

Systematics and Biogeography of the Genus *Gandaca* Moore (Lepidoptera: Pieridae)¹

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Abstract. All known species of the genus *Gandaca*; *G. harina* (Horsfield) and *G. butyroasa* (Butler) are redescribed and illustrated, with female genitalia illustrated for the first time. They are distinguished by wing markings, and male and female genitalia, and a key to species is provided. The subspecies *G. harina auriflua* (Fruhstorfer) stat. rev. from Sula and Banggai in Indonesia is transferred from *G. butyroasa*. A distribution map of both species is presented. From the viewpoint of biogeography, the remarkable distribution pattern of both species is discussed.

Key words: Lepidoptera, Pieridae, Coliadinae, *Gandaca*, diagnostic characters, *G. harina auriflua* stat. rev., biogeography.

Introduction

The known species of the genus *Gandaca* Moore, 1906 (Coliadinae, Pieridae), were formerly regarded as members of *Terias* Swainson, 1821, a subgenus of the genus *Eurema* Hübner, 1819, because of superficial similarity. Based on relatively slight differences in wing-shape and venation, Moore (1906) removed *harina* (Horsfield) from *Terias* and established a monotypic genus *Gandaca*. Klots (1933) illustrated and described the male genitalia of *G. harina*, and noted important differences between *Gandaca* and *Eurema* in structures of the male genitalia. He also suggested the possibility that *Gandaca* and *Eurema* may have a common origin. However, *Gandaca* is hitherto considered to occupy a rather "primitive" phylogenetic position in the Coliadinae and closely related to Dismorphiinae (Pieridae) because only *Gandaca* and Dismorphiine genera possess abundant anthoxanthine pigments in the Pieridae (Ford, 1941). We can not mention about the phylogenetic position of *Gandaca* from only his study. Yata & Fukuda (1980) suggested that the genus was not closely related to any other genera within the subfamily based on the morphology and behaviour of its early stages observed in Luzon, the Philippines.

Gandaca butyroasa (Butler) has long been consid-

ered conspecific with *G. harina* due to the similarity of external features of the adults (D'Abrera, 1978; Corbet & Pendlebury, 1978). Yata (1981) described external features and male and female genitalia of both species, however he did not provide any figures of the female genitalia. Based mainly on genital structure, he raised *butyroasa* to specific rank and proposed that the genus consists of two species: *G. harina* occurring from Assam and Sundaland to the Lesser Sundas, and *G. butyroasa* replacing it from Sulawesi to New Guinea (Yata, 1981). His treatment was followed by Peggie *et al.* (1995) and Parsons (1998), but some authors still regard *G. butyroasa* and *harina* as conspecific (Bridges, 1988; Smith, 1989).

Yata (1981) treated the prominent subspecies *auriflua* (Fruhstorfer) from Sula as a member of the species *G. butyroasa*, stating the ground color of the wing upperside of males is usually tinged with orange. From the examination of genitalia in the present study, however, it was revealed that the specimens considered as males by Yata were in fact females. Furthermore we compared male and female genitalia of *auriflua* with those of *G. harina* and found that they are almost identical.

In this paper we give descriptions and illustrations of *G. harina* and *G. butyroasa* in detail, especially the female genitalia illustrated herein for the first time and verify that *G. butyroasa* is a distinct species. Moreover we transfer the subspecies *auriflua* from *G. butyroasa* to *G. harina* based on male and female genital structures, and describe its external features. This recombination

¹ Contribution from the Biosystematics Laboratory, Graduate School of Social and Cultural Studies, Kyushu University (No. 49).

is remarkable not only in the peculiarity of the ground color of the female wing, but also in its distribution.

Material and Methods

Materials

Materials used in this study were all dried specimens. For detailed examination of male and female genitalia, the terminal abdominal segments were cut off, placed in a 10% solution of KOH at 48°C for 14 hours, then in a 8% solution of CH₃COOH for 30 minutes, transferred to 80% ethanol, and stained with Hematoxylin. Dissection and observation were carried out under a binocular stereoscopic microscope. The drawings of the genitalia were made with the aid of an ocular grid and graph paper. All genital preparations were preserved in a 65% glycerol after fixation with 80% ethanol.

The material used was mainly from the collection of the Biosystematics Laboratory, Graduate School of Social and Cultural Studies, Kyushu University, Fukuoka (BLKU). Additional specimens were borrowed from the Entomological Laboratory, Kyushu University (ELKU) and National Museum of Natural History, Leiden (NMNH). In the Natural History Museum, London (NHM), Yata photographed the type specimens. Depositories of the specimens examined are indicated by the above acronyms.

Measurements

Length of saccus was measured from the tip of the projection of its opening to the anterior end, and height of ring from its dorsal aspect to ventral aspect. Wing length was measured from the base to the tip of apex.

Terminology

The terminology mostly follows Shirôzu (1960) and Yata (1989) for male genitalia, and Kawazôé & Wakabayashi (1976) and Yata (1989) for female genitalia.

Description

Genus *Gandaca* Moore

Gandaca Moore, 1906: 33.

Type species: *Terias harina* Horsfield, 1829

Male. *Head*: Antenna covered with black scales and white-checked, 0.31–0.33 times as long as length of forewing, and with distinct concavity on each segment; club cylindrical, conspicuously concaved at tip. Labial palpus covered with same colored scales as

wing except dorsal portion bearing black scales; third segment oval, less than half as long as second; second segment from 1/2 to 1/3 as long as first segment. Head covered with same colored scales as wing except vertex mixed with black scales.

Thorax: Patagia sclerotized. Tegula elongate triangle, with comparatively wide dorsal process, tip rounded.

Legs: Pretarsus with both arolium and pulvilli.

Wing: Ground color usually lemon-yellow. Forewing upperside with black distal border. Hindwing upperside usually unmarked, but sometimes narrowly bordered with black distally. Both wings underside unmarked. Forewing usually somewhat rounded at apex and tornus; 4 radial veins; R₁ and R₂ derived from cell; R₃ and R₄₊₅ stalked; R₄₊₅ as long as distance from end of cell to fork of R₃ and R₄₊₅; stalk derived from M₁ ca. quarter of distance from end of cell to apex; middle discocellular (*mdc*) at least half as long as lower discocellular (*ldc*); 3 wing-folds in cell. Hindwing evenly rounded at termen; humeral vein thin and vestigial, directed basad; upper discocellular (*udc*) and *mdc* subequal, half as long as *ldc*. Sex-brand absent.

Genitalia: Posterior portion of 8th tergum well sclerotized, with pair of pointed superunci. Tegumen somewhat narrow, trapezoidal, well sclerotized on dorsal aspect, with pair of small projections at middle of anterior edge; Valvenansatz protruding anteroventrally at proximal portion of tegumen; vinculum very narrow and almost straight, gradually tapered ventrally, upper 1/3 convex anteriorly when viewed laterally; saccus fairly long and slender, arched ventrally around middle in various degrees, somewhat swollen anteriorly, angle between vinculum and saccus about 90–100°. Uncus short (dorsum proper about half as long as height of ring), protruding posterodorsally, sickle-shaped when viewed laterally, arched dorsally, broadened medially. Valva with distal process. Phallus very long (whole length of phallus about 1.8 times as long as height of ring) and slender, nearly straight but bending ventrally at subzonal sheath; peri-vesical area beginning ventrally from posterior 1/5 or less of phallus and broadened posteriorly; subzonal sheath about 1/5 of length of phallus; bulbus ejaculatorius arising from anterodorsal portion of subzonal sheath. Juxta posteriorly elongated as drain.

