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Contents

Cover photograph: *Paracarausius damingshanensis* **sp. nov.** 大明山副竹異蜻, adult male, Damingshan, Guangxi, China, 30 July 2012, photo by George Ho Wai-Chun.

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Contribution to the knowledge of Chinese Phasmatodea XV: New taxa and new nomenclature of the subfamilies Necrosciinae and Lonchodinae (Lonchodidae) from the Phasmatodea of China II

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ABSTRACT

This paper describes six new taxa including one new subspecies, two new species and three new genera from the Necrosciinae and Lonchodinae of China. They are namely, *Neoasceles hainanensis elongatus* **subsp. nov.**, *Korinnis xizangensis* **sp. nov.**, *Paracarausius damingshanensis* **sp. nov.**, *Longicarausius* **gen. nov.**, *Neopericentrus* **gen. nov.** and *Paracarausius* **gen. nov.** A total of 17 new combinations are suggested: *Korinnis notata* (Chen & Zhang, 2008) **comb. nov.** [*Aruanoidea*], *Longicarausius gracilicornis* (Ho, 2021) **comb. nov.** [*Carausius*], *Longicarausius luchunensis* (Ho, 2017) **comb. nov.** [*Carausius*], *Longicarausius yingjiangensis* (Ho, 2017) **comb. nov.** [*Carausius*], *Marmessoidea adelpha* (Günther, 1940) **comb. nov.** [*Sipyloidea*], *Neoasceles hainanensis hainanensis* (Chen & He, 2002) **comb. nov. & sen. str.** [*Sosibia*], *Neopericentrus wenxuani* (Ho, 2017) **comb. nov.** [*Neosinophasma*], *Paracarausius novus* (Ho, 2017) **comb. nov.** [*Carausius*], *Paracarausius rugosus* (Brunner von Wattenwyl, 1907) **comb. nov.** [*Carausius*], *Paramarmessoidea alata alata* (Ho, 2018) **comb. nov.** [*Marmessoidea*], *Paramarmessoidea alata elongata* (Ho, 2018) **comb. nov.** [*Marmessoidea*], *Paramarmessoidea guangdongensis* (Ho, 2013) **comb. nov.** [*Marmessoidea*], *Paramarmessoidea hainanensis hainanensis* (Ho, 2016) **comb. nov.** [*Marmessoidea*], *Paramarmessoidea hainanensis yinggelingensis* (Ho, 2016) **comb. nov.** [*Marmessoidea*], *Paramarmessoidea liuxingyuei* (Ho, 2018) **comb. nov.** [*Marmessoidea*], *Spinomarmessoidea mista* (Chen & He, 2008) **comb. nov.** [*Aruanoidea*], and *Varieganecroscia dianica* (Ho, 2017) **comb. nov.** [*Necroscia*]. One new synonym is suggested: *Spinomarmessoidea damingenis* Gao & Li, 2023 **syn. nov.** is synonymised with *Marmessoidea mista* (Chen & He, 2008) **comb. nov.** Korinnini Günther, 1953, *Korinnis* Günther, 1932, *Neoasceles* Seow-Choen, 2016, *Paramarmessoidea* Seow-Choen, 2021, *Varieganecroscia* Seow-Choen, 2016 and *Paracarausius rugosus* (Brunner von Wattenwyl, 1907) **comb. nov.** are for the first time recorded from China. Species list for Chinese *Korinnis*, *Marmessoidea* Brunner von Wattenwyl, 1893, *Neoasceles*, *Paramarmessoidea*, *Spinomarmessoidea*, and *Varieganecroscia* are provided.

Key words: stick insects, China, taxonomy, new genus, new species, new subspecies, new combinations, new synonym, new record

INTRODUCTION

Lonchodidae Brunner von Wattenwyl, 1893 is the largest stick insect family within the Phasmatodea, with two subfamilies, namely Necrosciinae Brunner von Wattenwyl, 1893, and Lonchodinae Brunner von Wattenwyl, 1893 (Brock and Büscher, 2022; Brock et al., 2024). In China, Lonchodidae has the highest diversity of taxa and more than 250 species have been described (Chen and He, 2008; Hennemann et al., 2008; Brock et al., 2024).

This study is additional to the previous studies of the Necrosciinae and Lonchodinae from China (Ho, 2017a, 2020), the present work describing six new taxa including three new genera, two new species and one new subspecies. It proposes 17 new combinations, one new synonym, and reports six new records (one tribe, four genera and one species) from the Necrosciinae and Lonchodinae in China.

MATERIALS & METHODS

The systematic treatment is according to Otte and Brock (2005), Komoto et al. (2011), Bradler et al. (2014), Bradler and Buckley (2018), Robertson et al. (2018), Bank and Bradler (2022), Brock and Büscher (2022) and Brock et al. (2024). Morphological terms are based on Bragg (2001), Hennemann and Conle (2008), and Brock and Büscher (2022). The Chinese names of all species mentioned in this paper have been provided and standardised for consistent use in the literature, enabling other researchers to reference them in the future. Measurements are provided in millimetres (mm). The abbreviations used for collections are: HKES: Hong Kong Entomological Society, Hong Kong, China; HBU: Hebei University, Hebei, China; IZCAS: Institute of Zoology, Chinese Academy of Sciences, Beijing, China; SYSBM: Museum of Biology, Sun Yat-Sen University, Guangzhou, China; and ZFMK: Zoologisches Forschungsmuseum Alexander Koenig, Bonn, Germany.

RESULTS

Lonchodidae Brunner von Wattenwyl, 1893

Necrosciinae Brunner von Wattenwyl, 1893

Korinnini Günther, 1953

Type-genus: *Korinnis* Günther, 1932: 66.

Distribution: China, India, Malaysia, Philippines and Thailand.

Notes: Korinnini Günther, 1953 consists of two genera and eight species (Brock and Büscher, 2022; Brock et al., 2024). Korinnini and *Korinnis* Günther, 1932 are firstly reported from China. The Chinese name for both the tribe and genus were subsequently adopted from Cai (1987).

Korinnis Günther, 1932

Type-species: *Korinnis potameis* Günther, 1932: 67, by original designation.

Distribution: China, India, Malaysia, Philippines and Thailand.

Notes: *Korinnis notatus* (Chen & Zhang, 2008) **comb. nov.** is here transferred to *Korinnis* Günther, 1932 from the genus *Necroscia* Audinet-Serville, 1838, based on the morphological and genital characteristics. Currently two species are known from China.

Species included in China:

1. *Korinnis notatus* (Chen & Zhang, 2008: 245, figs. 1-3) **comb. nov.** 刺胸婆羅蝽 [*Aruanoidea notata*; China (Yunnan)]

2. *Korinnis xizangensis* **sp. nov.** 西藏婆羅蝽 [China (Xizang)]

Korinnis xizangensis sp. nov. (Figs. 1-3)

Types: Holotype, ♂, Beibeng, Motuo, Xizang, China, 20 August 2013, Wu Chao (IZCAS); Paratype, 1♂, same data as holotype (HKES).

Diagnosis: *Korinnis xizangensis* **sp. nov.** can be separated from other species by the presence of curved spines on the pronotum, the unarmed mesonotum and the pale white anal region of alae. *Korinnis xizangensis* **sp. nov.** is similar to the general appearance of *K. notatus* (Chen & Zhang, 2008) **comb. nov.**, but can be separated by the distinctly larger size, the presence of a pale spot on tegmina, the pale white anal region of alae and the black apices of femora and tibiae.

Description of male (Figs. 1-3): Small size. General colour of body and legs yellowish-brown. Body slender, sparsely covered with short bristles.

Head: Oval, sparsely covered with small granules. Compound eyes small and rounded. Occiput flat. Occipital furrows distinct. Antennae dark brown, long and filiform, surpassing apices of protarsi; scapus as long as third segment, pedicellus shorter than scapus.

Thorax: Pronotum rectangular, longer than wide, anterior margin gently curved inwards, posterior margin truncate, transverse and longitudinal sulci crossing before middle area, with a pair of spines positioned before transverse sulcus, apices pointing forwards, also with a row of enlarged granules along each side of longitudinal sulcus. Mesonotum indistinctly swollen post-medially, densely covered with small granules, with a long furrow along lateral margins. Mesopleurae with small granules. Mesosternum with indistinct granulation. Metapleurae rugose, lacking granulation. Metasternum smooth.

Abdomen: Cylindrical, parallel-sided from second to seventh tergites. Eighth tergum gently expanded posteriorly. Ninth tergum as long as eighth tergum, gently expanded posteriorly. Anal segment shorter than ninth tergum, with a broad U-shaped emargination on posterior margin. Poculum small, cup-shaped, tapering posteriorly, posterior margin pointed and surpassing anterior margin of anal segment. Cerci long and cylindrical, strongly curved inwards, with pointed apices.

