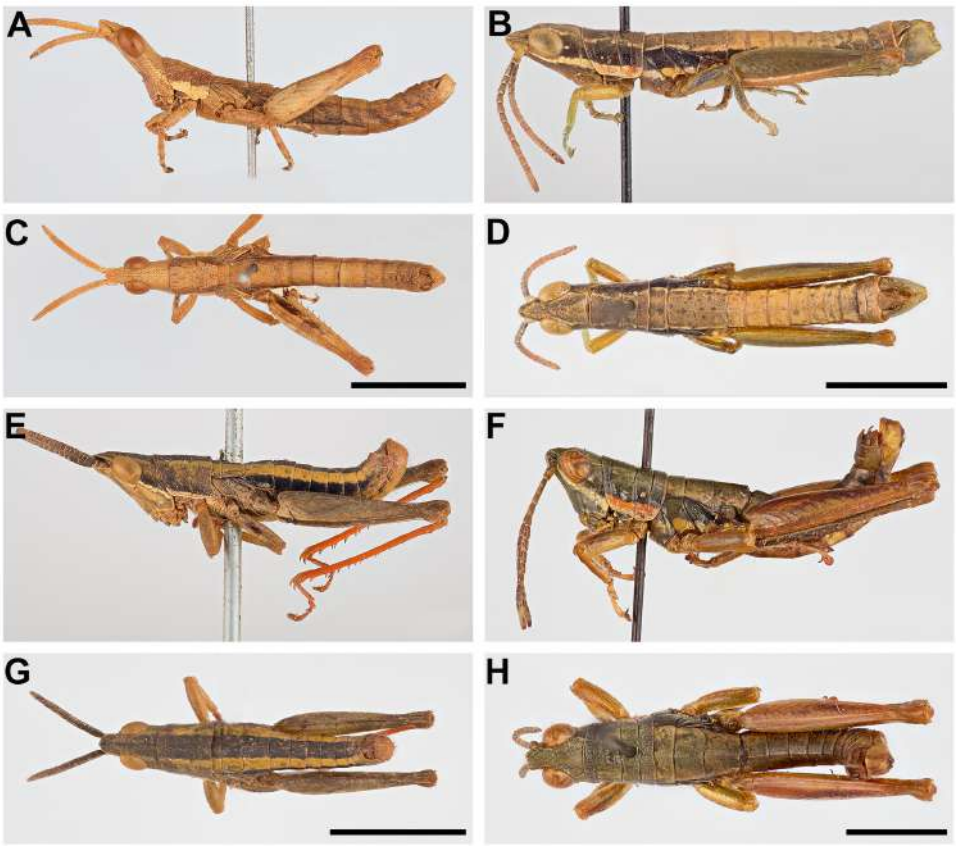

FIGURE 21. Lateral and dorsal views of Pyrgomorphidae species occurring in Indian subcontinent. (A, C) *Anarchita aptera*; (B, D) *Neorthacris acuticeps acuticeps*; (E, G) *Nilgiracris raoi*; (F, H) *Orthacris incongruens*. Scale bar = 5mm.

