



Taxonomic notes on the genus *Eucosia* (Orchidaceae) in Japan and Taiwan

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Goodyerinae (Cranichideae; Orchidoideae) is the subtribe of Orchidaceae comprising approximately 35 genera and 740 species (Chase *et al.* 2015). Despite its species-rich status, it is the least well-known terrestrial subtribe of Orchidaceae with complicated taxonomic histories (Pace 2020). *Goodyera* Brown in Aiton (1813: 197) *s.l.*, with approximately 100 species, is notorious for their taxonomic difficulty (Hu *et al.* 2016; Chen *et al.* 2019; Suetsugu *et al.* 2021). Phylogenetic studies based on nuclear and plastid regions revealed that *Goodyera s.l.* is embedded within many other genera (Chen *et al.* 2019; Hu *et al.* 2016). Consequently, Pace (2020) presented a broadscale taxonomic recircumscription of *Goodyera s.l.* based on a detailed morphological investigation. Accordingly, a new genus *Paorchis* (2020: 262) has been described and several genus including *Eucosia* Blume (1825: 415) have been resurrected, with 20 new combinations. The alternative solution on the taxonomic issue is expanding the concept of *Goodyera*, but it incurs synonymizing eight currently accepted genera containing ca. 270 species with significant differences in lip and column morphology (Pace 2020). Given that such an extraordinary assemblage of morphologies makes the genus undiagnosable, here we follow the criteria in Pace (2020). However, we also noticed that two of his new combinations, *Salacistis fumata* (Thwaites 1861: 314) Pace (2020: 265) [= *S. fumata* (Thwaites) Hsu in Hsu & Chung (2016: 184)] and *S. rubicunda* (Blume 1825: 408) Pace (2020: 266) [= *S. rubicunda* (Blume) Hsu in Hsu & Chung (2016: 184)], are superfluous as he was unaware of the earlier publication of Hsu & Chung (2016). The genus *Eucosia* can be distinguished from *Goodyera s.s.*, by typically unmarked ascending leaves, reddish to greenish pseudo-tubular flowers, lateral sepals usually strongly reflexed at base, lip usually strongly reflexed or curled at apex, and stigma embraced by elevated rims (Hsu & Chung 2016; Pace 2020; Fig. 1).

During our recent botanical surveys, we found an unknown *Eucosia* species on Okinawa Island in the Ryukyu Islands, Japan. It is characterized by the ovate, thin-textured, adaxially glossy pale green leaves without conspicuous reticulate venation, cleistogamous flowers and the columns lacking the long protruding rostellum found in other *Eucosia* species. After examining its morphology and comparing it to previously recorded species, we are convinced that the plant must be treated as *Eucosia carnea* Blume (1825: 415) that was previously recorded only in Java. This disjunct record led us to reevaluate the identity of *Eucosia* species distributed in Japan and Taiwan. Consequently, we found that some names synonymized with *E. viridiflora* (Blume) Pace (2020: 264) must be resurrected, while it is appropriate to lump *E. carnea* and *Eucosia hengchunensis* Hsu in Hsu & Chung (2016: 34), due to morphological synapomorphies. Therefore, here we provide a revision of the genus *Eucosia* in Japan and Taiwan.

Taxonomic treatment

Eucosia carnea Blume (1825: 415). Figs. 1(A–D), 2 & 3.

≡ *Goodyera carnea* (Blume) Schlechter in Schumann & Lauterbach (1905: 93), *nom. illeg.* Type:—INDONESIA. West Java: Mt. Salak (“in humidis montis Salak prope Passir Java”), *C.L. Blume s.n.* (holotype: L0061220 image!)

≡ *Eucosia hengchunensis* Hsu in Hsu & Chung (2016: 34); *Goodyera viridiflora* var. *hengchunensis* (Hsu) Lin (2019: 163), *syn. nov.* Type:—TAIWAN. Pingtung: Shouka, 300–400 m, 3 Jan 2016, *T.C. Hsu 8166* (holotype: TAIF496951!)

Morphological descriptions and illustrations:—See Blume (1858: 48; pl. 12b, f. 3; pl. 42, A) and Smith (1909: f. 96); Hsu & Chung (2016: 34), as *Eucosia hengchunensis*; Lin (2019: 163; f. 66-2), as *Goodyera viridiflora* var. *hengchunensis*.

Distribution:—This species is currently disjunctively recorded from Indonesia (Java), Taiwan (Pingtung) and S Japan (Okinawa and Kagoshima).