Legs: Slender and sparsely covered with short bristles. Unarmed. Apices of all femora and tibiae black. All femora thicker than corresponding tibiae. Profemora curved basally.

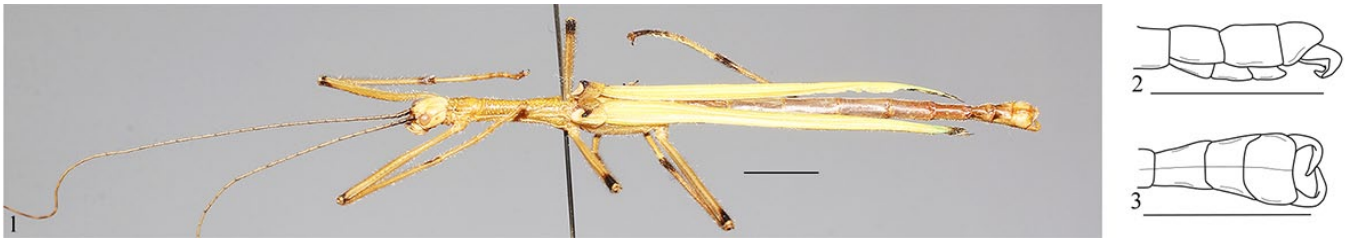
Wings: Tegmina small, with a pale spot in anterior area, posterior margin subtruncate. Alae long, apices reaching anterior area of eighth tergum, costal region green, anal region pale white, apices grayish black.

Measurements: See Table 1.

Distribution: China (Xizang).

Notes: The female is unknown.

Etymology: This new species is named after its type locality, Xizang, China; adjective.



Figures 1-3. *Korinnis xizangensis* **sp. nov.** 1. Male, habitus. 2. Male, apex of abdomen, lateral view. 3. Male, apex of abdomen, dorsal view. Scale bars = 10 mm. Photo and drawings by author.

Necrosciini Brunner von Wattenwyl, 1893

***Marmessoidea* Brunner von Wattenwyl, 1893 (= *Trigonophasma* Kirby, 1904: 436, synonymised by Brock, 1999: 175)**

Type-species: *Necroscia marmessus* Westwood, 1859: 49, by original designation.

Distribution: China, India, Indonesia, Malaysia, Philippines, Singapore and Vietnam.

Notes: Currently three species are recognised in China.

Species included in China:

1. *Marmessoidea adelpha* (Günther, 1940: 245) **comb. nov.** 寬翅瑪異螅 [*Sipyloidea*; China (Fujian)]

2. *Marmessoidea bispina* (Redtenbacher, 1908) 雙刺瑪異螅 [*Asceles bispinus*; China (Hainan, Guangxi, Zhejiang, Fujian, Guizhou & Yunnan) & Vietnam]

3. *Marmessoidea casignetus* (Westwood, 1859) 翅突瑪異螅 [*Necroscia*; China (Yunnan) & India (Assam)]

***Marmessoidea adelpha* (Günther, 1940) comb. nov.**

Sipyloidea adelpha, Günther, 1940: 245; Bi et al., 2001: 256; Otte and Brock, 2005: 316; Chen and He, 2008: 177; Hennemann et al., 2008: 38; Lampe et al., 2010: 143; Ho, 2017a: 42; Brock and Büscher, 2022: 544.

Type: Holotype, ♂, 2300m, Kuatun (Fukien), 27.40 n. Br. 117.40 ö. L. J. Klapperich, 17 June 1938 (ZFMK).

Distribution: China (Fujian).

Notes: This species is here transferred to *Marmessoidea* Brunner von Wattenwyl, 1893 from the genus *Sipyloidea* Brunner von Wattenwyl, 1893, and may potentially be a synonym of *Marmessoidea bispina* (Redtenbacher, 1908). The validation of this synonym will only be possible after additional specimens are collected from the type locality.

***Neoasceles* Seow-Choen, 2016**

Type-species: *Neoasceles rayi* Seow-Choen, 2016: 160, by original designation.

Distribution: Brunei, China, Indonesia and Malaysia.

Notes: *Neoasceles hainanensis* (Chen & He, 2002) **comb. nov.** is here transferred to *Neoasceles* Seow-Choen, 2016 from the genus *Necroscia* Audinet-Serville, 1838, based on the morphological and genital characteristics. Currently, one species and two subspecies are recognised in China.

Species included in China:

1. *Neoasceles hainanensis* (Chen & He, 2002, in Chen et al., 2002: 107) **comb. nov.** 海南新薔螅 [*Sosibia*; China (Guangxi & Hainan)]

1.1. *Neoasceles hainanensis elongatus* **subsp. nov.** 海南新薔螅 長體亞種 [China (Guangxi)]

1.2. *Neoasceles hainanensis hainanensis* (Chen & He, 2002, in Chen et al., 2002: 107, figs. 9a-b) **comb. nov. & sen. str.** 海南新薔螅 海南亞種 [*Sosibia*; China (Hainan)]

***Neoasceles hainanensis elongatus* subsp. nov.**
(Figs. 4-9)

Types: Holotype, ♀, Shiwandashan, Shangsi, Guangxi, China, 17 July 2016, George Ho Wai-Chun (HKES); Paratypes, 23 eggs (laid by holotype female), same data as holotype (HKES).

	Holotype Male	Paratype Male
Body	47.0	46.0
Head	2.5	2.5
Antennae	43.0	38.0
Pronotum	2.5	2.5
Mesonotum	8.0	8.0
Metanotum	5.5	5.5
Median Segment	2.5	2.5
Tegmina	2.5	2.5
Alae	29.0	30.0
Profemora	12.0	11.5
Mesofemora	9.5	9.0
Metafemora	12.0	12.0
Protibiae	9.5	9.5
Mesotibiae	7.5	7.0
Metatibiae	11.0	11.5

Table 1. Measurements of *Korinnis xizangensis* **sp. nov.**

Diagnosis: *Neoasceles hainanensis elongatus* **subsp. nov.** is similar to the nominate *N. hainanensis hainanensis* (Chen & He, 2002) **comb. nov. & sen. str.**, but it can be distinguished by its larger size, more elongate body (body length shorter than 83 mm in the nominate subspecies), longer subgenital plate, indistinct elevations on the anteroventral and posteroventral carinae of profemora and mesofemora, more apically pointed elevations on the anteroventral carina of metafemora and longer wings in the female.

Description of female (Figs. 4-7): Large size. Body elongate and slender. General colouration of body grayish-green, legs brownish-green with small blackish markings.

Head: Oval, shorter than pronotum, weakly constricted after compound eyes. Sparsely covered with small granules. Vertex and occiput flattened, median and lateral longitudinal furrows distinct, posterior margin with small swellings. Compound eyes small and rounded. Antennae long and filiform; scapus basally flattened, as long as third segment, longer than pedicellus.

Thorax: Sparsely granulated. Pronotum rectangular, longer than wide, anterior margin weakly incurved, posterior margin rounded, transverse and longitudinal sulci crossing before middle area. Mesonotum shorter than combined length of metanotum and median segment, median longitudinal carina distinct, also interspersed with a few enlarged and acute granules. Mesopleurae and metapleurae with a few enlarged and acute granules. Metanotum longer than median segment, shorter than mesonotum.

Abdomen: Cylindrical, tapering posteriorly, lacking granulation. Seventh sternum with two inconspicuous, short, carina-like preopercular organ posteromedially. Eighth tergum shorter than combined length of ninth tergum and anal segment. Anal segment longer than ninth tergum, posterior margin with a small and broad U-shaped emargination, posterolateral angles rounded. Supra-anal plate distinct, small, with median longitudinal carina, tapering posteriorly, posterior margin pointed and projecting over posterolateral angles of anal segment. Subgenital plate scoop-shaped, long, tapering posteriorly, posterior apex emarginated and surpassing the posterior margin of supra-anal plate. Cerci long, cylindrical, apices rounded and projecting over the posterior margin of anal segment.

Legs: Slender and long. Femora thicker than corresponding tibiae. Profemora basally curved, anteroventral and posteroventral carinae inconspicuously waved. Anteroventral and posteroventral carinae of mesofemora inconspicuously waved. Anteroventral carina of metafemora distinctly waved with triangular elevations. Protibiae and mesotibiae lacking elevation. Anteroventral carina of metatibiae distinctly wavy.

Wings: Tegmina small, distinctly elevated pre-medially, posterior margin subtruncate. Alae long, apices reaching posterior area of sixth tergum, costal region grayish green, anal region grayish brown.

Measurements: See Table 2.