Female. Similar to male except as follows:

Wing: Ground color usually lemon-yellow, sometimes yellowish cream and pale orange in some races. Forewing black distal border usually broad, with inner

edge somewhat projected along M_3 .

Genitalia: 7th abdominal sternum long, with large and somewhat sclerotized median hollow, anterior of which forms interior membranous sac opening, covered with elongate scales; lateral hollow small, narrowed anteriorly, strongly sclerotized. Genital plate strongly sclerotized, with lamella postvaginalis protruding as ridge; apophysis anterioris short nearly half as long as apophysis posterioris, with prominent protuberance at inner margin of most proximal portion. Ostium bursae situated at anterior end of genital plate, covered with posterior edge of 7th abdominal sternum. Ductus bursae slender, membranous, somewhat twisted anteriorly; ductus seminalis attached at $2/7-1/2$ of ductus bursae. Signum small, symmetrical, transverse, deeply concaved, weakly sclerotized, lacking spines, placed very close to opening of ductus bursae. Connecting duct slender, attaching corpus bursae at its subanterior part; appendix bursae spherical. Papilla analis hemicircular, with round apical lobe posteriorly, covered with setae except on anteromedian swollen bare-region; apophysis posterioris short, slightly arched inwardly, protruding somewhat ventrally when viewed laterally.

***Gandaca harina* (Horsfield, 1829)**

(Figs. 1, 3-4, 9-12)

Terias harina Horsfield, 1829: 137. Type locality: Java.

Holotype ♀ [NHM], genitalia not examined.

Eurema harina (Horsfield), Geyer, 1837: 43.

Gandaca harina (Horsfield), Moore, 1906: 33.

Diagnosis: Forewing black distal border of females usually broad, broadened toward apex, with inner edge strongly projected along M_3 . Superuncus with longitudinal dorsal keels running posteriorly from tips of superuncus. Uncus finely serrated along edge, with apex bluntly pointed. Distal process of valva spatulate, long, rather stout, with apex bluntly pointed. Phallus evenly slender, lacking spines around posterior tip. Median hollow deep; membranous elliptical sac large; lateral hollow small. Lamella antevaginalis with protruded anchor-shaped ridge.

Male. *Upperside:* Ground color usually lemon-yellow. Forewing black distal border usually narrow, beginning at various portions and gradually broadened apically, with inner edge not sharply defined and rather uniform. Hindwing usually unmarked, but in Philippine race usually with black distal border. *Underside:* Ground color usually same as on upperside.

Forewing usually somewhat rounded at apex, but in races from Assam to West Indo-China usually more

angulate; distal margin almost straight or slightly convex. Thorax and abdomen yellow, clothed with yellow hairs on thorax and base of abdomen.

Female. *Upperside:* Ground color usually pale lemon-yellow, but in races from the Philippines and Sula usually pale orange, and from Hainan, Simuk and Borneo yellowish cream. Forewing black distal border usually broad, broadened apically, with inner edge not sharply defined and usually somewhat projected along M_3 . Hindwing usually possessing narrow black distal border. *Underside:* Ground color usually same as on upperside.

Forewing somewhat rounded at apex; distal margin almost straight or slightly convex. Thorax and abdomen usually yellow, clothed with yellow hairs on thorax and base of abdomen.

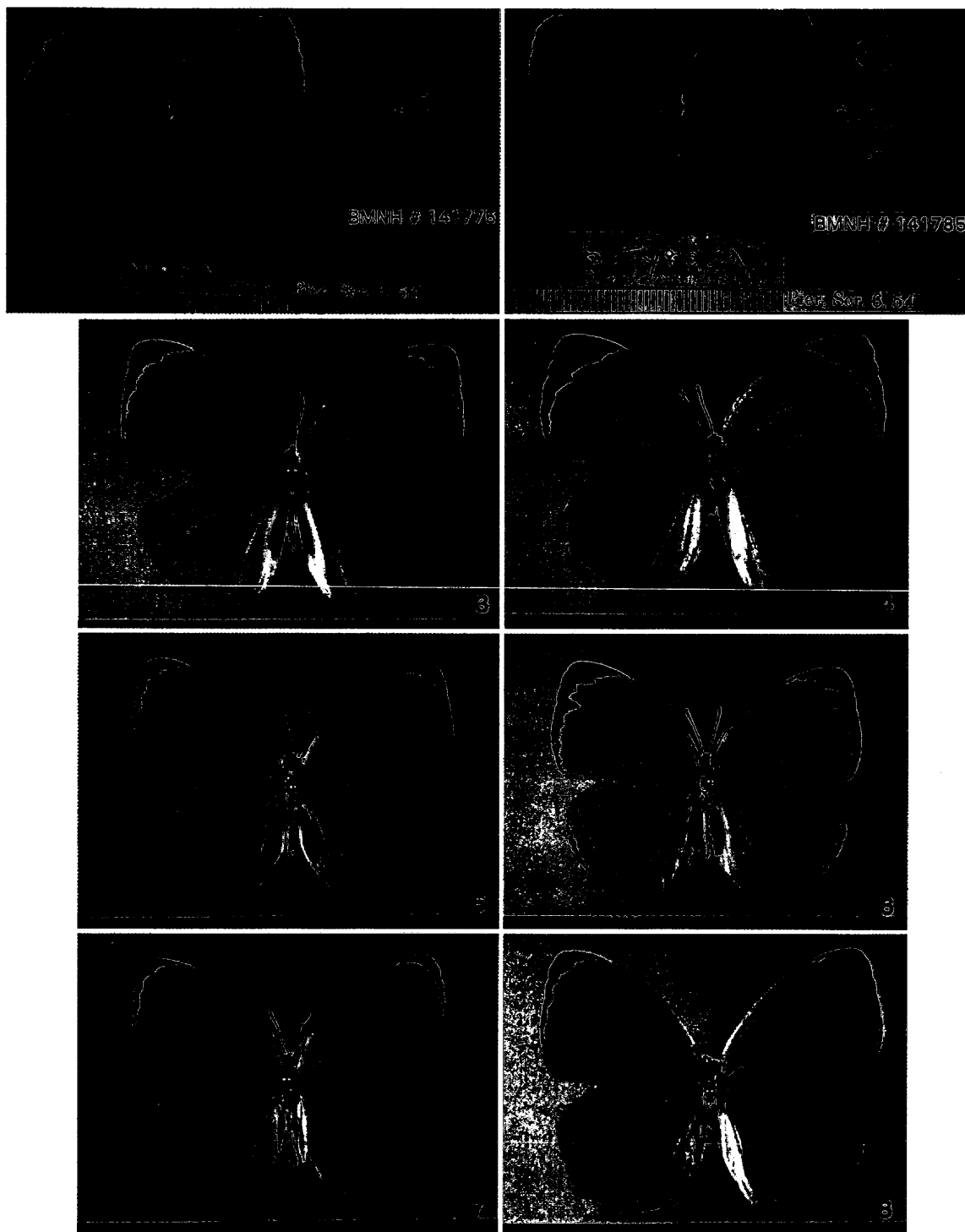
Forewing length: Male, 19.0-26.0 mm, female, 17.0-25.0 mm.

Male genitalia (Figs. 9, 10): Superuncus with longitudinal dorsal keels running from tip of superuncus to posterior $1/3$ of 8th tergum. Saccus slender, fairly long (about 1.3-1.4 times as long as height of ring), abruptly expanded at posterior portion, opened widely at posterior end; angle between vinculum and saccus about $95-100^\circ$. Uncus finely serrated along $1/2-1/3$ of posterior edge, with apex bluntly pointed, bearing setae sparsely proximally to medially. Width of valva nearly half as long as height of valva; distal process of valva spatulate, long, rather stout, tapered apically, with apex bluntly pointed. Phallus evenly slender, lacking spines around posterior tip; anterior end slightly convex anteriorly; peri-vesical area arising ventrally on posterior $1/5$ of phallus. Juxta weakly sclerotized, narrowly membranous at dorsal portion.