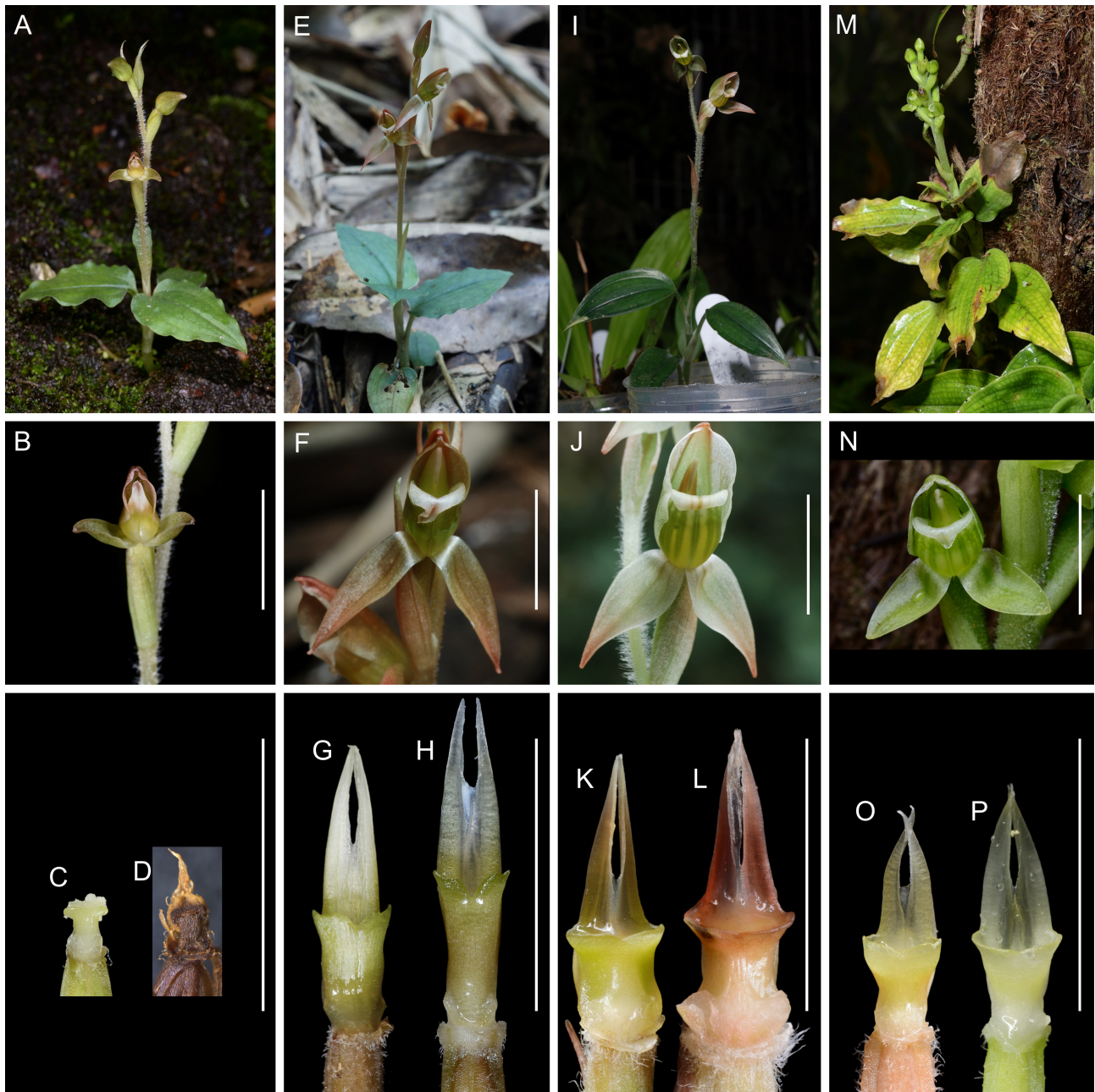


FIGURE 1. Morphological comparison of *Eucosia* species. A–D. *E. carnea*; A–C from Taiwan (*Hsu* 8166, TAIF); D from Japan (*H. Ueno* 364, KAG). E–H. *E. cordata*; E–G from Taiwan (*Hsu* 4615, TAIF); H from Vietnam (*Hsu* 12391, TAIF). I–L. *E. longirostrata*; I–K from Taiwan (*Hsu* 4262, TAIF); L from China (*Hsu* 6525, TAIF). M–P. *E. viridiflora*; M–O. from the Philippines (*Hsu* 6994, TAIF); P. from the Solomon Islands (*Hsu et al. SITW01587*, TNM). Scale bars = 1 cm.

Additional specimens examined:—TAIWAN. Pingtung: Hsuhai, 1 January 2015, *Hsu* 7413 (TAIF); 18 October 2016, *Chung* 12666 (TAIF); 1 November 2016, *Chung* 12666 (TAIF). JAPAN. Kagoshima: Takarajima Island, 15 March 1979, *H. Ueno* 364 (KAG). Okinawa: Okinawa Island, Kunigami, Ada, 2 December 2020, *Y. Miyazato* KS807 (KYO), Okinawa Island, Kunigami, Hiji, 14 December 2020, *Y. Miyazato* KS808 (KYO), Okinawa Island, Kunigami, Iji, 14 December 2020, *Y. Miyazato* KS809 (KYO).