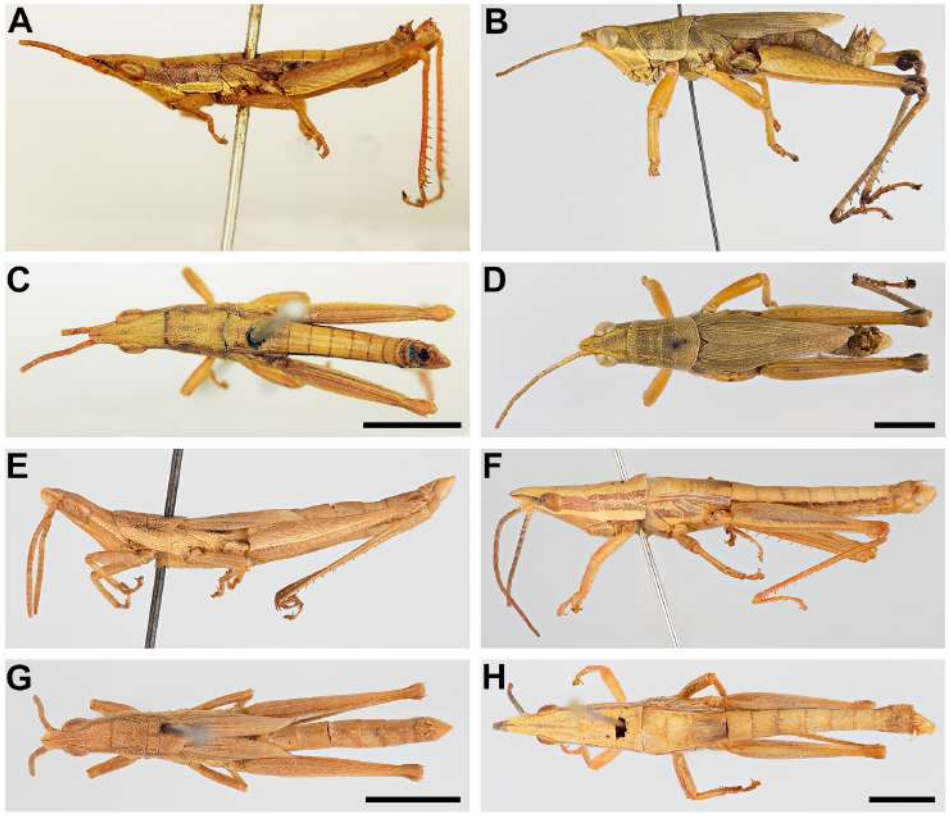

FIGURE 22. Lateral and dorsal views of Pyrgomorphidae species occurring in Indian subcontinent. (A, C) *Ramakrishnaia gracilis*; (B, D) *Chlorizeina unicolor*; (E, G) *Zarytes squalinus squalinus*; (F, H) *Colemania sphenarioides*. Scale bar = 5mm.

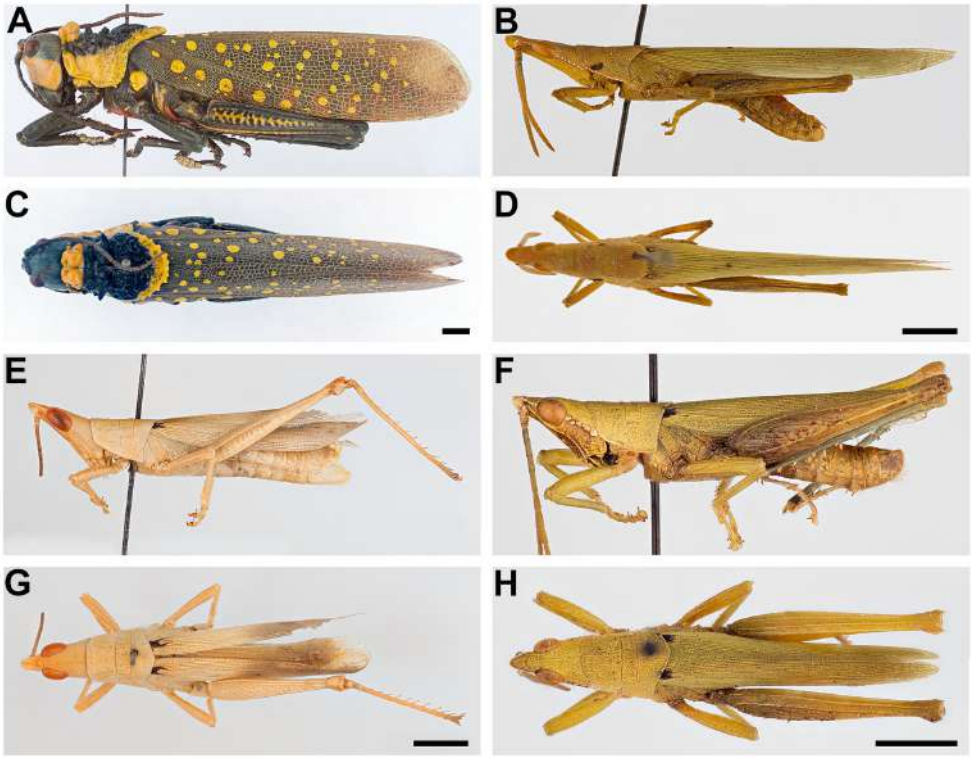

FIGURE 23. Lateral and dorsal views of Pyrgomorphidae species occurring in Indian subcontinent. (A, C) *Aularches miliaris*; (B, D) *Atractomorpha acutipennis acutipennis*; (E, G) *Pseudomorphacris notata*; (F, H) *Tagasta indica.* Scale bar = 5mm.