Description of egg (Figs. 8-9): Capsule greenish-brown, surface wrinkled; bullet-shaped, posterior pole pointed. Micropylar plate oval, anteriorly and posteriorly pointed. Micropylar cup located at posterior area of micropylar plate. Median line distinct. Operculum flattened, marginally thickened, with a small rounded elevation centrally.

Measurements: Length, 5.2 mm; width, 1.6 mm; height, 1.4 mm.

Distribution: China (Guangxi).

Notes: The male is unknown. Although this new subspecies is only known from one female specimen, the morphological features of the specimen are clearly different from those of the nominate subspecies mentioned in the diagnosis section. Further specimens collected from the type locality are necessary for a better understanding of the relationship with the nominate subspecies.

Etymology: This new subspecies is named for its elongated body in comparison to the nominate subspecies; adjective.

***Paramarmessoidea* Seow-Choen, 2021**

Type-species: *Phasma annulata* Fabricius, 1798: 189, by original designation.

Distribution: China, India, Malaysia, Myanmar, Thailand and Vietnam.

Figures 4-9. *Neoasceles hainanensis elongatus* **subsp. nov.** 4. Female, habitus. 5. Female, head and thorax, lateral view. 6. Female, apex of abdomen, lateral view. 7. Female, apex of abdomen, dorsal view. 8. Egg, lateral view. 9. Egg, dorsal view. Scale bars: habitus, head, thorax and apex of abdomen = 10 mm; egg = 1 mm. Photos and drawings by author.

Notes: *Paramarmessoidea guangdongensis* (Ho, 2013) **comb. nov.**, *P. hainanensis hainanensis* (Ho, 2016) **comb. nov.** and *P. hainanensis yinggelingensis* (Ho, 2016) **comb. nov.** are hereby transferred to *Paramarmessoidea* Seow-Choen, 2021 from the genus *Marmessoidea* Brunner von Wattenwyl, 1893, due to their morphological, genital, and egg characteristics. Currently, two species and two subspecies are recognised in China.

Additionally, two other species and two subspecies from Vietnam, including *P. alata alata* (Ho, 2018: 184, figs. 13-16, 30-31) **comb. nov.** [*Marmessoidea*; Vietnam], *P. alata elongata* (Ho, 2018: 185, fig. 32) **comb. nov.** [*Marmessoidea*; Vietnam], and *P. liuxingyuei* (Ho, 2018: 187, figs. 17-18, 33) **comb. nov.** [*Marmessoidea*; Vietnam], are also here transferred to *Paramarmessoidea* from *Marmessoidea* due to their morphological and genital characteristics.

Species included in China:

1. *Paramarmessoidea guangdongensis* (Ho, 2013a: 532, figs. 3-6) **comb. nov.** 廣東副瑪異螽 [*Marmessoidea*; China (Guangdong)]

2. *Paramarmessoidea hainanensis* (Ho, 2016: 319) **comb. nov.** 海南副瑪異螽 [*Marmessoidea*; China (Hainan)]

2.1. *Paramarmessoidea hainanensis hainanensis* (Ho, 2016: 319, figs. 5-10, 19) **comb. nov.** 海南副瑪異螽 海南亞種 [*Marmessoidea*; China (Hainan)]

2.2. *Paramarmessoidea hainanensis yinggelingensis* (Ho, 2016: 320) **comb. nov.** 海南副瑪異螽 鸚哥嶺亞種 [*Marmessoidea*; China (Hainan)]

***Spinomarmessoidea* Seow-Choen, 2021**

Type-species: *Spinomarmessoidea sharonae* Seow-Choen, 2021: 672, by original designation.

Distribution: China and Malaysia.

Notes: Currently, one species is recognised in China.

Species included in China:

1. *Spinomarmessoidea mista* (Chen & He, 2008: 110, figs. 75a-b) **comb. nov.** 刺粒刺瑪異螽 [*Aruanoidea mista*; = *Spinomarmessoidea damingenis* Gao and Li, 2023 **syn. nov.**; China (Guangdong, Guangxi, Guizhou & Yunnan)]

***Spinomarmessoidea mista* (Chen & He, 2008) comb. nov.**

Aruanoidea mista, Chen and He, 2008: 110, figs. 75a-b.
Necroscia mista, Ho, 2013b: 22, 2017a: 12; Brock and Büscher, 2022: 537.
Spinomarmessoidea damingenis, Gao and Li, 2023: 282, figs. 2-4. **syn. nov.**

Type: Holotype, ♂, Heishiding, Fengkai, Guangdong, China, 10 September 1985, De An (Lan Dean) (SYSBM).

Other material examined: 1 immature ♂, 2 immature ♀, Heishiding, Fengkai, Guangdong, China, 25-27 July 2011, George Ho Wai-Chun (HKES); 2♂, 2♀, Damingshan, Wuming, Guangxi, China, 28-30 July 2012, George Ho Wai-Chun (HKES); 2♀, Jinping, Yunnan, China, 4 September 2016, George Ho Wai-Chun (HKES); 1♂, Dashahe, Daozhen Guizhou, China, 17-26 August 2004, Shi Fuming (HBU).

Distribution: China (Guangdong, Guangxi, Guizhou & Yunnan).

Notes: This species matches the characteristics of *Spinomarmessoidea* Seow-Choen, 2021 and is here transferred from the genus *Necroscia* Audinet-Serville, 1838. *Spinomarmessoidea damingenis* Gao & Li, 2023

	Holotype Female
Body	95.0
Head	6.0
Antennae	84.0
Pronotum	5.5
Mesonotum	13.0
Metanotum	9.0
Median Segment	6.0
Tegmina	13.0
Alae	53.0
Profemora	25.0
Mesofemora	17.0
Metafemora	26.0
Protibiae	27.0
Mesotibiae	16.0
Metatibiae	27.0

Table 2. Measurements of *Neoasceles hainanensis elongatus* **subsp. nov.**

syn. nov. is the corresponding sex of this species and here synonymised. This species may also possibly be found in other provinces, such as Fujian, Hunan, and Jiangxi, in South China, as well as in neighbouring countries like Vietnam.

***Varieganecroscia* Seow-Choen, 2016**

Type-species: *Varieganecroscia bicolor* Seow-Choen, 2016: 248, by original designation.

Distribution: Brunei, China, Indonesia, Malaysia and Sri Lanka.

Notes: *Varieganecroscia dianica* (Ho, 2017) **comb. nov.** is here transferred to *Varieganecroscia* Seow-Choen, 2016 from the genus *Necroscia* Audinet-Serville, 1838, based on the morphological and genital characteristics. Currently, one species is recognised in China.

Species included in China:

1. *Varieganecroscia dianica* (Ho, 2017a: 12, figs. 12-15, 32-39) **comb. nov.** 滇雜斑角臀蝽 [*Necroscia*; China (Yunnan)]

Lonchodinae Brunner von Wattenwyl, 1893

***Longicarausius* gen. nov.**

Type-species: *Carausius luchunensis* Ho, 2017a: 48, by present designation.

Diagnosis: *Longicarausius* **gen. nov.** is similar to *Carausius* Stål, 1875, but can be separated by the slenderer and thinner body, the oblong head, the flattened occiput of head and the less wavy posterodorsal carina of protibiae in both sexes and the smooth egg capsule surface.

Description: Medium-sized for Lonchodinae. Apterous. Body slender, cylindrical, male distinctly slimmer and smaller than female; rugose, with small granulations. Head oblong. Vertex unarmed or with a pair of small horns between compound eyes. Occiput flat. Antennae filiform, slender, apices surpassing middle area of protibiae. Thorax slender, rough and wrinkled, sparsely granulated, also interspersed with a few short, spine-like tubercles or enlarged granules. Pronotum rectangular, longer than wide. Mesonotum elongate and slender, longer than combined length of metanotum and median segment. Metanotum longer than median segment. Abdomen cylindrical, wrinkled and sparsely granulated. Median segment rectangular, longer than wide. Female sixth tergum lacking or with small elevations or crest-like structures post-mediolaterally. Female seventh sternum with a small hump-like, spine-like or horn-like preopercular organ posteromedially. Male anal segment spilt into two semi-tergites, female with emarginated posterior margin. Supra-anal plate distinct in female, indistinct in male. Female subgenital plate scoop-shaped, posterior margin pointed and reaching posterior margin of supra-anal plate. Supra-anal plate small and distinct. Male poculum small, cup-shaped, weakly elevated medially. Cerci short and flattened. Legs slender, lacking noticeable armature. Femora thicker than corresponding tibiae. Anterodorsal and posteroventral carinae of profemora raised. Posteroventral carinae of mesofemora and metafemora with a few small teeth. Posterodorsal carina of protibiae distinctly raised. First segment of protarsi lacking or with a small semi-circular lamella dorsally. Egg capsule oval, surface smooth. Micropylar plate oval. Operculum with closed-stalked and rounded capitulum centrally.