Taxonomic remarks:—*Eucosia carnea* could be characterized by the ovate, thin-textured, adaxially glossy pale green leaves without conspicuous reticulate venation, small, usually cleistogamous flowers with 7–9 mm long sepals and petals, and the columns that are lacking the long protruding rostellum typically found in other congeneric species. The morphological synapomorphies among populations found in wide areas including Japan, Java and Taiwan and distinctiveness against other *Eucosia* species implies that this entity is not just an “abnormal form” of *E. viridiflora* as suspected by Smith (1905), Schuiteman (1996) and Lin (2019) but an isolated lineage that is better kept as an independent species. Although Lin (2019)

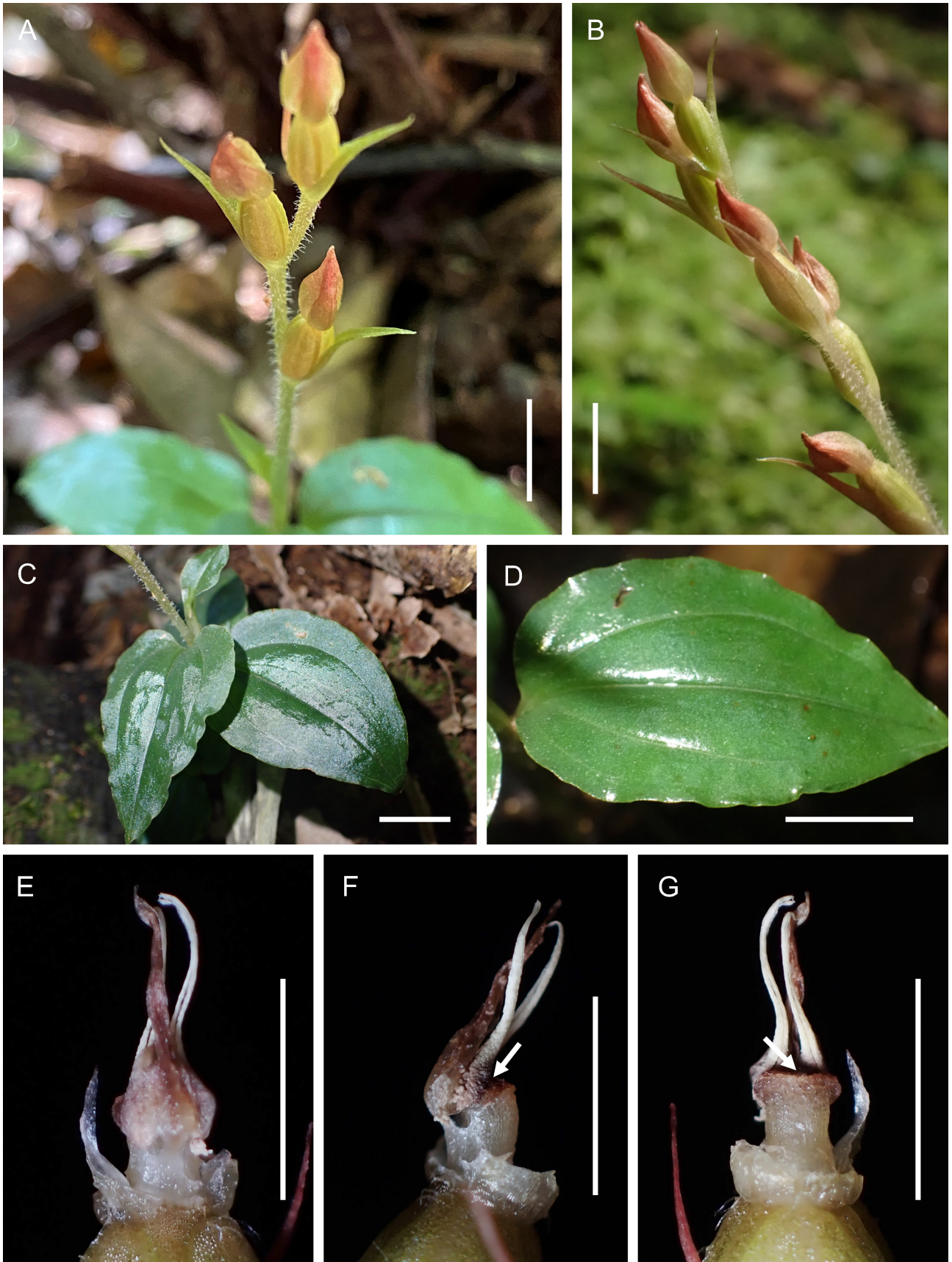


FIGURE 2. *Eucosia carnea* from Japan (*Y. Miyazato KS807*, KYO). A. Flowering plant. B. Inflorescence. C–D. Leaves. E–G. Column; dorsal view (E), lateral view (F), ventral view (G); arrows indicate the position of stigma. Scale bars: A–D = 1 cm; E–G = 3 mm.