Female genitalia (Figs. 11, 12): 7th abdominal sternum with deep median hollow; large membranous elliptical sac² densely covered with numerous elongate scales; lateral hollow 0.1-0.2 times as long as 7th tergum. Lamella postvaginalis with anchor-shaped ridge close to ostium bursae, bearing setae on anteroventral surface of ridge; ductus seminalis attached at posterior $2/7$ of ductus bursae. Papilla analis hemicircular, somewhat elongated dorsally and ventrally.

Variation: As stated in the description, the genitalia are variable locally in several features, especially width of superuncus at base, shape of uncus except apex, shape of ventral portion of vinculum, shape of distal process, shape of anterior end of subzonal

² During dissecting the female genitalia of *G. harina*, we found whitish pasty secretion in the sac of 7th sternum.



Figs. 1-8. *Gandaca harina* and *G. butyroasa*, upperside. — 1, *G. harina harina* ♀, holotype [NHM], Java; 2, *G. butyroasa butyroasa* ♂, holotype [NHM], Aru; 3, *G. harina harina* ♂, [BLKU], Java; 4, ditto ♀, [BLKU], Java; 5, *G. butyroasa cuneata* ♂, [BLKU], Ambon; 6, ditto ♀, [BLKU], Ambon; 7, *G. harina auriflua* ♂, [BLKU], Sula Taliabu; 8, ditto ♀, [BLKU], Sula Mangole.

sheath and shape of anchor-shaped ridge. Detailed analysis and discussion of local variations and local forms require greater material.

Material studied: INDIA: Assam, Khasihills (1♂). THAILAND: Chieng Dao, 3. iii. 1982 (1♂). LAOS:

Vang Vieng, 10. x. 1992 (1♂). CHINA: Hainan, 1943-1945 (1♂, ELKU). VIETNAM: 1♂. MALAYSIA: 30 mi N. Tapah (300-600 m), 28. x. 1975 (1♂); Jaysm Bay, 16. iv. 1969 (1♀); Taiping, iv. 1983 (2♂♂); Taiping, vi. 1983 (1♂); Taiping, v. 1984 (1♂);

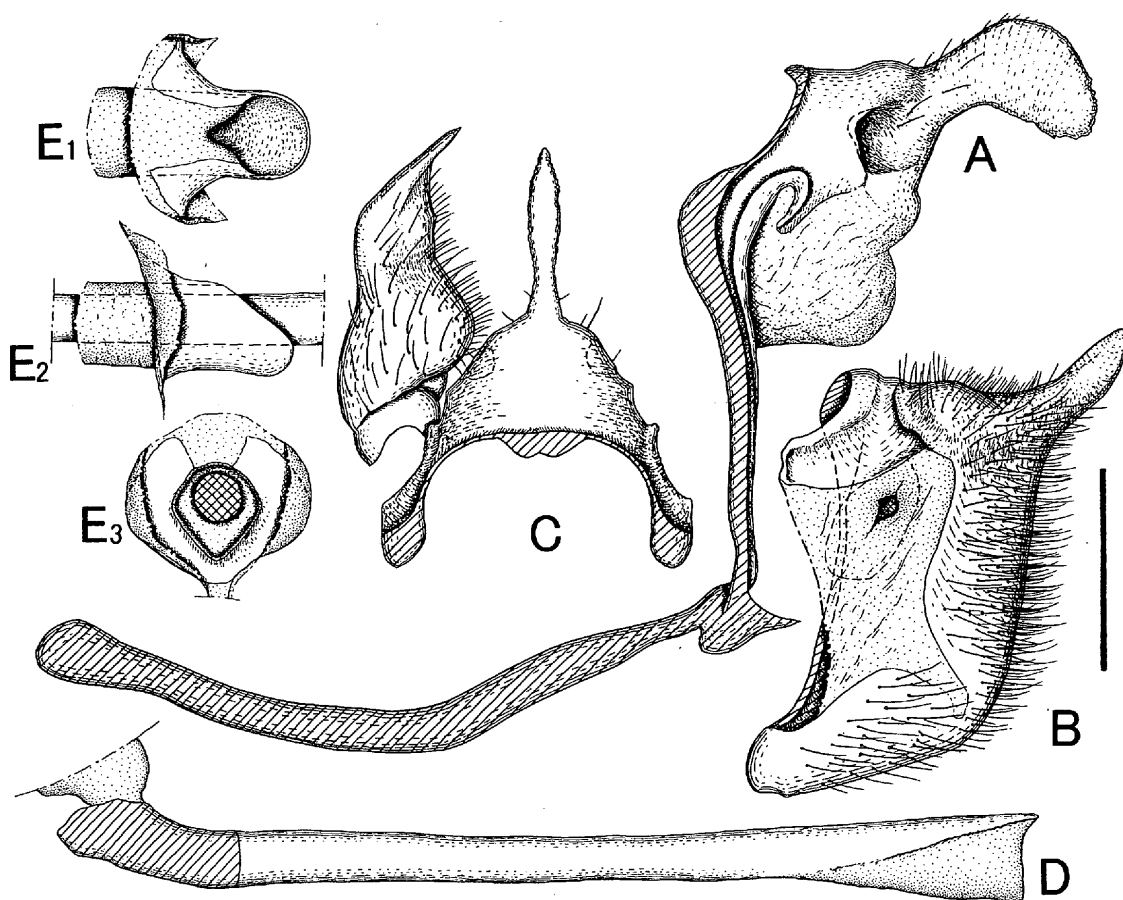


Fig. 9. Male genitalia of *Gandaca harina harina* from Java. A: Ring (lateral). B: Valva (inner aspect of right-side). C: Dorsum and valva (dorsal). D: Phallus (lateral). E₁: Juxta (dorsal). E₂: Juxta (lateral). E₃: Juxta (posterior). Scale=1.0 mm.

Taiping, iii. 1985 (1♂); Taiping, viii. 1985 (1♂); Langkawi, 1. iii. 1973 (1♀); Borneo, Sarawak, N. Kuching, 19–20. xi. 1975 (1♀). SINGAPORE: 5. viii. 1973 (1♂). INDONESIA: Simeulue, 3. vi. 1984 (2♂♂); 17. vi. 1984 (1♀); 15. vii. 1984 (1♂); Babi, xi. (1♂); Nias, Telukdalam, vi. 1979 (1♂); Tanahmasa, viii. (1♂); Weh, (2♂♂); Breueh, ?1966 (1♂); Sumatra, Kurui, vii. 1979 (1♂); Belitung, viii. 1992 (1♀); Java, Halimun (2♂♂); Halimun, (5♂♂); E. Java, 7. v. 1981 (1♀); Kangean, ii–iii. 1992 (1♂); Tawitawi, 29. i. (1♂); 2. ii. (1♂); Bali, vi. 1992 (1♀); Sumbawa, iv. 1985 (1♂); Flores, W. Flores (1♀). PHILIPPINES: 22. viii. (1♀); Luzon, Atimonan, Quezon Pr., 1. viii. 1973 (1♂); Marinduque, iii. 1973 (1♂); Masbate, vii. 1990 (1♂); Negros, Mt. Macapantho (1♀); Bohol, Biar, 23. vii. 1970 (1♂); Leyte, 27. viii. 1978 (1♀); Mindanao, Mt. Halkon, i. 1996 (4♂♂); Mt. Apo, viii. 1978 (1♂); Tandag, 1995 (1♂); Palawan, Olanguan (1♂); 2. iii. 1986 (1♂); Basilan, Maloong, 25. v. 1932 (1♀, ELKU) (all in BLKU except as indicated).