Distribution: China.

Notes: *Longicarausius gracilicornis* (Ho, 2021) **comb. nov.**, *L. luchunensis* (Ho, 2017) **comb. nov.** and *L. yingjiangensis* (Ho, 2017) **comb. nov.** are hereby transferred to *Longicarausius* **gen. nov.** from the genus *Carausius* Stål, 1875. Currently, three species are recognised in this new genus. Once the morphological, genital, and egg characteristics of certain other *Carausius* species are known, they may also be classified within this genus.

Etymology: Masculine. The specific epithet of this new genus is derived from the words 'Longi' (= slender and long body) and 'carausius' referring to the morphological similarity to *Carausius* Stål, 1875.

Species included:

1. *Longicarausius gracilicornis* (Ho, 2021: 14, figs. 5-8, 19-22) **comb. nov.** 細角長竹異蝽 [*Carausius*; China (Yunnan)]

2. *Longicarausius luchunensis* (Ho, 2017a: 48, figs. 203-206, 231-238, 290-291) **comb. nov.** 綠春長竹異蝽 [*Carausius*; China (Yunnan)]

3. *Longicarausius yingjiangensis* (Ho, 2017a: 51, figs. 211-212, 248-252) **comb. nov.** 盈江長竹異蝽 [*Carausius*; China (Yunnan)]

***Neopericentrus* gen. nov.**

Type-species: *Neosinophasma wenxuani* Ho, 2017b: 524, by present designation.

Diagnosis: *Neopericentrus* **gen. nov.** is similar to *Pericentrus* Redtenbacher, 1908, but can be separated by the smaller size, the slenderer body, the absence of clusters of spines on thorax, the weakly swollen mesonotum with unarmed lateral margins, the absence of expanded posterolateral angles from sixth to seventh tergites, the less developed armature on abdomen and the less distinct armature on the anterodorsal and posterodorsal carinae of mesofemora and metafemora.

Description: Small size for Lonchodinae. Apterous. Body robust, cylindrical; surface rough, with lamellae, granules and wrinkles. Head oval. Vertex armed with a pair of small triangular horns between compound eyes. Occiput gently convex, with two pairs of small

lamellae. Antennae filiform, slender, apices surpassing middle area of protibiae. Thorax rough and granulated. Pronotum trapezoidal, gently expanded posteriorly. Mesonotum parallel-sided, with three pairs of lamellae. Abdomen cylindrical, rough, tapering posteriorly. Median segment rectangular, wider than long. Fourth and fifth tergites with expanded posterolateral angles. Seventh sternum with a crest-like preopercular organ posteromedially. Subgenital plate scoop-shaped, posterior margin notched and surpassing posterior margin of supra-anal plate. Supra-anal plate small and distinct. Cerci short and flattened. Legs slender. Femora thicker than corresponding tibiae. Anterodorsal and posterodorsal carinae of profemora with small serrations. Anterodorsal, posterodorsal, anteroventral and posteroventral carinae of mesofemora and metafemora with small serrations, medioventral carina indistinct. Tibiae with a few small serrations.

Distribution: China.

Notes: This new genus only consists of the type-species *Neopericentrus wenxuani* (Ho, 2017) **comb. nov.** Ho (2017b: 524) originally placed *Neosinophasma wenxuani* Ho, 2017 in the tribe Medaurini Hennemann & Conle, 2008 [Family Phasmatidae Leach, 1815, Subfamily Clitumninae Brunner von Wattenwyl, 1893], based on a single female specimen. This specimen resembles the general appearance of other taxa in the genus *Neosinophasma* Ho, 2017. However, by reexamining the specimens in more detail and making further comparisons to other taxa, it is considered to be closely related to *Pericentrus* Redtenbacher, 1908 within Lonchodinae and is here transferred to the new genus *Neopericentrus* **gen. nov.** from *Neosinophasma*. In fact, *Neopericentrus* **gen. nov.** matches the general features of Lonchodinae including the absence of wings, the long and slender antennae, the longer median segment and the genital structure in the female. *Neopericentrus* **gen. nov.** obviously violates the main features of Clitumninae by the long antennae with apices surpassing apices of profemora, the parallel-sided scapus and the indistinct medioventral carina on mesofemora and metafemora in the female. The characteristics of both the male and the eggs of the genus remain unknown, and additional specimens collected from the type locality are essential for clarifying its taxonomic classification. The remaining species of *Neosinophasma*, including *N. biangulatum* (Chen & Zhang, 2008), *N. tangliangi* Ho, 2017 and *N. yunnanense* Ho, 2017, exhibit the characteristics of *Neosinophasma*.

Etymology: Masculine. The specific epithet of this new genus is derived from the words 'Neo' (= new) and 'pericentrus' referring to the morphological similarity to *Pericentrus* Redtenbacher, 1908.

Species included:

1. *Neopericentrus wenxuani* (Ho, 2017b: 524, figs. 37-38, 120-124) **comb. nov.** 文烜新束棘螳 [*Neosinophasma*; China (Xizang)]

***Paracarausius* gen. nov.**

Type-species: *Carausius novus* Ho, 2017a: 49, by present designation.

Diagnosis: *Paracarausius* **gen. nov.** is similar to *Carausius* Stål, 1875, but can be separated by the thick-built and elevated carina-like armature on the vertex of head and the strongly raised and waved posterodorsal carina of protibiae in both sexes, the short and straight anal abdominal segment in the male and the fimbriated egg capsule.

Description: Medium-sized for Lonchodinae. Apterous. Body slender, cylindrical; rugose, with sparse granulations. Head oval. Vertex with thick-built and elevated carina-like armature between compound eyes. Occiput flattened or weakly convex. Antennae filiform, slender, apices surpassing middle area of protibiae. Thorax slender, rugose and sparsely granulated. Pronotum rectangular, longer than wide. Mesonotum broadly emarginated medially, longer than combined length of metanotum and median segment. Metanotum longer than median segment. Abdomen cylindrical, rugose and sparsely granulated. Median segment rectangular, longer than wide. Female seventh sternum with a small crest-like preopercular organ posteromedially. Male anal segment spilt into two short and straight semi-tergites, as long as eighth tergum, female with emarginated posterior margin. Supra-anal plate distinct in female, indistinct in male. Female subgenital plate scoop-shaped, posterior margin pointed and reaching posterior margin of supra-anal plate. Male poculum small, cup-shaped, weakly elevated medially. Cerci short and flattened. Legs slender. Femora thicker than corresponding tibiae. Profemora with a rounded and elevated lamella near apex on posteroventral carina in female. Posterodorsal carina of protibiae strongly raised and waved, anteroventral carina strongly raised. Posteroventral carina of mesofemora and metafemora with two small teeth near apices. First segment of protarsi lacking or with a small semi-circular lamella dorsally. Egg capsule oblong, fimbriated, and fringed with feather-like bristles. Micropylar plate elliptical or oval. Operculum with rounded capitulum centrally.

Distribution: China and Vietnam.

Notes: This new genus currently includes *Paracarausius damingshanensis* **sp. nov.**, *P. novus* (Ho, 2017) **comb. nov.** and *P. rugosus* (Brunner von Wattenwyl, 1907) **comb. nov.** (Fig. 16), here transferred from the genus *Carausius* Stål, 1875. Once the morphological, genital, and egg characteristics of certain other *Carausius* species have been identified, they could also be categorised within this genus.

Etymology: Masculine. The specific epithet of this new genus is derived from the words 'Para' and 'carausius' referring to the morphological similarity to *Carausius* Stål, 1875.