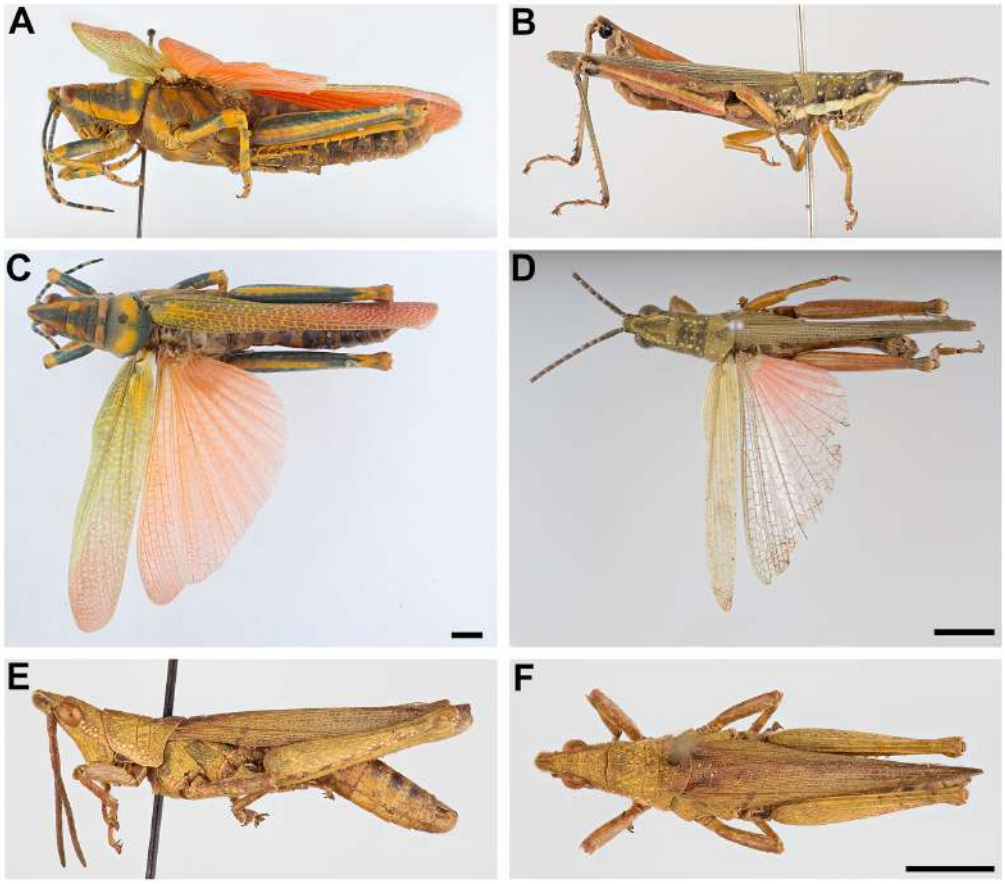

FIGURE 24. Lateral and dorsal views of Pyrgomorphidae species occurring in Indian subcontinent. (A, C) *Poekilocerus pictus*; (B, D) *Pterorthacris subcallosa*; (E, F) *Pyrgomorpha vignaudii*. Scale bar = 5mm.

Discussion

In this study, we have provided an illustrated key to genera for Pyrgomorphidae of the Indian subcontinent. While there have been a small number of regional keys available for this group, our study is the first to include the entire geographic region of the Indian subcontinent. We show that the generic identification of the 21 Pyrgomorphidae genera can be easily achieved based on the examination of external morphological traits. We hope that this illustrated identification key can positively contribute to the understanding of the grasshopper fauna in this important biogeographic region.