Distribution: This species is distributed almost all over the Oriental region, from Assam across Indone-

sia, Sundaland to the Lesser Sundas and the Philippines, and Banggai and Sula. New to Weh, Breueh, Simeulue, Tanahmasa, Belitung, Tawitawi, Banggai and Sula.

Gandaca harina includes the following 22 subspecies.

- andamana* Moore, 1906. Andaman
- aora* Moulton, 1923. Tioman and Aur
- assamica* Moore, 1906. Assam, Sikkim and Bengal
- auriflua* (Fruhstorfer, 1899) stat. rev. Banggai and Sula
- austrosundana* Fruhstorfer, 1910. Lombok and Sumba
- babiensis* Hanafusa, 1994. Babi
- batanea* Fruhstorfer, 1911. Panaon
- beruta* Corbet, 1941. Siberut
- burmana* Moore, 1906. Burma, Thailand and Indo-China
- distanti* Fruhstorfer, 1910. Malay Peninsula, Sumatra, Enggano and ?Nias
- elis* Fruhstorfer, 1910. N. Borneo
- euxenia* Fruhstorfer, 1911. Luzon

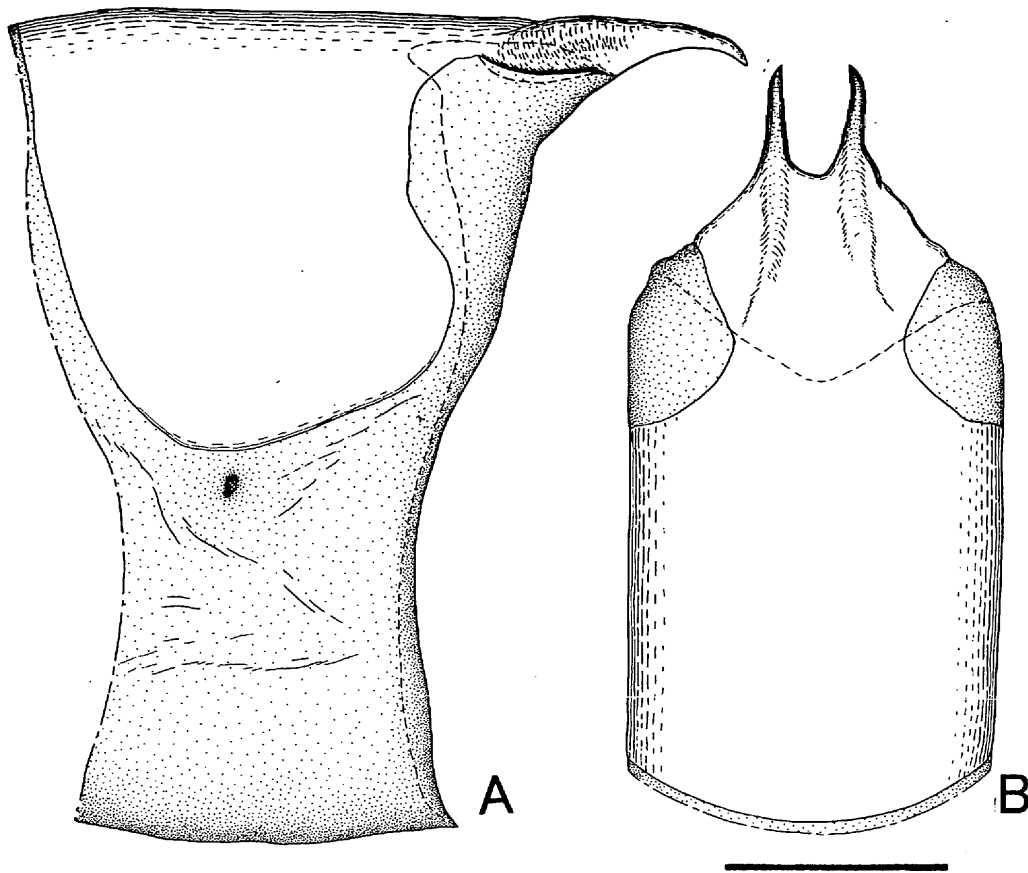


Fig. 10. The 8th tergum of *Gandaca harina harina* from Java. A: lateral. B: dorsal. Scale = 1.0 mm.

gardineri Fruhstorfer, 1910. Bazilan
hainana Fruhstorfer, 1910. Hainan
harina (Horsfield, 1829). Panaitan and Java
kangeana Okano, 1993. Kangean
kaystia Fruhstorfer, 1911. Mindoro
mindanaensis Fruhstorfer, 1910. S. Philippines
nicobarica Evans, 1932. Nicobar
palawanica Fruhstorfer, 1910. Palawan
porana Corbet, 1941. Sipora and N. Pagi Is.
simukensis Yamauchi et Yata, 1999. Simuk

In addition, *G. harina* is recorded from China (Li & Li, 1993; Gu & Chen, 1997), Bali (Yamada, 1988), Sumbawa and Flores (Fruhstorfer, 1899), with subspecific name uncertain. This species is also recorded from Taiwan (Gu & Chen, 1997), but we have never seen, so do not include it in the distribution map (Fig. 17). In the distribution map of Yata (1981) *harina*'s distribution included South part of Borneo, but confirmed record is not present as far as we know, so do not include this region in the distribution map (Fig. 17).

Taxonomic remarks: The subspecies *avra* [!] Moulton, 1923 (Bridges, 1988) is not listed above because it is a misspelling of *aora* Moulton, 1923 from Tioman

and Aur. Furthermore, *G. h. auriflua* (Fruhstorfer, 1899) is transferred from *G. butyrosa* based on a recombination discussed below.

Habitat and habits: According to Corbet & Pendlebury (1978), *G. harina* does not occur in abundance in the Malay Peninsula. They also pointed out that, although the species is often found flying in the same localities as the *Eurema* species, it is shade-loving and males never congregate at moist spots at roadsides or forest streams. According to Yata & Fukuda's observation (1980), females lay their eggs one by one and only on young leaves or shoots of the larval foodplant.

Early stages: The early stages were described in detail by Yata & Fukuda (1980) for populations from Luzon.

Larval foodplant: *Ventilago oblongifolia* (Rhamnaceae) in the Malay Peninsula and in Luzon.

***Gandaca harina auriflua* (Fruhstorfer, 1899), stat. rev.**

(Figs. 7–8)

Terias auriflua Fruhstorfer, 1899: 430. Type locality: Sula Mangole and Sula Sanana.