suspected that the deterioration of column structure lead to demographic collapse and extinction, *E. carnea* possesses a self-pollination system, allowing contact between the stigma and pollinaria and producing many viable seeds. Its widespread distribution indirectly supports the effectiveness of the reproductive strategy. We thus treat this taxon as an independent species rather than an infraspecific taxon of *E. viridiflora*. This notion is also based on biological species concept, which defines a species as a group that can interbreed in nature, because obligate selfing in *E. carnea* eliminates potential gene flow with other *Eucoxia* species. Due to its historical confusion with *Eucoxia viridiflora*, detailed studies are still needed to clarify its exact geographic range.

Eucoxia cordata (Lindley) Hsu in Hsu & Chung (2016: 33). Figs 1(E–H) & 4.

≡*Georchis cordata* Lindley (1840: 496); *Goodyera cordata* (Lindley) Nicholson (1885: 81); *Orchiodes cordatum* (Lindley) Kuntze (1891: 675); *Epipactis cordata* (Lindley) Eaton (1908: 64), *nom. illeg.* Type:—SRI LANKA. “Zeylona”, *J. Macrae s.n.* (holotype: K000364601!).

=*Goodyera ogatae* Yamamoto (1927: 9), [as “Ogatai”]; *Goodyera viridiflora* var. *ogatae* (Yamamoto) Liu & Su (1978: 1016), [as “ogatai”], *syn. nov.* Type:—TAIWAN. Taipei: Sozan, 1925, *M. Ogata s.n.* (holotype: TI00082034!).

=*Goodyera subuniflora* Ohwi (1937: 47), *syn. nov.* Type:—JAPAN. Okinawa: Okinawa Island, Guiku, *Y. Taira s.n.* (holotype: KYO00092541!).

Morphological descriptions and illustrations:—See Hooker (1894: pl. 2187), as *Goodyera cordata*; Maekawa (1971: 272; pl. 99), as *Goodyera ogatae*; Seidenfaden (1978: 20; f. 6), Leou (2000: 912; photo 121), Averyanov (2008: 124; f. 33, s; f. 36, i), Chen *et al.* (2009: 49; f. 64, 1–4), Barretto *et al.* (2011: 118; f. 93–96), Nakajima (2012: 123; pl. 29–16), Kumar & Rao (2015: 4; f. 1), Yokota (2016: 238), Bhattacharjee & Chowdhery (2018: 84; pl. 22) and Lin (2019: 162; f. 66–1), all as *Goodyera viridiflora*; Hsu & Chung (2016: 33).

Distribution:—This species is currently known from China, India, Japan, Sri Lanka, Taiwan, Thailand and Vietnam.