Acknowledgements

We would like to thank the curators and collection managers of the following institutions for loaning valuable specimens: Jason Weintraub (Academy of Natural Sciences, Philadelphia, PA, U.S.A.); George Beccaloni (the Natural History Museum, London, U.K.); Simon Poulain (Muséum National d'Histoire Naturelle, Paris, France). This work was supported by the Orthoptera Species File Grant 'Enhancing digital content for Pyrgomorphidae (Orthoptera: Caelifera) in the Orthoptera Species File' to HS and RMP, as well as the United States Department of Agriculture (Hatch Grant TEX0-1-6584) to HS. RMP was supported by CONACYT scholarship number 409158 and SZ was supported by the International Research Support Initiative Program (IRSIP) of the Higher Education Commission of Pakistan.

References

Ayyar, T.V.R. (1940) *Handbook of Entomology for South India*. Government Press, Madras, 528 pp.

Briggs, J.C. (2003) The biogeographic and tectonic history of India. *Journal of Biogeography*, 30 (3), 381–388. https://doi.org/10.1046/j.1365-2699.2003.00809.x

Chandra, K., Shishodia, M.S. & Gupta, S.K. (2010) Diversity of Orthoptera (Insecta) in India: State of our knowledge. *In:* Gupta, R.K. (Ed.), *Advancements in Invertebrate Taxonomy and Biodiversity*. Agrobios, odhpur, Rajasthan, pp. 43–80.

Chopard, L. (1924) On some cavernicolous Orthoptera and Dermaptera from Assam & Burma. *Records of the Indian Museum* 26, 81–92.

Cigliano, M.M., Braun, H., Eades, D.C. & Otte, D. (2020) Orthoptera Species File. Version 5.0/5.0. 02 February 2020. Available from: http://Orthoptera.SpeciesFile.org (accessed 25 November 2020)

Eades, D.C. (2000) Evolutionary relationships of phallic structures of Acridomorpha (Orthoptera). *Journal of Orthoptera Research*, 9, 181–210. https://doi.org/10.2307/3503648

Ghosh, A.K. (1996) Insect biodiversity in India. *Oriental Insects*, 30, 1–10. https://doi.org/10.1080/00305316.1996.10433828

Haldhar, S.M. & Swaminathan, R. (2012) A key and systematic account of the short horned grasshopper (Orthoptera: Pyrgomorphidae) in south western Rajastan. *Journal of Insect Science*, 25 (2), 164–176.

Hubbell, T.H. (1960) The sibling species of the Alutacea group of the bird-locust genus *Schistocerca* (Orthoptera, Acrididae, Cyrtacanthacridinae). *Miscellaneous Publications, University of Michigan Museum of Zoology*, 116, 1–91.

Kevan, D.K.M. (1968) A revision of the Pseudomorphacridini (Orthoptera: Acridoidea: Pyrgomorphidae). *Oriental Insects*, 2 (2), 141–154. https://doi.org/10.1080/00305316.1968.10433878

Kevan, D.K.M. (1969) A preliminary revision of the Asiatic Chlorizeinini (Orthoptera: Acridoidea: Pyrgomorphidae). *Transactions of the American Entomological Society*, 94, 355–378.

Kevan, D.K.M. & Akbar, S.S. (1964) The Pyrgomorphidae (Orthoptera: Acridoidea): their systematics, tribal divisions and distribution. *The Canadian Entomologist*, 96, 1505–1536. https://doi.org/10.4039/Ent961505-12

Kevan, D.K.M., Akbar, S.S. & Chang, Y.C. (1970) The concealed copulatory structures of the Pyrgomorphidae (Orth. Acridoidea). Part II—Tribes Fijipyrgini, Verduliini, Brunniellini, Psednurini, Mitricephalini, Geloiini, Sagittacridini, Gymnohippini and Malagasphenini. *Eos*, 45, 173–228.

