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# New addition and observations of the orchid flora of Taiwan: *Calanthe*, *Cheiostylus*, *Gastrodia*, and *Goodyera* (Orchidaceae)

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ABSTRACT: This report presents 1 new orchid from Taiwan, viz., *Goodyera maculata* T.P. Lin. New insights revealed a progenitor and progeny relationship between *Cheirostylis chinensis* and *Che. takeoi*. I also present trimorphic flowers of *Calanthe lyroglossum* and dimorphic *Gastrodia flexistyla*.

KEY WORDS: *Calanthe lyroglossum*, *Cheirostylis takeoi*, dimorphic flower, *Gastrodia flexistyla*, *Goodyera maculata*, trimorphic flower

## INTRODUCTION

The present paper is a continuation of efforts to update the orchid flora of Taiwan. A comprehensive description of native orchids of Taiwan was recently published (Lin, 2019). In that book, about 465 species, varieties, and natural hybrids belonging to 108 genera were reported. However, the emergence of new observations on orchids from different locations has continued due to ongoing orchid surveys. The rate of adding new orchids to the country's flora is gradually slowing down. Explorers are now transferring their attention to morphological variations of known species. Thus, increasing reports of new natural hybrids and varieties could be expected. Recent field explorations have resulted in new insights into several orchids of Taiwan in the genera *Calanthe*, *Cheirostylus*, *Gastrodia*, and *Goodyera*, which are presented below.

## TAXONOMIC TREATMENT

***Goodyera maculata*** T.P. Lin, ***sp. nov.***

**高山斑葉蘭 Figs. 1 & 2 A–C**

*Goodyera schlechtendaliana* auct. non Rchb. f.: T.P. Lin, Native Orch. Taiwan 1: 186, photo 115. 1975.

***Type*:** Taiwan: Nantou Co., Piluchi, 2400 m, Sept. 3, 2018, *P.N. Shen s.n*. (TAI288180).

***Diagnosis***: *Goodyera maculata* resembles *G. schlechtendaliana* and *G. kwangtungensis*, but differs from them in having white spots or blotches on green upper surface, while longitudinal green lines/veins and/or the tessellated network are hardly ever seen.

***Description***. Terrestrial. Flowering plant 6.5–18 cm tall above creeping base. **Leaves** 2–6, ovate, ovate-elliptic or ovate-lanceolate, 0.8–3 × 0.6–1.5 cm, acute, rounded or subcordate at base, green with irregular white spots or blotches (not rectangular tessellation) on upper surface, pale-green beneath, papery to sub-coriaceous; petiole ca. 1 cm long. **Flowering stems** 5–15 cm long, slender and slightly stiff, glandular-pubescent; sheath-bracts ca. 3, relatively long, amplexicaul, basal one as long as leaf; spike ca. 5 cm long, 2–7-flowered. Floral bracts narrowly ovate, 8 × 4.5 mm, hairy. Ovary pedicellate, 1 cm long, hairy. **Flowers** white tinged greenish, 1.1–1.6 cm across; sepals narrowly ovate, 8–10.5 × 3–3.5 mm, acute, glandular-pubescent outside; lateral sepals slightly oblique, recurved; petals 8.5–9.5 × 2.1–3 mm, white, obliquely spatulate, appressed to upper sepal forming a hood over column, with 2 round green spots near apex. **Lip** 6–9 × 2.9–3.5, mm, curved, saccate at base, tongue-shaped at apex, recurved, acute at apex, limb with 2 low ridges along midrib, sac with scattered glandular hairs. **Column** 2.8–3.5 mm long, slightly dilated at apex, constricted in middle, basal part free or fused to basal lip for 1/3 column length. **Rostellar** arms narrow, ca. 1 mm long, deeply bifid. Stigma located on ventral side, broadly orbicular, protruding. **Anther-cap** ovate, ca. 1.5 mm long; pollinia 2, each with 2 subequal partitions, yellow, 1.5 mm long, attached to lanceolate viscidium.

***Etymology***: Species epithet "maculata" refers to white spots or stains on the leaf surface.

***Flowering time***: July–September.

***Distribution***: **Taiwan**: Found in alpine forests of high mountain at elevations of 1800–3000 m. ***Outside Taiwan***: It is difficult to tell the difference between similar species of specimens in herbaria. Fresh leaves and flower are required for diagnosis.

***Note***: In 1975, I reported *Goodyera schlechtendaliana* as being from Taiwan in my early work (Lin, 1975) which I mistakenly applied to *Goodyera maculata* T.P. Lin. This error, however, escaped attention until recently when I learned of the true *G. schlechtendaliana* of Japan from Suetsugu and Hayakawa (2019) and Suetsugu *et al*. (2021) in which color images of leaf decorations of *G. schlechtendaliana* were identical to those of *G. kwangtungensis* of Taiwan (Fig. 2D-F). Since the type of *G. schlechtendaliana* was based on *Göring s.n*. (W. Herb.