Additional specimens examined:—CHINA. Fujian: Jiangle, Longxishan, 18 September 1991, *Anonymous collectors* (“陇西山考察队”) 2311 (PE); Longxishan, 26 September 1991, *Anonymous collectors* (“陇西山考察队”) 2817 (PE). Guangxi: Ziyuan, Maoershan, 20 September 2016, *Anonymous collectors* (“资源县普查队”) 450329160920012LY (IBK). Jiangxi: Pingxiang, *Anonymous collectors* (“江西队”) 3003 (PE). Yunnan: Malipo, Laojunshan Natural Reserve, 7 July 2009, *Jin et al. YN-ET 995* (PE); Tengchong, 4 September 2007, *Jin 9218* (PE). INDIA. Meghalaya: Khasiya, 1844, *Griffith s.n.* (K); Khasia, *Hooker & Thomson 344* (K). JAPAN. Kagoshima: Kuroshima Island, Ohkawa, 23 September 1981, *K Maruno s.n.* (KAG), Nakanoshima Island, 21 August 1958, *S. Sako & K. Kawanabe 1935* (KAG), Tanegashima Island, Minamitane-cho, 23 September 1997, *K. Maruno s.n.* (KAG), Uchinoura-cho, Ohura, 25 August 1965, *S. Sako 5695* (KAG, KYO), Yakushima Island, 10 October 1962, *K. Komura s.n.* (KYO), Yakushima Island, 23 August 1926, *G. Masamune s.n.* (TI), Yakushima Island, along Nagata River, 30 July 1969, *Hatusima & Sako 31849* (KAG), Yakushima Island, along Nagata River, 29 September 2006, *S. Tagane & K. Fuse TF001* (TNS), Yakushima Island, Anbo, October 1989, *J. Haginiwa JH040561* (TNS), Yakushima Island, Mocchomudake, 13 October 1989, *J. Haginiwa JH021209* (TNS), Yakushima Island, Kurio, 13 October 1953, *Ohwi & Okamoto s.n.* (TNS), Yakushima Island, Miyanoura, 19 September 1961 *S. Sako s.n.* (KAG), Yakushima Island, between Onoaida and Hananoego, 5 November 1965, *S. Sako 5786* (KAG), Yakushima Island, Onoaida, along Suzu river, 29 August 1963, *T. Yamazaki* (TI), Yakushima Island, Hanayama, 24–27 September 1967, *S. Sako 6869* (KAG), Yakushima Island, Hirauchi, 10 October 1986, *Hatusima 41625* (KAG), Yakushima Island, near Segiri, 9 December 1967, *S. Sako 7001* (KAG). Miyazaki: Yamanokuchi, Awoidake, 13 October 1935, *K. Yoshie s.n.* (TI). Okinawa: Ishigaki Island, Omotodake, 5 November 1977, *G. Ikeda 4437* (KAG), Okinawa Island, Yohanadake, November 1931, *S. Sonohara s.n.*, (KYO), Okinawa Island, Kunigami, Iji, 19 December 2020, *Y. Miyazato KS810* (KYO), Okinawa Island, Yohanadake, 28 October 1970, *C. Chuma s.n.*, (TI), Okinawa Island, Kushidake, 17 January 1940, *T. Kinjo 2096*, (TNS). Iriomote Island, 29 November 2002, *Chung 6103* (TAIF), Iriomote Island, eastern part, 8 October 1984, *Y. Hanei s.n.* (TNS), Iriomote Island, along Nakara River, 13 October 1940, *Y. Kimura & I. Furusawa s.n.* (TI). TAIWAN. Hsinchu: Mt. Hsiakelo, 10 September 2011, *Chung 10455* (TAIF); Ssumakussu Ancient Trail, 10 September 2011, *Hsu 4615* (TAIF). Ilan: Mt. Poyao, 15 October 2003, *Chung 6745* (TAIF). Miaoli: Nanchuang, 16 July 1975, *Lin 219* (TAIF). Nantou: Huesuen, 1 August 1973, *Lin 180* (TAIF); Shueishetashan, 9 December 2005, *Chung 8268* (TAIF). New Taipei: Sanhsia, *Masanune 4030* (TAI); Mt. Tatao, 7 September 2005, *Chung 8304* (TAIF); 6 September 2006, *Hsu 571* (TAIF); 11 September 2011, *Lu 22873* (TAIF). Pingtung: Lanjen Stream, 17 October 2005, *Hsu 357* (TAIF). Taichung: Tahsuehshan, 23 August 1973, *Lin 53* (TAIF). VIETNAM. Lam Dong: Bidoup-Nui Ba National Park, Cong Troi Station, 24 September 2018, *Hsu 10963* (SGN, TAIF, TNM); Cong Troi Station, 30 January 2020, *Hsu 12391* (SGN, TAIF).