Khan, I.K., Usmani, M.K., Usmani, S. & Naz, H. (2018) Taxonomic studies on gaudy grasshoppers (Orthoptera: Pyrgomorphoidea: Pyrgomorphidae) from the Northeastern states of India. *Journal of Threatened Taxa*, 10 (15), 12953–12968. https://doi.org/10.11609/jott.3891.10.15.12953-12968

Kirby, W.F. (1910) *A Synonymic Catalogue of Orthoptera (Orthoptera Saltatoria)*. British Museum (Natural History), London,

674 pp.
Kirby, W.F. (1914) *The Fauna of British India, including Ceylon and Burma, Orthoptera (Acridiidae). Vol. 1*. British Museum (Natural History), London, 276 pp.
https://doi.org/10.5962/bhl.title.109305
Mandal, S.K., Dey, A. & Hazra, A.K. (2007) *Pictorial Handbook on Indian Short-homed Grasshopper Pests (Acridoidea: Orthoptera)*. Zoological Survey of India, Kolkata, 57 pp.
Mariño-Pérez, R. & Song. H. (2018) Phylogeny of the grasshopper family Pyrgomorphidae (Caelifera, Orthoptera) based on morphology. *Systematic Entomology*, 43, 90–108.
https://doi.org/10.1111/syen.12251
Priya, A.V. & Narendran, T.C. (2003) A key and checklist of the genera of short horned grasshopper (Orthoptera: Acridoidea) of Kerala. *Entomon*, 28, 223–230.
Schmidt, G.H. (2004) A new species of *Plerisca* from South India (Orthoptera, Pyrgomorphidae). *Fragmenta entomologica*, 36, 17–24.
Shishodia, M.S., Chandra, K. & Gupta, S.K. (2010) An annotated checklist of Orthoptera (Insecta) from India. *Records of the Zoological Survey of India Occasional Paper No.* 314, 1–366.
Song, H. (2010) Grasshopper systematics: Past, present and future. *Journal of Orthoptera Research*, 19, 57–68.
https://doi.org/10.1665/034.019.0112
Song, H. & Mariño-Pérez, R. (2013) Re-evaluation of taxonomic utility of male phallic complex in higher-level classification of Acridomorpha (Orthoptera: Caelifera). *Insect Systematics and Evolution*, 44, 241–260.
https://doi.org/10.1163/1876312X-04402008
Song, H., Amédégnato, C., Cigliano, M.M., Desutter-Grandcolas, L., Heads, S.W., Huang, Y., Otte, D. & Whiting, M.F. (2015) 300 million years of diversification: elucidating the patterns of orthopteran evolution based on comprehensive taxon and gene sampling. *Cladistics*, 31, 621–651.
https://doi.org/10.1111/cla.12116
Sultana, R. & Wagan, M.S. (2015) *Grasshoppers and locusts of Pakistan*. Higher Education Commission-Pakistan, Islamabad, 200 pp.
Tandon, S.K. (1976) A check-list of the Acridoidea. *Records of Zoological Survey of India*, *Occasional Paper*, 3, 1–48.
Tandon, S.K. & Shishodia, M.S. (1969) On a collection of Acridoidea (Orthoptera) from the Nagarjuna Sagar Dam Area. *Oriental Insects*, 3, 265–267.
https://doi.org/10.1080/00305316.1969.10433915
Tandon, S.K. & Shishodia, M.S. (1989) *Insecta: Orthoptera: Acridoidea*. *In*: *Fauna of Orissa Part 2, State Fauna Series 1*. Zoological Survey of India, Calcutta, pp. 93–145.
Usmani, M.K. & Shafee, S.A. (1985) A new species of the genus *Ramakrishnaia* I. Bolivar (Orthoptera: Pyrgomorphidae) from India. *International Journal of Entomological Research*, 27, 204–207.
Uvarov, B.P. (1925) Grasshoppers (Orthoptera: Acrididae) from the Mount Everest. *Annals and Magazine of Natural History*, 16, 165–173.
https://doi.org/10.1080/00222932508633283
Uvarov, B.P. (1929) Acrididen (Orthoptera) aus Sud-Indien. *Revue suisse de Zoologie*, 36, 533–563.
https://doi.org/10.5962/bhl.part.117634
van Hinsbergen, D.J., Lippert, P.C., Dupont-Nivet, G., McQuarrie, N., Doubrovine, P.V., Spakman, W. & Torsvik, T.H. (2012) Greater India Basin hypothesis and a two-stage Cenozoic collision between India and Asia. *Proceedings of the National Academy of Sciences*, 109 (20), 7659–7664.
https://doi.org/10.1073/pnas.1117262109