Species included:

1. *Paracarausius damingshanensis* **sp. nov.** 大明山副竹異螽 [China (Guangxi)]

2. *Paracarausius novus* (Ho, 2017a: 49, figs. 207-210, 239-27) **comb. nov.** 新副竹異螽 [*Carausius*; China (Yunnan)]

3. *Paracarausius rugosus* (Brunner von Wattenwyl, 1907: 275) **comb. nov.** 皺副竹異螽 [*Carausius*; China (Guangxi) & Vietnam]

***Paracarausius damingshanensis* sp. nov.** (Figs. 10-15, 17-20)

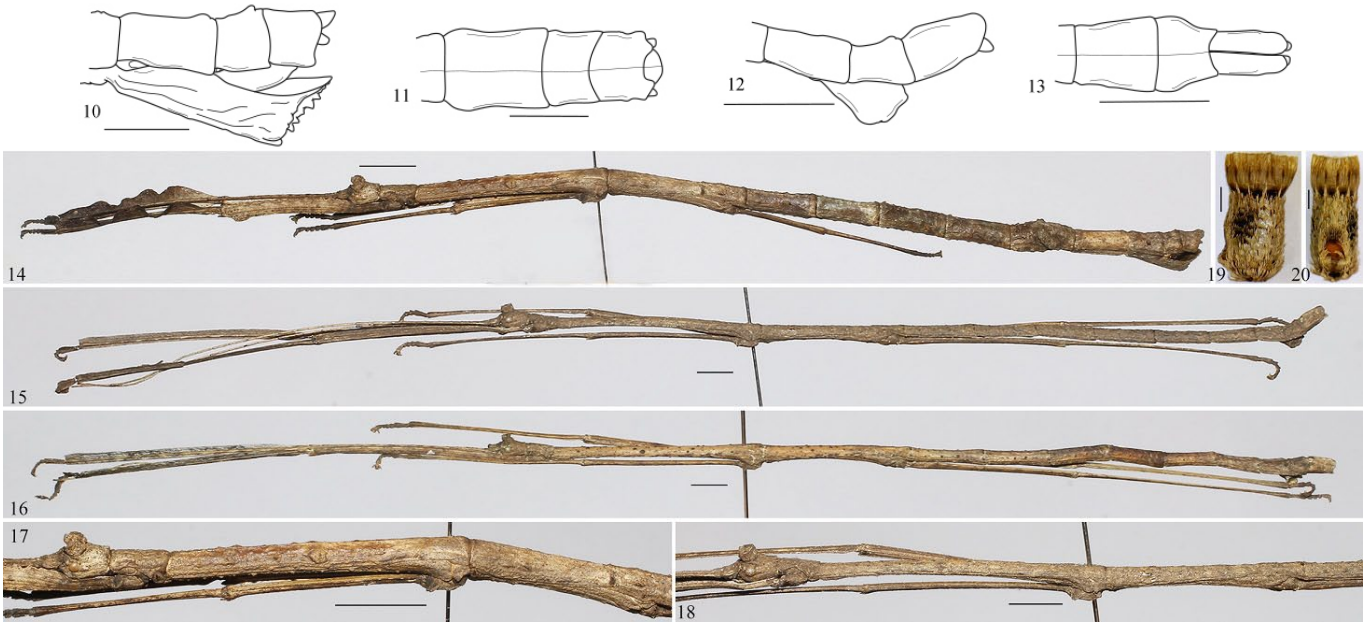
Types: Holotype, ♀, Damingshan, Wuming, Guangxi, China, 31 July 2012, George Ho Wai-Chun (HKES); Paratypes, 1♀, 1♂, 37 eggs (laid by holotype and paratype females), Damingshan, Wuming, Guangxi, China, 30 July 2012, George Ho Wai-Chun (HKES).

Diagnosis: *Paracarausius damingshanensis* **sp. nov.** is similar to *P. novus* (Ho, 2017) **comb. nov.**, but can be separated by the larger size and the more robust body in both sexes, the presence of enlarged granules on mesonotum and metanotum and the small crest-like preopercular organ on seventh sternum in the female and the more thick-built crest on vertex of head and the broader anal segment in lateral view in the male. The general appearance of the male is similar to *P. rugosus* (Brunner von Wattenwyl, 1907) **comb. nov.**, but can be separated by the comparatively more robust body, the less granulations on thorax and the absence of black granules on thorax and abdomen in the male.

Description of female (Figs. 10-11, 14, 17): Medium-sized. Body elongate and slender, more robust than male. Body surface rough, wrinkled and granulated. General colouration of body brown, legs brown with a few small and whitish markings.

Head: Oval, shorter than pronotum, weakly constricted after compound eyes. Rough, densely covered with small granules. Vertex with a thick-built and elevated carina-like armature between compound eyes, U-shaped in dorsal view. Occiput flattened, median and lateral longitudinal furrows distinct, posterior margin with small swellings. Compound eyes small and rounded. Antennae filiform; scapus dorsoventrally flattened, constricted basally, as long as combined length of third segment and pedicellus; third segment longer than pedicellus.

Thorax: Rough and granulated, also interspersed with a few enlarged granules. Pronotum rectangular, longer than wide, anterior margin gently incurved, posterior margin rounded, transverse and longitudinal sulci crossing at middle area. Mesonotum longer than combined length of metanotum and median segment, broadly emarginated medially, median longitudinal line



Figures 10-20. *Paracarausius* **gen. nov.** spp. 10. *Paracarausius damingshanensis* **gen. nov. & sp. nov.**, female, apex of abdomen, lateral view. 11. *Paracarausius damingshanensis* **gen. nov. & sp. nov.**, female, apex of abdomen, dorsal view. 12. *Paracarausius damingshanensis* **gen. nov. & sp. nov.**, male, apex of abdomen, lateral view. 13. *Paracarausius damingshanensis* **gen. nov. & sp. nov.**, male, apex of abdomen, dorsal view. 14. *Paracarausius damingshanensis* **gen. nov. & sp. nov.**, female, habitus. 15. *Paracarausius damingshanensis* **gen. nov. & sp. nov.**, male, habitus. 16. *Paracarausius rugosus* (Brunner von Wattenwyl, 1907) **gen. nov. & comb. nov.**, male, habitus. 17. *Paracarausius damingshanensis* **gen. nov. & sp. nov.**, female, head and thorax, dorsolateral view. 18. *Paracarausius damingshanensis* **gen. nov. & sp. nov.**, male, head and thorax, dorsolateral view. 19. *Paracarausius damingshanensis* **gen. nov. & sp. nov.**, egg, lateral view. 20. *Paracarausius damingshanensis* **gen. nov. & sp. nov.**, egg, dorsal view. Scale bars: apex of abdomen, head, thorax and habitus = 10 mm; vomer and egg = 1 mm. Drawings and photos by author.

distinct. Mesosternum with distinct longitudinal carina. Metanotum longer than median segment.

Abdomen: Cylindrical, rough, wrinkled and with sparse granulations. Median segment rectangular, longer than wide, longer than pronotum. Sixth tergum with a pair of lateral crest-like structures. Seventh sternum with a small, inconspicuous crest-like preopercular organ posteromedially. Eighth tergum almost as long as combined length of ninth tergum and anal segment. Anal segment as long as ninth tergum, posterior margin with a small and broad U-shaped emargination, posterolateral angles rounded. Supra-anal plate distinct, small, with median longitudinal carina, tapering posteriorly, posterior margin rounded and projecting over posterolateral angles of anal segment. Subgenital plate boat-shaped, median longitudinal carina distinct, posterolateral areas raised, also with a few short tubercles situated at posterior area, posterior margin pointed and reaching posterior margin of supra-anal plate. Cerci short, flattened, apices rounded and not projecting over posterior margin of anal segment.

Legs: Slender and long. Femora thicker than corresponding tibiae, shorter than mesonotum. Profemora basally curved, anterodorsal carina distinctly waved with small rounded elevations, posteroventral carina distinctly elevated, subapical area raised with a rounded lamella. Posteroventral carina of mesofemora and metafemora with two small teeth near apices. Posterodorsal carina of protibiae strongly raised and waved, anteroventral carina strongly raised. First segment of protarsi with a small semi-circular lamella dorsally.

Description of male (Figs. 12-13, 15, 18): Body slender and long, distinctly slimmer and thinner than female. General colouration of body brown, legs brown with inconspicuous blackish markings.

Head: Oval, weakly constricted posteriorly after compound eyes, almost as long as pronotum. With sparse granulations. Vertex with a pair of thick-built and carina-like armature between compound eyes, U-shaped in dorsal view. Occiput flattened, with distinct median and lateral longitudinal furrows, posterior margin with small swellings. Compound eyes rounded and small. Antennae long and filiform; scapus dorsoventrally flattened, weakly constricted basally, longer than third segment; pedicellus shorter than third segment.

Thorax: Sparsely covered with small granules, also interspersed with a few enlarged granules. Pronotum rectangular, longer than wide, anterior margin weakly incurved, posterior rounded, transverse and longitudinal sulci crossing at middle area. Mesonotum slender and elongate, longer than combined length of metanotum and median segment, broadly emarginated medially, median longitudinal line distinct. Metanotum longer than median segment.

Abdomen: Slender and cylindrical, with small and inconspicuous granules, also interspersed with a few enlarged granules. Median segment rectangular, longer than wide, longer than pronotum. Seventh tergum as long as combined length of eighth and ninth tergites. Eighth tergum expanded posteriorly, longer than ninth tergum. Anal segment as long as eighth tergum, split into two semi-tergites, inner margin almost straight at posterior area, interior surfaces with a few small dentations, posterior margin rounded. Poculum cup-like, medially elevated, posterior margin rounded and reaching posterior area of ninth tergum. Cerci short, flattened, apices rounded and not surpassing apices of semi-tergites.