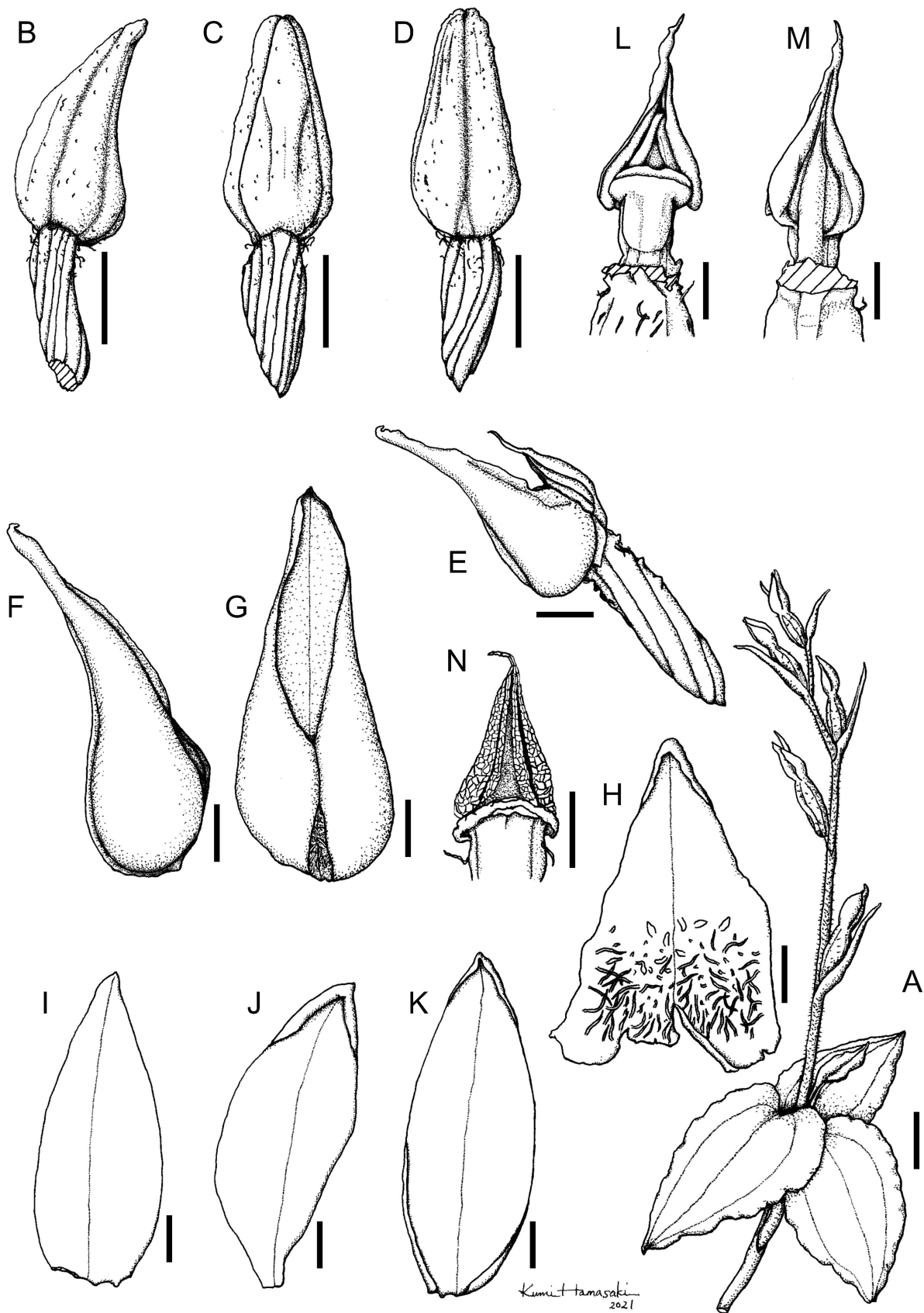


FIGURE 3. *Eucosia carnea* from Japan (*Y. Miyazato* KS807, KYO). A. Flowering plant. B–D. Flower; lateral view (B), dorsal view (C), ventral view (D). E. Lip and column, lateral view. F–H. Lip; lateral view (F), dorsal view (G), flattened and dorsal view (H). I. Lateral sepal. J. Lateral petal. K. Dorsal sepal. L–N. Column; ventral view (L), dorsal view (M). Scale bars: A = 1 cm; B–D = 3 mm; E–N = 1 mm.



FIGURE 4. *Eucosia cordata* from Japan (Y. Miyazato KS810, KYO). A. Inflorescence. B. Leaves. C–D. Flowers; lateral view (C), front view (D). E–F. Leaf; dorsal view (E), ventral view (F). Scale bars = 1 cm.

Taxonomic remarks:—Following Hsu & Chung (2016), we reinstate *Eucosia cordata* because it is readily separable from *E. viridiflora* (Blume) M.G. Pace, described from Java (syntypes: L, possibly missing; P 00137122!), in both vegetative and floral characteristics. The leaves of *E. cordata* are generally ovate to ovate-lanceolate with shorter (ca. 1–2 cm) stipes, subtruncate to subcordate bases and greyish green background color; yet the leaves of *E. viridiflora* are generally ovate-

elliptic to elliptic with longer (ca. 2–4 cm) stipes, rounded bases and green coloration. In addition, *E. cordata* typically has fewer (1–5(–8) vs. (3–)5–10 flowers per inflorescence) but larger (i.e. sepals 12–15 vs. 9–12 mm long) flowers comparing to *E. viridiflora*. The morphology of column also serves as the key characteristic to diagnose these two species, especially from herbarium specimens. *E. cordata* has a distinctly longer column (10–12 mm including rostellum) with a notched or cleft stigma rim (Fig. 1, G & H), while *E. viridiflora* has a shorter (7–8 mm) column with a subentire stigma rim (Fig. 1, O & P). Our current specimen and literature studies revealed that *E. cordata* occurs from Indian subcontinent through Mainland SE Asia toward E Asia, and the distribution of true *E. viridiflora* seemingly restricted to Maritime SE Asia and the Pacific Islands. However, detailed regional studies are still critically necessary to clarify the exact native range of both species. Nevertheless, here we could at least confirm that *E. viridiflora* should be excluded from the Floras of Taiwan and Japan, where previous records of *Goodyera viridiflora* are exclusively misidentifications of *Eucosia carnea*, *E. cordata* and *E. longirostrata*.

Eucosia longirostrata (Hayata) Hsu in Hsu & Chung (2016: 35). Figs. 1(I–L) & 5.

=*Goodyera longirostrata* Hayata (1914: 115).