Gandaca harina auriflua (Fruhstorfer); Fruhstorfer,

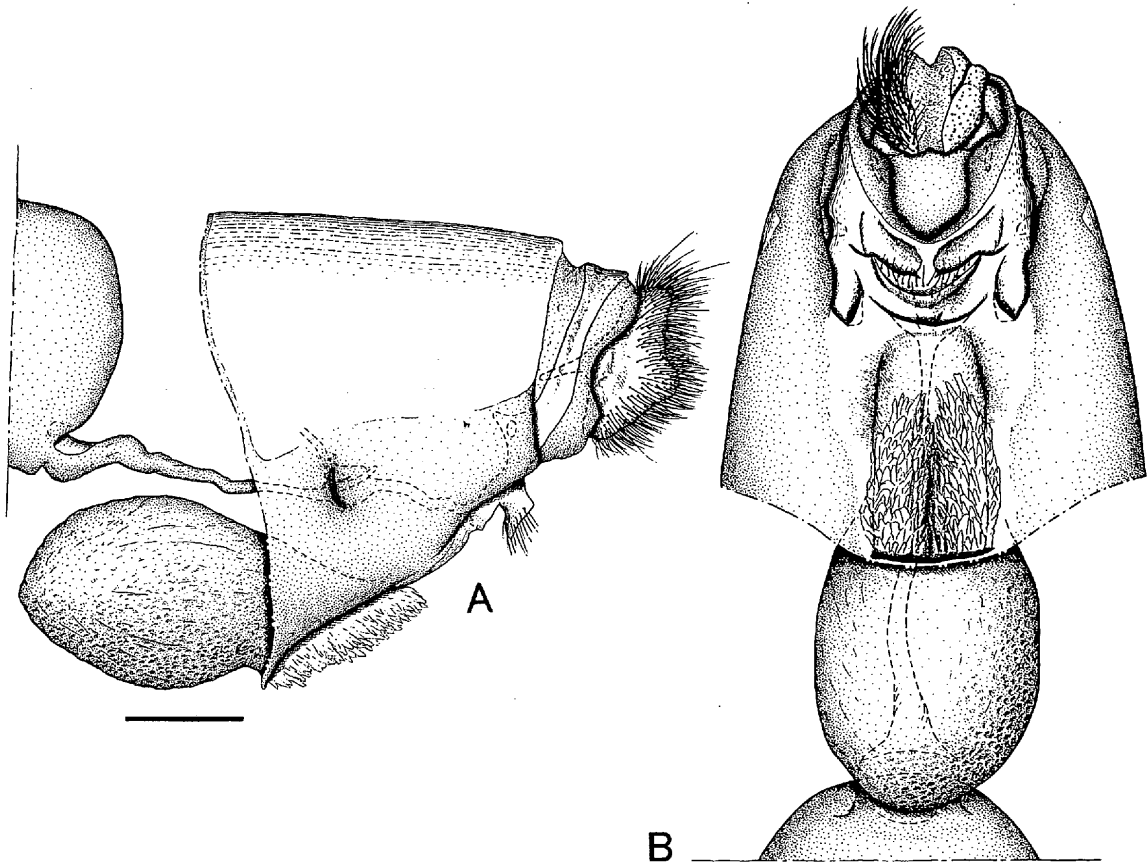


Fig. 11. Female genitalia of *Gandaca harina harina* from Java. A: lateral. B: ventral. Scale=1.0 mm.

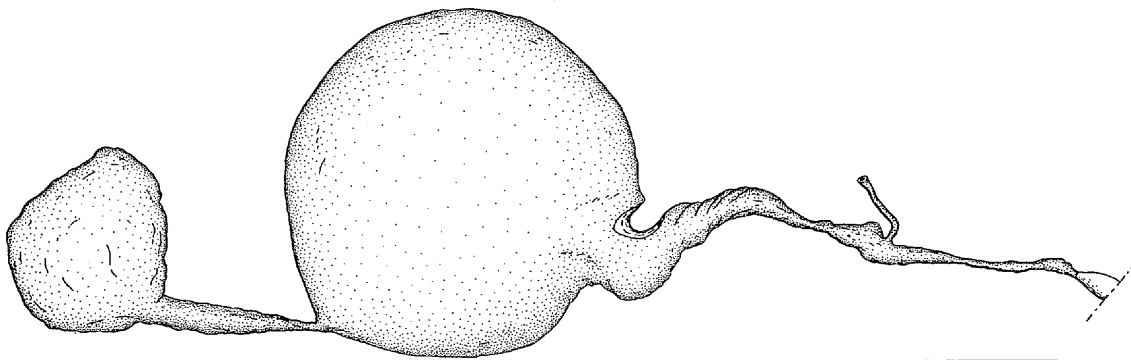


Fig. 12. Female genitalia of *Gandaca harina harina* from Java. Bursa copulatrix (lateral). Scale=1.0 mm.

1910: 173.

Gandaca butyroasa auriflua (Fruhstorfer); Yata, 1981: 210.

This subspecies is distinguishable from the nominal subsp. *harina* from Java by the following combination of characters.

Male. Upperside: Ground color lemon-yellow. Forewing black distal border very narrow, continued from R_2 to near CuA_2 , gradually broadened apically, with inner edge weakly projected along M_1 , M_2 and M_3 ;

fringe lemon-yellow, but mixed with black; width of black border 1.2–1.9 mm at R_{4+5} ($av=1.5$ mm, $N=6$, $st=0.2$), 0.4–0.6 mm at M_3 ($av=0.5$ mm, $N=5$, $st=0.1$), 0.1–0.3 mm at CuA_2 ($av=0.2$ mm, $N=5$, $st=0.1$). Hindwing unmarked; fringe lemon-yellow. **Underside:** Ground color almost same as on upperside.

Forewing somewhat angulate at apex; distal margin almost straight. Thorax and abdomen yellow, clothed with yellow hairs on thorax and base of abdomen.

Female. Upperside: Ground color pale orange. Forewing black distal border very narrow, continued

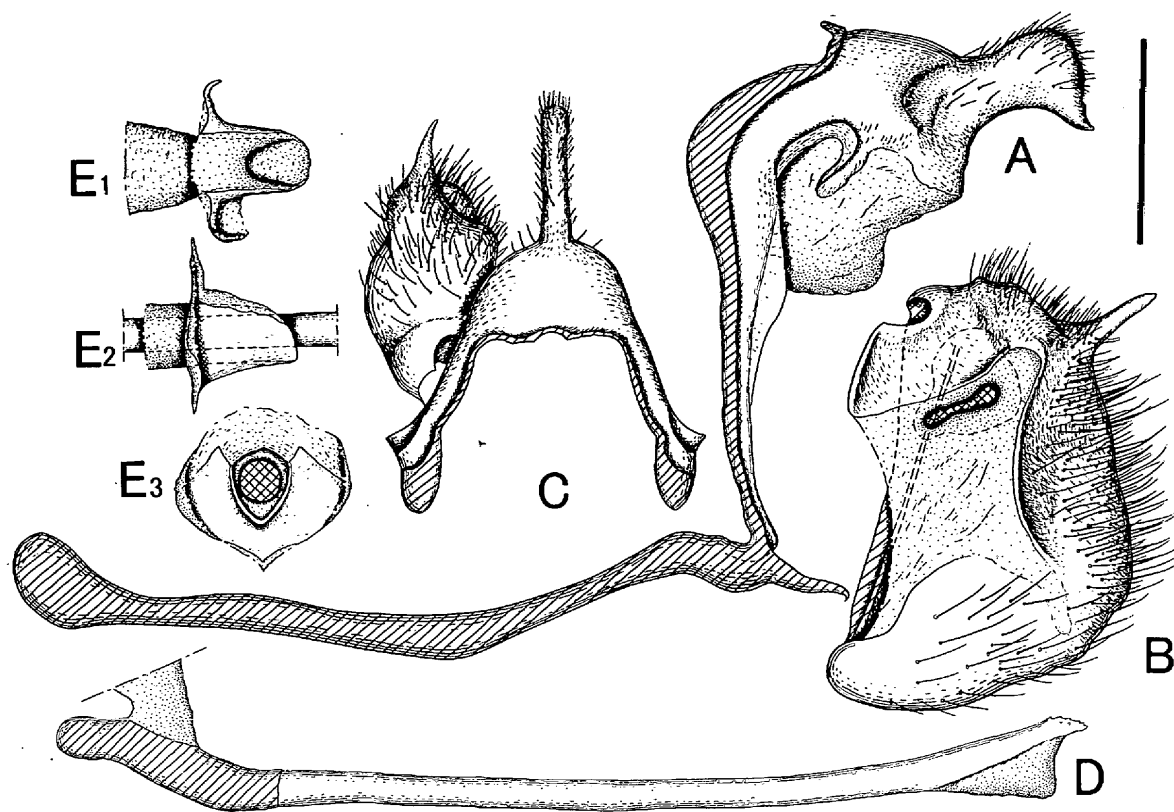


Fig. 13. Male genitalia of *Gandaca butyrosa cuneata* from Ambon. A: Ring (lateral). B: Valva (inner aspect of right-side). C: Dorsum and valva (dorsal). D: Phallus (lateral). E₁: Juxta (dorsal). E₂: Juxta (lateral). E₃: Juxta (posterior). Scale = 1.0 mm.