Legs: Slender and long, lacking noticeable armature. Profemora incurved basally, anterodorsal carina waved with small teeth. Posteroventral carina of mesofemora and metafemora with two small teeth near apices. Medioventral carina of tibiae raised. Posterodorsal carina of protibiae strongly raised.

Measurements: See Table 3.

Description of egg (Figs. 19-20): Capsule brown,

	Holotype Female	Paratype Female	Paratype Male
Body	144.0	125.0	111.0
Head	5.5	5.5	4.5
Antennae	50.0	49.0	57.0
Pronotum	6.0	5.0	4.0
Mesonotum	32.0	27.0	27.0
Metanotum	16.5	14.5	14.5
Median Segment	6.5	5.5	5.0
Profemora	27.0	25.0	28.0
Mesofemora	20.0	18.0	19.0
Metafemora	22.0	19.0	22.0
Protibiae	28.0	26.0	32.0
Mesotibiae	20.0	18.0	21.0
Metatibiae	23.0	20.0	26.0

Table 3. Measurements of *Paracarausius damingshanensis* **gen. nov. & sp. nov.**

surface fimbriated, densely fringed with long, feather-like bristles; oblong, posterior pole rounded. Micropylar plate elliptical, anteriorly and posteriorly rounded. Micropylar cup located at posterior area of micropylar plate. Median line indistinct. Operculum strongly elevated marginally, with a stalked and rounded capitulum centrally.

Measurements: Length, 6.2 mm; width, 2.5 mm; height, 2.8 mm.

Distribution: China (Guangxi).

Etymology: This new species is named after its type locality, Damingshan, Guangxi, China; adjective.

CONCLUSION

The subfamilies Necrosciinae and Lonchodinae are rich in diversity in China, with over 250 species documented (Chen and He, 2008; Hennemann et al., 2008; Brock and Büscher, 2022; Brock et al., 2024; Ho, unpub. data). Collecting additional specimens from remote, primitive forests is expected to reveal a greater number of new species. Ultimately, each specimen collected would enhance our understanding of phasmid biodiversity in China. In future, molecular studies would enhance knowledge and help in distinguishing the validity of species with similar appearance.

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中國蠜目之新知XV：中國蠜目長角枝蠜亞科及長角棒蠜亞科（長角棒蠜科）新分類群及新分類命名II

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摘要：本文記述中國長角枝蠜亞科及長角棒蠜亞科一新亞種、二新種及三新屬：海南新薔蠜長體亞種 *Neoasceles hainanensis elongatus* **subsp. nov.**、西藏婆羅蠜 *Korinnis xizangensis* **sp. nov.**、大明山副竹異蠜 *Paracarausius damingshanensis* **sp. nov.**、長竹異蠜屬 *Longicarausius* **gen. nov.**、新束棘蠜屬 *Neopericentrus* **gen. nov.**及副竹異蠜屬 *Paracarausius* **gen. nov.**；建立十七新組合：刺胸婆羅蠜 *Korinnis notata* (Chen & Zhang, 2008) **comb. nov.**、細角長竹異蠜 *Longicarausius gracilicornis* (Ho, 2021) **comb. nov.**、綠春長竹異蠜 *Longicarausius luchunensis* (Ho, 2017) **comb. nov.**、盈江長竹異蠜 *Longicarausius yingjiangensis* (Ho, 2017) **comb. nov.**、寬翅瑪異蠜 *Marmessoidea adelpha* (Günther, 1940) **comb. nov.**、海南新薔蠜 海南亞種 *Neoasceles hainanensis hainanensis* (Chen & He, 2002) **comb. nov. & sen. str.**、文烜新束棘蠜 *Neopericentrus wenxuani* (Ho, 2017) **comb. nov.**、新副竹異蠜 *Paracarausius novus* (Ho, 2017) **comb. nov.**、皺副竹異蠜 *Paracarausius rugosus* (Brunner von Wattenwyl, 1907) **comb. nov.**、長翅副瑪異蠜 長翅亞種 *Paramarmessoidea alata alata* (Ho, 2018) **comb. nov.**、長翅副瑪異蠜 長胸亞種 *Paramarmessoidea alata elongata* (Ho, 2018) **comb. nov.**、廣東副瑪異蠜 *Paramarmessoidea guangdongensis* (Ho, 2013) **comb. nov.**、海南副瑪異蠜 海南亞種 *Paramarmessoidea hainanensis hainanensis* (Ho, 2016) **comb. nov.**、海南副瑪異蠜 鸚哥嶺亞種 *Paramarmessoidea hainanensis yinggelingensis* (Ho, 2016) **comb. nov.**、劉氏副瑪異蠜 *Paramarmessoidea liuxingyuei* (Ho, 2018) **comb. nov.**、刺粒刺瑪異蠜 *Spinomarmessoidea mista* (Chen & He, 2008) **comb. nov.**及滇雜斑角臀蠜 *Varieganecroscia dianica* (Ho, 2017) **comb. nov.**；建議一新同物異名：*Spinomarmessoidea damingenis* Gao & Li, 2023 **syn. nov.**為刺粒刺瑪異蠜 *Spinomarmessoidea mista* (Chen & He, 2008) **comb. nov.**的同物異名；報告六新紀錄：婆羅蠜族 Korinnini Günther, 1953、婆羅蠜屬 *Korinnis* Günther, 1932、新薔蠜屬 *Neoasceles* Seow-Choen, 2016、副瑪異蠜屬 *Paramarmessoidea* Seow-Choen, 2021、雜斑角臀蠜屬 *Varieganecroscia* Seow-Choen, 2016及皺副竹異蠜 *Paracarausius rugosus* (Brunner von Wattenwyl, 1907) **comb. nov.**；以及制定婆羅蠜屬 *Korinnis*、瑪異蠜屬 *Marmessoidea* Brunner von Wattenwyl, 1893、新薔蠜屬 *Neoasceles*、副瑪異蠜屬 *Paramarmessoidea*、刺瑪異蠜屬 *Spinomarmessoidea* Seow-Choen, 2021及雜斑角臀蠜屬 *Varieganecroscia* 的名錄。

關鍵詞：竹節蟲，中國，分類，新屬，新種，新亞種，新組合，新同物異名，新紀錄

Effect of insect pollinators on crop yield and quality of cowpea (*Vigna unguiculata* (L.) Walp.) in Wukari, Nigeria

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ABSTRACT

Investigations were conducted to determine the impact of insect pollinators on the yield and quality of cowpea plant (*Vigna unguiculata* (L.) Walp.). The experiment was carried out at the Biological Garden of Federal University Wukari, Nigeria within the 2023 wet season. Two treatments were evaluated: T_1: Insect pollination inclusion/opened plants (crops allowed to have access to self, wind, and insect pollination) and T_2: Insect pollination exclusion/netted plants (plots were netted with synthetic nylon netting and crops restricted from insect pollination). The treatments were randomly assigned to plots in 3 replicates. Yield and seed quality data were collected. Statistical comparisons were made between the treatments using Student's t-test. The most common insect associated with cowpea flower was observed to be *Apis mellifera* L. with average number of 6.00/plot. This was followed by *Danaus plexippus* L. and *Eurema lisa* Bois & Lec. each with an average count of 4.00/plot. The least abundant, which may be adjudged accidental visitors, were *Libellula luctuosa* Bur and *Aesha grandis* L. with average count of 1.00/plot. While we observed no colour variation between the harvested seeds of opened and netted plants; we found out that the absence of insect pollinators largely and significantly ($t\alpha<0.05$) impacted negatively on the yield and the other qualitative parameters assessed. Marginal but significant differences were observed in the proximate compositions of the grains retrieved from the opened vis-à-vis netted plants. Crude fibre (4.56±0.37%), moisture (9.90±0.30%), and ash content (3.42±0.02%) were significantly ($t\alpha<0.05$) higher in the opened crops as detected by student's t-test; while crude protein (20.68±0.72%), lipids (1.79±0.01%), and carbohydrate (57.90±0.57%) were significantly ($t\alpha<0.05$) higher in the netted plants. The study's findings indicate that insect pollination significantly benefits the yield of cowpea grown in Wukari, Nigeria. Results of this study reinforce knowledge on the importance of pollination services in crop production by showing the significance of insect pollinators in crop yield and quality.