Type:—TAIWAN. Pingtung County: Mt. Wuwei (“Akocho, Buisan”), 24 March 1910, *T. Kawakami & S. Sasaki s.n.* (holotype: TI-00082033!).

=*Goodyera seikoomontana* Yamamoto (1932: 187); *Goodyera viridiflora* var. *seikoomontana* (Yamamoto) Ying (1977: 198); *Eucosia seikoomontana* (Yamamoto) Pace (2020: 263), [as “seikomontana”], *syn. nov.*

Type:—TAIWAN. Taitung County: Mt. Chenkuanao (“ad circ. 4000 ped. alt. montis Seikoozan”), May 1932, *Yamamoto s.n.* (holotype: TAI118722!).

=*Goodyera youngsayei* Hu & Barretto (1976: 10), *syn. nov.*

Type:—CHINA. Hong Kong: Pat Sin Range, 12 March 1975, *G. Barretto 107* (holotype: K 000942761!; isotype: AMES00074539 image!).

Morphological descriptions and illustrations:—See Leou (2000: 909; photo 121), Chen *et al.* (2009: 49), Barretto *et al.* (2011: 116; f. 90–92), Huang *et al.* (2012: 761; pl. I, E) and Lin (2019: 159; f. 64; pl. 8), all as *Goodyera seikoomontana*; Hsu & Chung (2016: 35).

Distribution:—This species is confined to Taiwan and S China (Guangdong, Guangxi, Hainan and Hong Kong).

Additional specimens examined:—CHINA. Guangdong: Xinyi, Daping, 25 March 1932, *Huang 31882* (IBSC). Guangxi: Jingxi, Hurun, 15 June 2010, *Xu & Liu 10503* (IBK); Shangsi, *Anonymous collectors* (“十万大山采集队”) 1742 (IBK). Hainan: Ledong, Jianfenglinh, 23 April 2013, *Hsu 6525* (TAIF). Hong Kong: Pat Sin Ridge, January 1974, *Guile 6926* (K). TAIWAN. Hualien: Tatong 18 March 2011, *Hsu 4262* (TAIF); Kuangfu Logging Road, 14 February 2007, *Lii 1518* (TAIF). Miaoli: Nanchuang, 25 October 1972, *Lin 36* (TAIF). Pingtung: Chachayalaishan, 29 February 1992, *Liao 196* (HAST); Lilungshan, 1 January 1974, *Lin 111* (TAIF); Lilungshan, 14 February 1989, *Su 8798* (HAST); Lilungshan, 24 January 1990, *Su 9262* (HAST); Mt. Lilung, 3 April 2004, *Chung 7054* (TAIF); Puanshan, *Wang 19011* (HAST). Taitung: Hsinkangshan, 24 February 1987, *Su 7737* (HAST); Mt. Tulan, 2 March 2006, *Chung 9282* (PE, TAIF); Mt. Tulan, 29 March 2007, *Chung et al. 9061* (TAIF); Mt. Tulan, 5 February 2007, *Wang 26* (TAIF); Mt. Tulan, 23 February 2007, *Wang 38* (TAIF); Mt. Tulan, 1 March 2013, *Lu 26518* (TAIF).

Taxonomic remarks:—The holotype of *Goodyera longirostrata* (Fig. 5G) contains a single plant with several leaves and two flowers (one had been cut and dissected). The leaves are thick-textured, broadly cuneate to rounded at base and flat in margins, with submarginal main lateral veins and 2–4 cm long stipes (Fig. 5H); the flowers are relatively large, with sepals ca. 1.5 cm long and column plus rostellum ca. 9 mm long. All these characteristics indicate that this plant corresponds to the species commonly known as *Goodyera seikoomontana* (e.g., Barretto *et al.* 2011; Huang *et al.* 2012; Lin 2019), rather than a synonym of *Eucosia* (*Goodyera*) *viridiflora* as proposed by some authors (eg. Lin 2019; Pace 2020). The earlier published *G. longirostrata* should thus take priority against *G. seikoomontana*.

Key to the *Eucosia* species in Japan and Taiwan:

1. Leaves subleathery, ±stiff, broadly cuneate to rounded at base, 3-veined, main lateral veins obviously closer to margins; stipes 2–4 cm long *E. longirostrata*
- Leaves membranous to papery, soft-textured, rounded to subcordate at base, margin usually ±undulate, 3- or 5-veined, if 3-veined then main lateral veins ±medial between midrib and margins; stipes 1–2 cm long 2
2. Sepals 12–15 mm long; rostellum well developed; leaves adaxially dull greyish green, usually with dark green reticulate venation *E. cordata*
- Sepals 7–9 mm long; rostellum absent; leaves adaxially glossy pale green, without conspicuous reticulate venation *E. carnea*