from R₂ to near CuP, broadened apically, with inner edge weakly projected along each vein; fringe pale orange, but mixed with black; width of black border 1.9–2.1 mm at R₄₊₅ (av=2.0 mm, N=3, st=0.1), 0.7–1.2 mm at M₃ (av=1.0 mm, N=3, st=0.3), 0.3–0.6 mm at CuA₂ (av=0.5 mm, N=3, st=0.1). Hindwing with weak black anteciliary line along edge from M₁ to M₃, fringe pale orange. *Underside*: Ground color pale yellowish orange.

Forewing obtusely angulate at apex; distal margin slightly undulated. Thorax and abdomen pale orange, clothed with pale orange hairs on thorax and base of abdomen.

Forewing length: Male, 19.5–24.0 mm (av=21.6 mm, N=6, st=1.7), female 19.5–21.5 mm (av=20.7 mm, N=3, st=0.1).

Male & female genitalia: Although the materials (4 males and 2 females) show slight individual variations, they are within the range of variation observed for *G. harina*.

Material studied: INDONESIA: Peleng, (1♂); Banggai, Sambiet, 31. x. 1933, (1♂, RNH); Noelion, 27. xii. 1935, (1♂, RNH); Sula Taliabu, 1. iii. 1981 (1♂); 3. iii. 1988 (1♂); Sula Mangole, 5. iii. (1♀); 7. iii. (1♀); Sula Sanana, 1. xii. 1979 (1♂1♀) (all in

BLKU except as indicated).

Distribution: This subspecies occurs in Banggai and Sula. New to Peleng and Banggai.

Habitat and habits: Unknown.

Early stage: Unknown.

Taxonomic remarks: In the original description of *auriflua*, Fruhstorfer (1899) stated that *Terias auriflua* flew together with *Terias harina* at the same time in Sula Sanana and Sula Mangole. Because males of *auriflua* are not tinged orange but yellow at present knowledge, the description of *T. harina* by Fruhstorfer might have been based on a male of *auriflua*. Yata (1981) treated *auriflua* as a subspecies of *G. butyrosa* based on wing markings, but we examined male and female genitalia and concluded that *auriflua* should be assigned to *G. harina*.

Females of *G. h. auriflua* resemble those of subspecies from the Philippines whose wings ground color are sometimes pale orange, but can be distinguished from the latter by the presence of a narrow forewing black distal border as in males. Males of *G. h. auriflua* are similar to subspecies *assamica*, *andamana*, and *porana*. These can not be distinguished from *auriflua* as yet. A detailed analysis of the diagnosis of male external features should be attempted when more

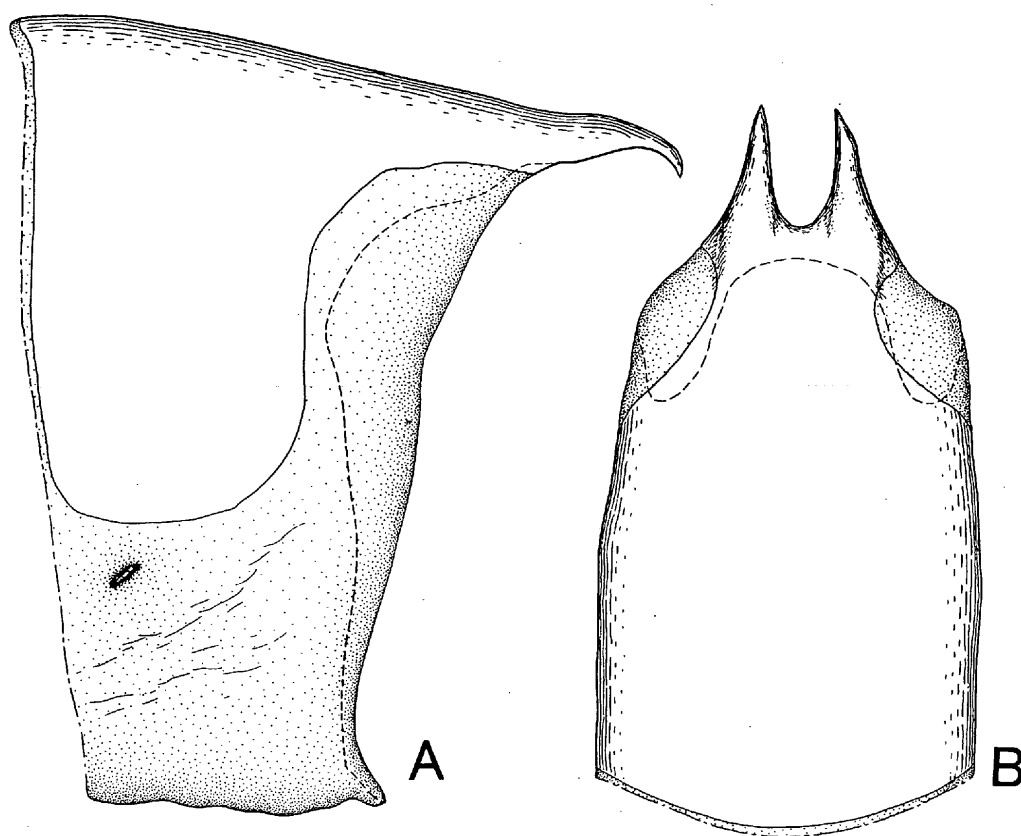


Fig. 14. The 8th tergum of *Gandaca butyroa cuneata* from Ambon. A: lateral. B: dorsal. Scale=1.0 mm.

material is obtained.

Although we could not examine females from Peleng and Banggai, we temporarily include these in the subsp. *auriflua* based on male external features.

***Gandaca butyroa* (Butler, 1875)**

(Figs. 2, 5-6, 13-16)

Terias butyroa Butler, 1875: 396. Type locality: Aru.

Holotype ♂ [NHM], genitalia not examined.

Terias harina butyroa Butler, Fruhstorfer, 1899: 430.

Gandaca harina butyroa (Butler), Fruhstorfer, 1910: 173.

Gandaca butyroa (Butler), Yata, 1981: 210.

Diagnosis: Forewing black distal border of females broadened apically, with inner edge usually strongly projected along each vein. Superuncus with no dorsal keels. Uncus finely serrated along dorsal edge medially to apically, with apex sharply pointed. Distal process of valva sword-like in shape, short, less developed, with apex sharply pointed. Phallus evenly rather slender, with minute spines around posterior tip. Median hollow shallow; membranous sac small;

lateral hollow very small. Lamella antevaginalis with protruded spoon-shaped ridge.

Male. Upperside: Ground color usually lemon-yellow. Forewing black distal border usually narrow, beginning near tornus and slightly broadened apically, with inner edge sharply defined and slightly projected along each vein. Hindwing usually unmarked, but sometimes very narrow black distal border present. **Underside:** Ground color same as on upperside.