Key words: *Apis mellifera*, Cowpea, *Danaus plexippus*, Flower visiting insects, Entomophily, Plant-pollinator relationship, Pollination exclusion, Pollination inclusion

INTRODUCTION

Research evidences have shown that, ecological services such as pollination enhance crop production (Pablo et al., 2021). Global food production is largely pollinator-dependent as > 70% of crop plants depend largely on entomophily (Klein et al., 2007; Aizen et al., 2008; Okrikata et al., 2019). Some crops depend wholly on insect pollinators to set fruit, while many others produce well over 90% of their potential yield without animal pollinators (Klein et al., 2007). Pollinators are important in improving the growth and yield of crops, including cowpea (Lindström et al., 2016). Insect pollinators not only help maintain yields but also promote genetic variability and reduce inbreeding depression in crops, as noted by Stein et al. (2017). Pollination is required to produce quantitative food in agricultural crops. Both abiotic and biotic factors are responsible for pollination. Abiotic pollination occurs with the involvement of non-living agents like wind and rain/water. On the other hand, biotic pollination occurs through the involvement of living agents such as insects (entomophily) and birds (ornithophily). Among animals, insects play a critical role in pollination (Shivanna, 2015). Declining pollinators can reduce global food production. Crops are pollinated more efficiently by wild insects (Garibaldi et al., 2013). In some crops, the order Lepidoptera (comprising mainly Nymphalidae and Pieridae) has been reported as the most prominent insect pollinators, followed by Hymenoptera. Diptera and Coleoptera were reported as less prominent (Das et al., 2018). Given that bees visit more than 90% of staple crops worldwide, they can be adjudged the main contributors to pollination (Klein et al., 2007; Khalifa et al., 2021).

Cowpea (*Vigna unguiculata* L.) is predominantly self-pollinated, but it maintains certain floral characteristics, such as extrafloral nectaries that attract insect pollinators (Purseglove, 1968). The flowers of cowpea are largely self-fertilizing before opening (cleistogamy) (Asiwe, 2009), and their morphology favors self-pollination as the anthers are in direct contact with the stigmas (Ige et al., 2011). However, some African countries have reported substantial cross-pollination (Fatokun and Ng, 2007; Kouam et al., 2012).

Sharp changes and decline in the assemblages of flower visiting insects is well reported globally (Bartomeus et al., 2014; Pablo et al., 2021). Hence, it is imperative to assess the impact of insect pollinators on crop yield and quality of crops. More so, though the importance of the diversity and abundance of pollinators on crop yield have been well established (Bartomeus et al., 2014; Dainese et al., 2019), the contribution of pollinator visits to cowpea yield and yield-related traits have been found to give dissimilar results in similar trials (Lazaridi et al., 2023). This further justifies the importance of assessing cowpea-pollinator relationship and impact separately in each environment. Furthermore, while the measurement of pollination dependence with adequate

controls is necessary to properly account for the impact of entomophily on crop quality and yield, field studies aimed at manipulating flower visitation by insects to assess its qualitative and quantitative impact on crop performance, particularly in cowpea, are rare. This study therefore aims to fill these research gaps.

MATERIALS & METHODS

Study site and experimental description

The experiment was conducted at the Biological Garden, Federal University Wukari, Taraba State, Nigeria; located at 7.51°N 9.47°E longitude and 7.85°N 9.783°E latitude of the Southern Guinea Savannah Ecological Zone of Nigeria, within the rainy season of 2023. The study area experiences a warm tropical climate characterised by wet and dry season. The wet season starts in April and end in October with peak in June and September (Okrikata et al., 2019). The experiment however lasted within the months of May to August, 2023. A land was mapped out with a gross plot size 4.6m x 9.5m (43.7m²) and net plot size of 4.5m x 1.2m (5.4m²). The land was cleared, harrowed and ridged. The cowpea seeds (brown variety) were sown at inter-row spacing of 75cm and intra-row spacing of 20cm. Half a metre bund was placed between treatments.

Experimental design and treatments evaluated

Two (2) treatments were evaluated:

T_1: Insect pollination inclusion/opened plants (crops allowed to have access to self, wind and insect pollination).

T_2: Insect pollination exclusion/netted plants (plots were netted with synthetic nylon netting, and thus the crops were restricted from insect pollination).

The treatments were arranged in a completely randomized design (CRD) in 3 replicates in which weed control was carried out by hoe weeding till harvest and Laraforce (Lambda-Cyhalothrin 2.5% EC) insecticide was applied once a week at the rate of 1.2ml/L using a 2 litres handheld sprayer during the vegetative stage to control insect pests which were observed in the field. Harvesting was done when the crop attained maturity which is indicated by dried, yellow brown coloured pods. Pods from each plot were harvested into well labelled polyethene bags and were taken to the laboratory for further investigation.

Different methods were used to monitor and quantify the abundance and diversity of insect pollinators in the study plots. This includes sweep netting, visual observation and hand picking. Insects were sampled at the active flowering stage of cowpea (which lasted 2 weeks) within 06:30h - 09:30h. Specimens were identified using an insect identification App (Picture Insect) and were further confirmed using Seek app and Google Lens (Manderfield, 2022).

Crop yield measurement

The following quantitative data were collected: Number of pods/plot, number of pods/plant, and number of seeds/pod.

Quality assessment

The following qualitative data were collected:

1. Seed size [seed length (mm), and diameter (mm)]: Vernier calliper was used and the average record of 100 grains/plot was taken.

2. Seed colour: Hand lens, visual observation and microscope were used to assess the seed colour of 10 seeds/plot.

3. 100-grains weight (g): 100 grains were randomly selected from both open and netted plots. They were weighed and the average was recorded.

4. Grain weight (kg/ha): All the grains harvested from plots per treatments were weighed and the average was recorded and converted to kgha-1.

5. Proximate composition: Moisture, ash, crude lipid, crude protein, crude fiber, and carbohydrate of samples of harvested seeds were assessed using standard analytical methods as described by Okwu and Morah (2004) and Okrikata et al. (2023).

Data analysis

All the collected data (except for the seed colour) were subjected to Student's t-test analysis to compare insect pollination inclusion from exclusion using SPSS version 2021, and the level of significance was pegged at p=0.05.

RESULTS

Insects associated with flowers of cowpea

Flowering commenced at week eight (8) after planting and actively lasted for 2 weeks. Thirteen (13) insect species were retrieved. In the 1st week of flowering, *Danaus plexippus* L., *Papilio demoleus* L., *Eurema lisa* Bois & Lec., *Cercyonis pegala* F., *Apis mellifera* L., *Eremnophila aureonotata* C., *Polistes carolina* L., *Meliponila ferruginea* Cock., *Harmonia axyridis* P., *Libellula luctuosa* Bur., and *Musca domestica* L. were observed. In the second week of flowering, *Halyomorpha haly* S., *Aeshna grandis* L. and *Camponotus* sp. were further observed in addition to the species recorded in week 1 (Table 1). The mean count shows that honey bee (*A. mellifera*) with average number of 6.00/plot was the most abundant insect associated with cowpea flower. This was followed by Monarch butterfly (*D. plexippus*) and Little yellow butterfly (*E. lisa*) with average number of 4.00/plot. The least abundant, which apparently are accidental visitors, were the Brown hawker (*A. grandis*)

and Window skimmer (*L. luctuosa*) each with a weekly mean count of 1.00/plot (Table 1).

Cowpea yield from open and netted plants

Student's t-test detected significant differences in yield parameters between the opened and netted plants. Number of pods per plot, number of pods per plant, number of seeds per pod, seed weight, and seed weight ($kgha^{1}$) were significantly ($t\alpha<0.05$) higher in insect pollinated plants (Table 2).

Comparison of cowpea seed quality between opened and netted crops

Though no variation was observed in the seed colour of the seeds harvested from plants in opened and netted plots; student's t-test showed differences between the opened and netted plants with respect to the seed parameters assessed with the insect pollinated plants being significantly ($ta<0.05$) superior (Table 3).

Quality assessment in terms of proximate composition of cowpea seeds obtained from open and netted plants

While the differences in proximate contents between the opened and netted plants were largely marginal; student's t-test detected significant differences between them. Insect pollination resulted in significantly ($t\alpha<0.05$) higher crude fibre, moisture, and ash content. The netted plants had significantly ($t\alpha<0.05$) higher crude protein, lipids, and carbohydrate (Table 4).