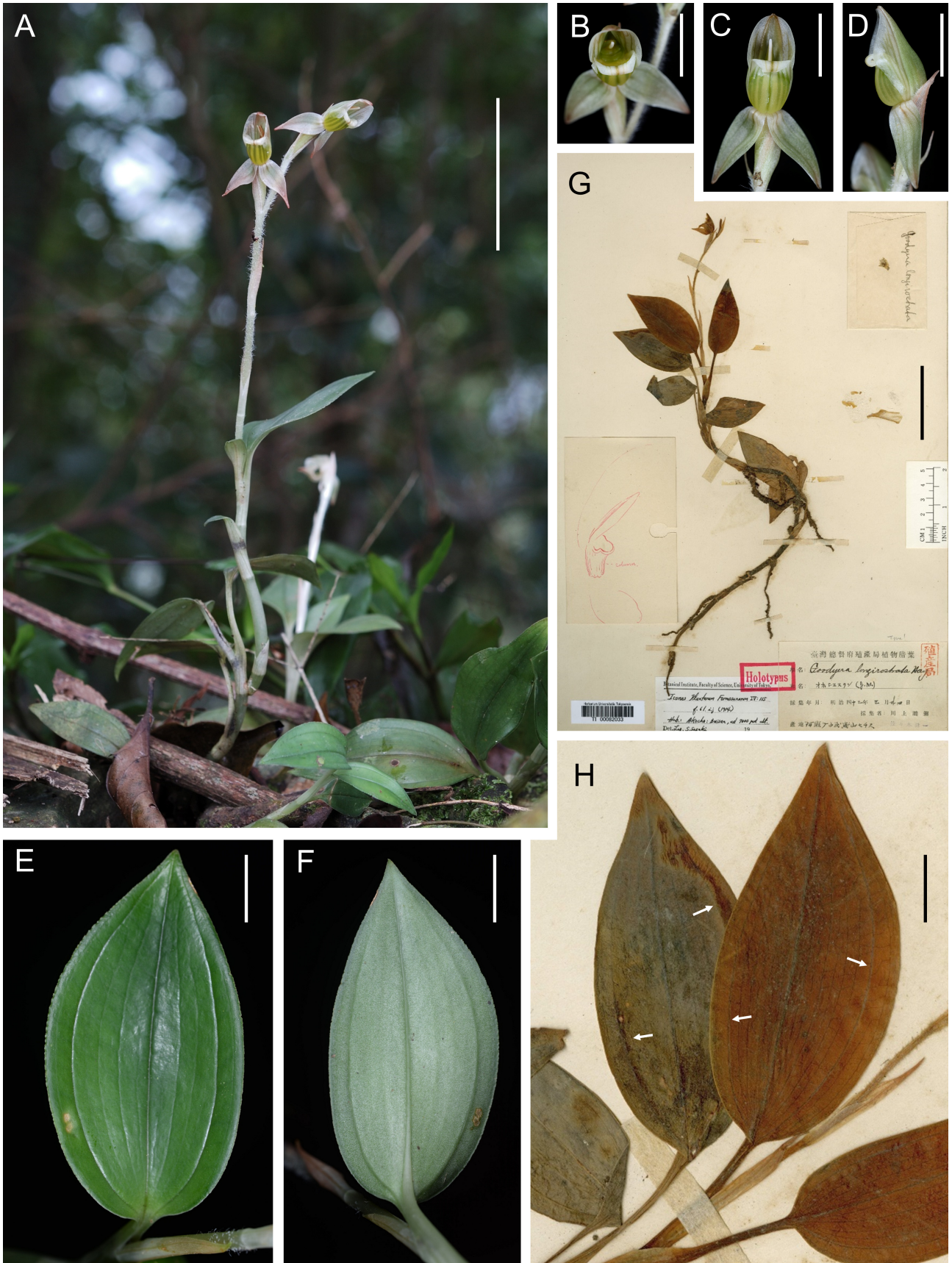


FIGURE 5. *Eucosia longirostrata* from Taiwan (A–F, Hsu 13339, TAIF). A. Habit. B–D. Flower. E–F. Leaf; dorsal view (E), ventral view (F). G–H. Holotype of *Goodyera longirostrata* (Kawakami & Sasaki s.n., TI); arrows indicate the positions of main lateral veins. Scale bars: A & G = 5 cm; B–F & H = 1 cm.

Acknowledgements

We appreciate the curators of AMES, HAST, IBK, K, KAG, KYO, L, P, PE, TAI, TAIF, TI, TNM and TNS for the access of herbaria and/or collection databases. We are grateful to Masayuki Iha and Yoshiko Miyazato for providing specimens and pictures of *Eucosia carnea* in Japan. This study was financially supported by a Grant-in-Aid for Scientific Research (17H05016, KS) from the Ministry of Education, Culture, Sports, Science, and Technology, Japan and by the Environment Research and Technology Development Fund (#4-2001, KS) from the Ministry of Environment, Japan.

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