Forewing somewhat rounded at apex; distal margin slightly convex. Thorax and abdomen yellow, clothed with yellow hairs on thorax and base of abdomen.

Female. Upperside: Ground color usually pale lemon-yellow. Forewing black distal border broad, broadened toward apex, with inner edge sharply defined and projected along each vein, especially M_3 . Hindwing usually possessing narrow black distal border. **Underside:** Ground color almost same as on upperside.

Forewing somewhat rounded at apex; distal margin slightly convex. Thorax and abdomen yellow, clothed with yellow hairs on thorax and base of abdomen.

Forewing length: Male, 18.5-26.5 mm, female, 20.5-

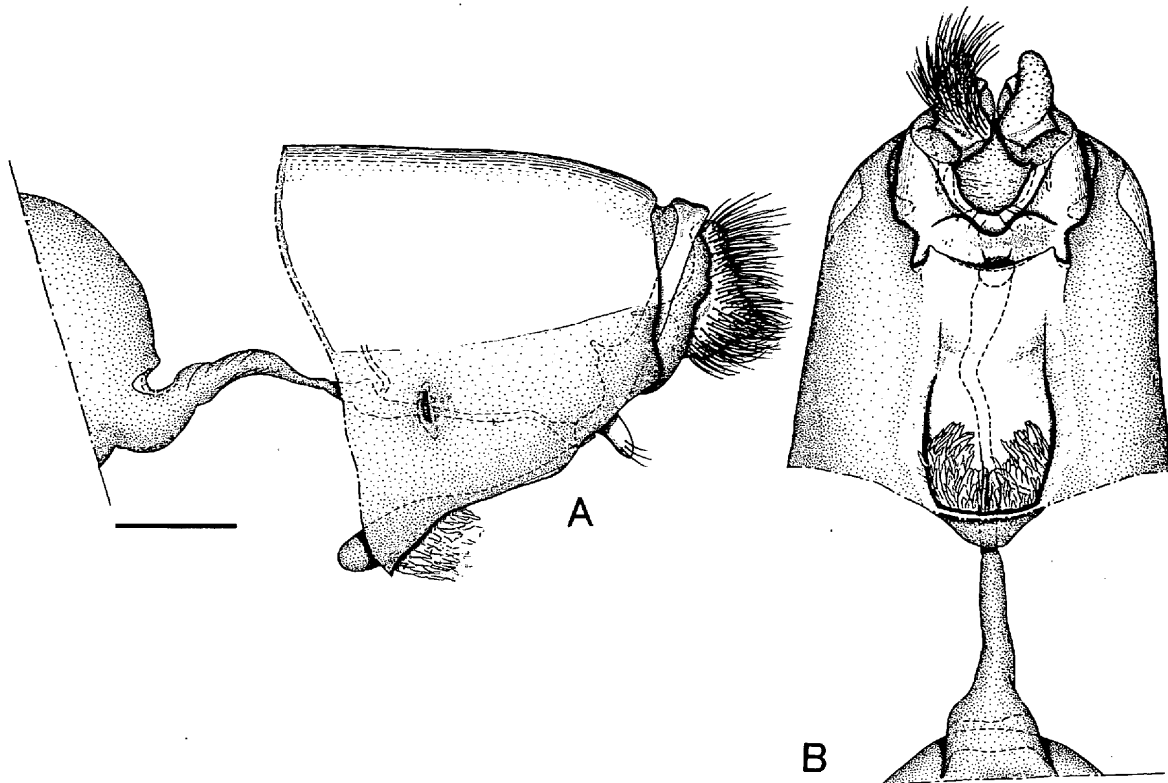


Fig. 15. Female genitalia of *Gandaca butyrosa cuneata* from Ambon. A: lateral. B: ventral. Scale=1.0 mm.

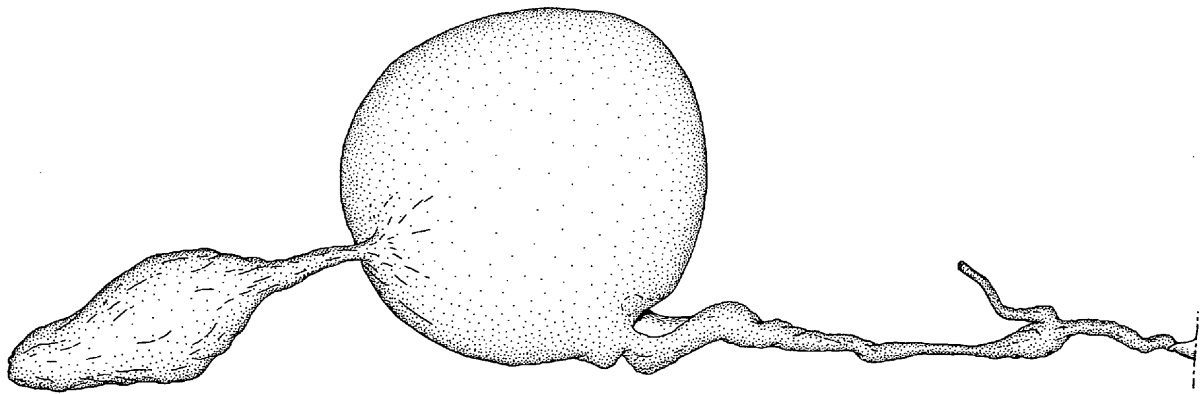


Fig. 16. Female genitalia of *Gandaca butyrosa cuneata* from Ambon. Bursa copulatrix (lateral). Scale=1.0 mm.

24.5 mm.

Male genitalia (Figs. 13, 14): Superuncus with no dorsal keels. Saccus slender, fairly long (about 1.5–1.8 times as long as height of ring), evenly and slightly expanded at posterior portion, opened narrowly at posterior end; angle between vinculum and saccus about 90° . Uncus finely serrated along dorsal edge medially to apically, with apex sharply pointed, bearing setae along entire length. Width of valva slightly shorter than 0.8 times as long as height of valva; distal process of valva sword-like in shape, short, less devel-

oped, tapered apically with apex sharply pointed. Phallus evenly rather slender, with minute spines around posterior tip; anterior end convex anteriorly; peri-vesical area arising ventrally on posterior 1/6 of phallus. Juxta sclerotized, rather broadly membranous at dorsal portion.

Female genitalia (Figs. 15, 16): 7th abdominal sternum with shallow median hollow; extremely small membranous sac densely covered with many elongate scales; lateral hollow slightly shorter than 0.1 times as long as 7th tergum. Lamella postvaginalis with flat