DISCUSSION

Active flowering commenced at week eight (8) after planting and lasted for 2 weeks. Insect pollinators play a crucial role in the production of plants, including cowpea (*V. unguiculata*). Cowpea is primarily a self-pollinating crop, but it can also benefit from insect pollination. Thirteen (13) insect species were found to be associated with cowpea flowers in the study location. Some of which are *D. plexippus*, *P. demoleus*, *A. mellifera*, *E. aureonotata* C., *P. carolina*, *M. ferruginea*, *H. axyridis*., *L. luctuosa*, *E. aureonotata*, *L. luctuosa*, *A. grandis*, *E. lisa* and *C. pegala*. The most common insect associated with cowpea flower was honey bee (*A. mellifera*) with average number of 6.00/plot. Findings from the study are in consonance with the report of Singh (1979) in India who reported honey bees among the most important flower visitors of strawberry. However, Hooper (1932) reported that pollination is carried mainly by insects other than bees and especially by Dipterans when it is cold. In our study, the least abundant insects which visited the cowpea flowers, which apparently were accidental visitors, were widow skimmer (*L. luctuosa*) and brown hawker (*A. grandis*) with average number of 1.00/plot. Insect pollinators are reported to vary from crop to crop, one location to another, and during different parts of the year. However, research evidence are increasingly suggesting that honeybees are not always the most efficient or effective pollinators (Grass et al., 2018), including in legume crops where they are among the most frequent flower visitors (Marzinzig et al., 2018).

The seed yield data obtained revealed that seed set was significantly ($t\alpha<0.05$) lower under insect exclusion. The mean 100-grains seed weight (g) was 22.10±0.50 and 18.10±0.50 in insect pollination inclusion and insect pollination exclusion treatments, respectively. Our assessment also revealed that grain weight (kg/ha) was significantly ($t\alpha<0.05$) higher in the opened than in the netted cowpea plants. The comparatively lower yield performance in crops that were excluded from insect pollination can be attributed to lack of visitation by insects which are known to be largely efficient pollinators (Ibarra-Perez et al., 1999). Another explanation could be that common bean flowers do not activate well without insect visits. Therefore fewer pollen grains contact stigmas of self-pollinated flowers for fertilization. As the insects forage, they move/shake flowers which increases pollen-stigma contact and augment fertilization (Mainkete et al., 2019). While our results conform with the findings of Kumar and Jaiswal (2012) who opined that insect pollinators increases the yield performance of *Coriandrum sativum* L., it contrasts the findings of Free (1966) who showed that only moderate yield benefits is attributable to cowpea visited by insect pollinators.

Pollinators ensure pollen grain dispersal which is a key step of fruit and seed formation. The contact of pollen grains and stigma leads firstly to fertilization and then to seed formation; and auxins synthesized in seeds control cell division resulting in growth (Kumar et al., 2014). Bee species from various families are reported worldwide as cowpea major insect pollinators (Dingha et al., 2021). In addition, species of family Noctuidae, Pieridae and Vespidae have been mentioned as effective pollinators (Dingha et al., 2021). This is confirmed by our findings.

Junqueira and Augusto (2017) opined that poor seed quality could be as a result of pollination deficit. We recorded about 14% increase in the diameter of the cowpea seeds under insect pollination inclusion. More so, our assessment also revealed that seed length (mm) and 100 grains weight were significantly ($t\alpha<0.05$) higher in the opened than in the netted cowpea plants. These increase in the qualities of cowpea seeds from opened crops is an indication of improved seed yield brought about by pollinating insects (Douka et al., 2018). Our observations in this respect are not in consonance with those of Bhowmik et al. (2017) at West Bengal which revealed that the diameter of *C. sativum* seed was increased in opened insect pollination. Our findings however, corroborates that of Paikara and Paikara (2021) who observed maximum seed size in total open, and minimum seed size in total closed treatment in their study on *C. sativum* at Chhattisgarh. While pod weight was not affected (Dingha et al., 2021), number of seeds per pod, weight of seeds per pod and pod length were reported to be reduced when crops were covered to

prevent insect visitation (Fohouo et al., 2009; Musa et al., 2013). These findings are similar to ours.

Open pollinated crop varieties are known to be inherently genetically variable. Colour shades of fruits and seeds have been reported to vary at varying degrees in relation to whether a plant was exposed to pollination intervention by insects or not (Halder et al., 2018). In our study however, no such colour shade variation was detected. This perhaps, may be because cowpea is predominantly a self-pollinated crop.

While crude fibre, moisture, ash content were significantly ($t\alpha<0.05$) higher in the opened cowpea crops exposed to insect pollination, we observed crude protein, lipids, and carbohydrate to be significantly ($t\alpha<0.05$) higher in the netted plants which were excluded from insect pollination. However, it is interesting that the differences, although significant ($t\alpha<0.05$), were marginal. Findings from the present studies are not in consonance with observations of Toni et al. (2021), who reported high lipids composition in pollinator dependent crops. More so, the results of the present study also contradict the report of Wang and Ding (2012), who found that insect pollinators induce more than 80% of macronutrients such as protein and fibre. In entomophilous crops, adequate pollination often leads to produce with enhanced quality (Anderson et al., 2016). Absence of insect pollinators has generally been linked to decrease crop yield and, also quality

CONCLUSION

We assessed the impact of flower-visiting insects to yield and quality of cowpea. Findings from the present study revealed that insect pollination offers a significant benefit to the yield and quality of cowpeas grown in Wukari, Nigeria. The study suggests that sustainable crop yield is possible among smallholder farmers in the study area by maximizing pollination services, and conversely that income losses can be avoided by farming practices that reduce risk to pollinator populations, such as excessive spraying of pesticides. However, more information is needed on which species are the most important pollinator of cowpea crops and which specific field margin plants are more important in supporting them.

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TABLES

Common name*	Scientific name	Order	Family	Number/plot
Monarch butterfly	*Danaus plexippus* L.	Lepidoptera	Nymphalidae	4.00
Lime butterfly	*Papilio demoleus* L.	Lepidoptera	Papilionidae	1.50
Little yellow butterfly	*Eurema lisa* Bois & Lec.	Lepidoptera	Pieridae	4.00
Common wood nymph	*Cercyonis pegala* F.	Lepidoptera	Nymphalidae	3.50
Honey bee	*Apis mellifera* L.	Hymenoptera	Apidae	6.00
Thread-waist wasp	*Eremnophila aureonotata* C.	Hymenoptera	Sphecidae	3.50
Red paper wasp	*Polistes carolina* L.	Hymenoptera	Vespidae	3.00
Stingless bee	*Meliponila ferruginea* Cock.	Hymenoptera	Apidae	3.50
Lady beetle	*Harmonia axyridis* P.	Coleoptera	Coccinellidae	2.50
Widow skimmer	*Libellula luctuosa* Bur.	Odonata	Libelludidae	1.00
Housefly	*Musca domestica* L.	Diptera	Muscidae	3.50
Brown hawker	*Aeshna grandis* L.	Odonata	Aeshnidae	1.00
Carpenter ant	*Camponotus* sp.	Hymenoptera	Formicidae	3.00

Table 1. Insects associated with cowpea in the study area [* = Insects observed/retrieved from opened plots during the 2 weeks active flowering period of cowpea].

Variables	Opened plants	Netted plants	Mean difference	t-value	p-value
Number of pods per plot	536.67±7.54	465.00±4.86	71.67±2.68	17.53	0.001**
Number of pods per plants	21.00±1.15	17.00±0.56	4.00±0.59	7.22	0.001**
Number of seeds per pod	14.00±0.00	13.67±0.33	0.33±0.33	5.43	0.002**
Seed weight (kg/ha)	229.43±6.35	189.37±5.46	40.06±0.89	9.62	0.009**

Table 2. Yield comparison between opened and netted cowpea [Results presented as mean ± standard error; ** = Significantly different (P≤0.01)].

Parameter	Opened plants	Netted plants	Mean difference	t-value	p-value
100 grains weight (g)	22.10±0.50	18.10±0.50	4.00±0.00	6.51	0.001**
Seed length (mm)	8.98±0.50	8.75±0.10	0.23±0.40	3.54	0.001**
Diameter of seed (mm)	7.45±0.01	6.45±0.05	1.00±0.04	3.12	0.001**
Seed weight (kg/ha)	229.43±6.35	189.37±5.46	40.06±0.89	9.62	0.009**

Table 3. Comparative assessment of cowpea seed quality from opened and netted crops [Results presented as mean ± standard error; ** = Significantly different (P≤0.01)].

Treatment	Opened plants	Netted plants	Mean difference	t-value	p-value
Crude fibre (%)	4.56±0.37	3.79±0.10	0.77±0.27	15.32	0.001***
Moisture (%)	9.90±0.30	9.69±0.30	0.21±0.00	17.35	0.001***
Crude protein (%)	19.19±0.65	20.68±0.72	-1.49±0.12	-10.2	0.001***
Ash (%)	3.42±0.02	3.40±0.01	0.02±0.01	20.32	0.001***
Lipids (%)	1.38±0.00	1.79±0.01	-0.41±0.01	-6.55	0.001***
Carbohydrate (%)	54.75±0.95	57.90±0.57	-3.15±0.37	-4.62	0.001***

Table 4. Comparing the proximate composition of cowpea seeds obtained from opened and netted plants [Results presented as mean ± standard error; *** = Significantly different (P≤0.001)].