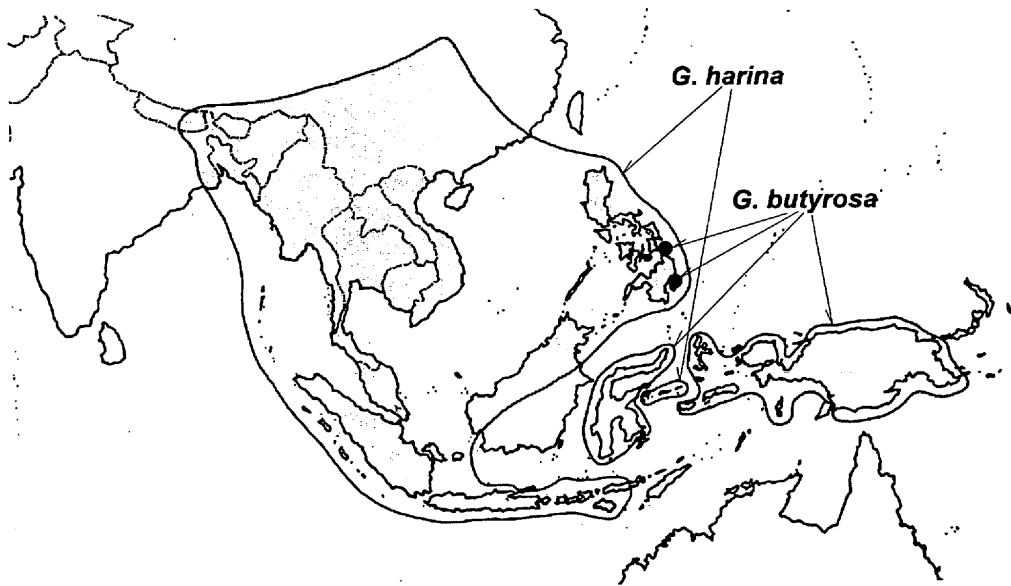


Fig. 17. Distribution of *Gandaca harina* and *G. butyroza*.

spoon-shaped ridge close to ostium bursae, bearing setae on ventral surface of ridge; ductus seminalis attached at middle of ductus bursae. Papilla analis hemispherical, much elongated dorsally.

Variation: As stated in the description, several features show local variations, especially the shape of the valva and width of the base of the superuncus. Much more material is needed for detailed analysis of the local variations and the local forms.

Material studied: PHILIPPINES: Dinagat, (1♂); Mindanao, Masara, 6–8. ii. 1972 (1♂). INDONESIA: Celebes, Palolo-Palu, xii. 1992 (1♂); Makassar 50 m, 28–30. xi. 1973 (1♂); Bantimurung, 27. vii. 1984 (1♂); Halmahera, 17. v. (1♂); Batjan, ix. 1991 (1♀); Ambelau, xii. (1♂); Ambon, 18. i. 1973 (1♂); 31. i. 1973 (1♂2♀♀); 1. ii. 1973 (1♂1♀); New Guinea, W. Irian, Kobakma-Wamena (1♂) (all in BLKU).

Distribution: This species occurs from Sulawesi and Moluccas to New Guinea. New to Dinagat, Mindanao, Halmahera and Ambelau.

Gandaca butyroza includes the following 5 subspecies.

aiguina (Fruhstorfer, 1910). Obi, Buru, Waigeo and Schouten Is.

butyroza (Butler, 1875). Aru

cuneata Joicey & Talbot, 1924. Seram and Ambon

samanga Fruhstorfer, 1910. Sulawesi

thesiades Fruhstorfer, 1911. Onin and Ati-Ati (West Irian)

In addition, *G. butyroza* is recorded from Morotai, Batjan, Misool, and Saporua (Fruhstorfer, 1899;

Peggie *et al.*, 1995) with subspecific name uncertain.

Taxonomic remarks: Although *G. butyroza* is widely distributed over New Guinea (Parsons, 1998), only a race distributed in the western part of this Island, Onin and Ati-Ati, has been assigned the subspecific name *thesiades*.

Habitat and habits: In Papua New Guinea, males imbibe mineralized water from damp sand or creek margins, often in the company of species of *Eurema*. However, they do not gather in groups as in *Eurema* (Parsons, 1998).

Early stages: Unknown.

Larval foodplant: Unknown.

Key to species of the genus *Gandaca*

1. Forewing black distal border with inner edge not sharply defined and not strongly projected along each vein; superuncus with dorsal keels; uncus bluntly pointed apically; distal process of valva long and spatulate, with its apex bluntly pointed; phallus with no spines around posterior tip; median hollow deep, with large membranous sac; lamella antevaginalis protruding anchor-shaped ridge *G. harina*
- Forewing black distal border with inner edge sharply defined and strongly projected along each vein, especially M₃ in females; superuncus without dorsal keels; uncus sharply pointed apically; distal process of valva short and sword-like in shape, with its apex sharply pointed; phallus with minute spines around posterior tip; median

hollow shallow, with small membranous sac; lamella antevaginalis protruding spoon-shaped ridge *G. butyrosa*

Discussion

Yata (1981) listed several characters to distinguish *G. butyrosa* from *G. harina*, of which the basal width of the superuncus appears quite variable in both species and is probably an unreliable distinguishing feature. Our detailed study of male genitalia in *G. butyrosa* and *G. harina* revealed the following differences: superuncus with no dorsal keels; saccus slightly expanded at posterior portion, opened narrowly at posterior end; uncus finely serrated along dorsal edge medially to apically, with apex sharply pointed; distal process of valva sword-like in shape, short, less developed, with apex sharply pointed; phallus evenly rather slender, with minute spines around posterior tip; juxta sclerotized, rather broadly membranous at dorsal portion. On the other hand, females of *G. butyrosa* are distinguishable from *G. harina* based on the following genitalic characters: median hollow shallow; membranous sac small; lateral hollow very small; lamella postvaginalis with protruded spoon-shaped ridge; ductus seminalis attached at middle of ductus bursae; papilla analis hemicircular, elongated dorsally. On the basis of the above characters and key, we treat *G. butyrosa* and *G. harina* as distinct species.

From the viewpoint of biogeography, Yata (1981) found that *G. butyrosa* replaces *G. harina* in the area from Sulawesi and the Moluccas to West Irian, with its western border along Wallace's line. We obtained a few specimens of *G. butyrosa* from Dinagat (1♂) and from Masara of Mindanao (1♂) of the Philippines, which are situated to the west of Wallace's line. Although *G. harina* is distributed in Mindanao, it is unclear whether or not the two species are sympatric. Moreover, we recognized that the subspecies *auriflua* from Banggai and Sula, situated to the east of Wallace's line, is not *G. butyrosa*, but *G. harina*. With its peculiar external features taken into consideration, it is unlikely that *G. h. auriflua* has recently emigrated from western populations, but the subspecies is a relatively old endemic race to these islands. It follows that the distribution range of *G. harina* and *G. butyrosa* is not sharply divided into west and east by Wallace's line (Fig. 17).

The transfer of *auriflua* from *G. butyrosa* to *G. harina* results in disjunct distributions for both *G. harina* and *G. butyrosa* because Banggai and Sula are separated from the main distribution range of *G.*

harina by Sulawesi, and Sulawesi is separated from the main distribution range of *G. butyrosa* by Banggai and Sula (Fig. 17). However, the possibility remains that *G. butyrosa* from the northern part of Sulawesi (no specimens were available) are *G. harina*. If it is *G. butyrosa*, however, we must say that it is a very remarkable distribution. As far as we know, such a distributional pattern in butterflies is unique to these two species.

Acknowledgments

Yamauchi wishes to express his thanks to Profs. T. Saigusa and H. Shima (BLKU) for constant guidance and encouragement. We thank Dr. B. J. Sinclair (BLKU) for critically reviewing an early draft of this paper. We are much indebted also to Dr. R. de Jong (NMNH) and Prof. J. Yukawa (ELKU) for loaning specimens, to Dr. H-l. Xu and Mr. H. Inoue (ELKU) for offering information, to Mr. T. Iwai (BLKU) for assisting to make Fig. 17, and to Dr. K. Ueda, Kitakyushu Museum of Natural History for kind suggestion. Special thanks go to Messrs. R. I. Vane-Wright and P. Ackery (NHM), who kindly allowed Yata to examine the type specimens preserved in NHM. This work is supported by Grant-in-Aids for Scientific Research (No. 11691192) from the Ministry of Education, Science and Culture, Japan.

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(Received November 10, 1999; Accepted February 9, 2000)