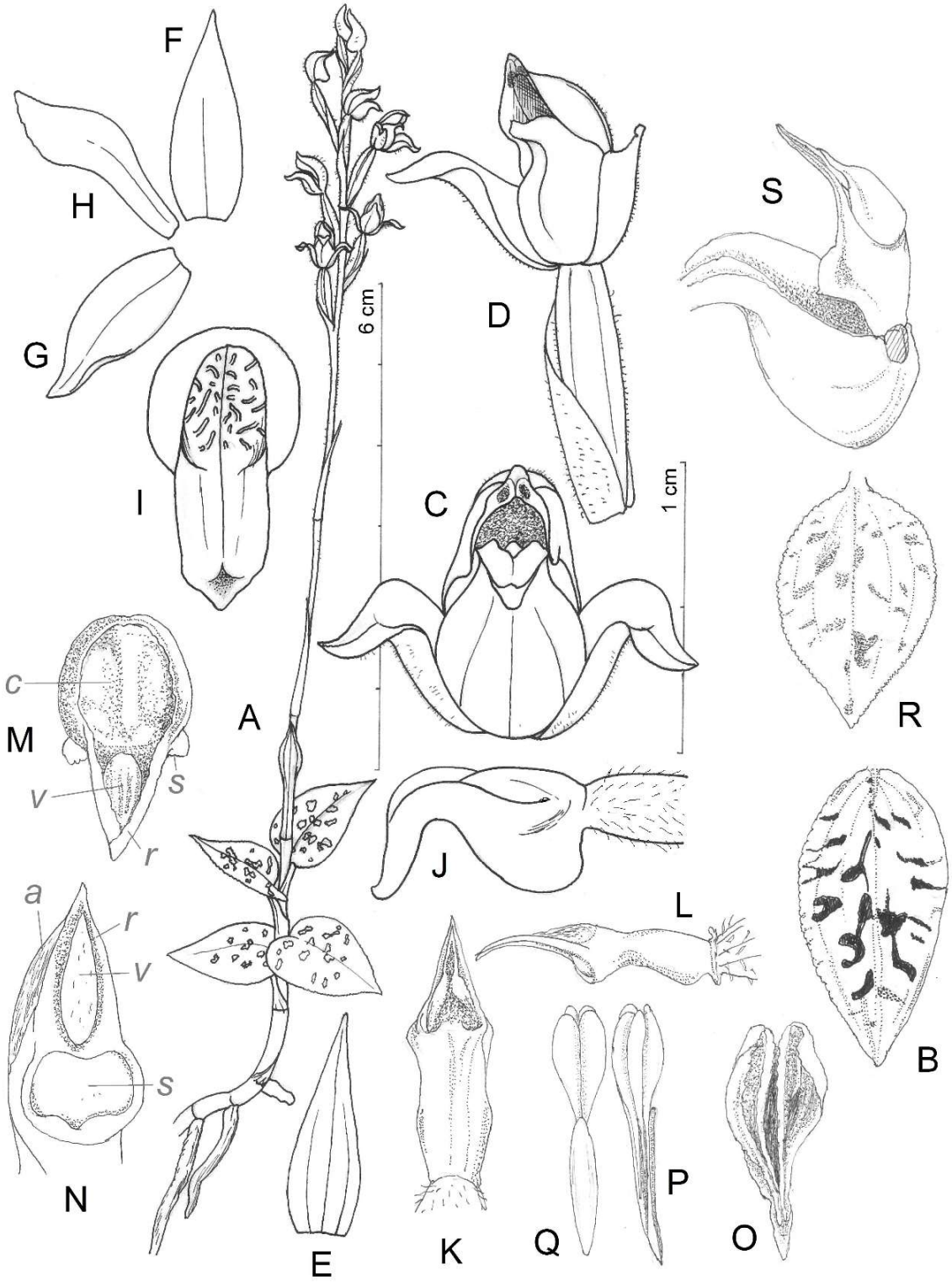


**Fig. 1**. ***Goodyera maculata*** T.P. Lin. **A**: Flowering plant. **B**: Leaf. **C**: Flower, frontal view. **D**: Flower, view from below. **E**: Floral bract. **F**: Upper sepal. **G**: Lateral sepal. **H**: Petal. **I**: Lip, view from above. **J**: Lip fused with 1/4 column from base, side view. **K**: Column with anther attached, view from above. **L**: Column with anther attached, side view. **M**: Column with anther removed, view from above. **N**: Column with anther attached, view from below. **O**: Anther-cap, view from below. **P**: Pollinarium, side view. **Q**: Pollinarium, view from below. **R**: Leaf. **S**: Lip and column, side view. M and N were derived from a developing flower. a, anther; c, clinandrium; r, rostellum; s, stigma; v, viscidium. A–Q, from Piluchi, 2400 m (TAI288180); R and S, from Taoyuan City, 1800 m (TAI 289826).

**Table 1**. Comparisons among three ***Goodyera*** species.

| Species | ***G. maculata*** (Fig. 2A–C) | ***G. daibuzanensis*** (Fig. 2G–I) | ***G. schlechtendaliana*** (Fig. 2D–F) |
|---|---|---|---|
| Height of flowering plant | 11.5 ± 2.66 (6.5–18) cm | 28 ± 8 (12–47) cm | 21.0 ± 4.7 (10–29) cm |
| Leaf shape | **Ovate-elliptic**, ovate, ovate-lanceolate | **Ovate-oblong,** ovate-elliptic, oblong | **Ovate-elliptic**, elliptic, ovate-oblong |
| No. of leaves | 4 ± 1 (2–6) | 6 ± 1 (3–13) | 4 ± 1 (3–9) |
| Leaf decoration | Green with **white spots or blotches** | Green with **longitudinal green lines** & **whitish-green blotches** | Green with a **white tessellated network** |
| Leaf margin | Minutely **wavy** or entire | Entire | Entire |
| Size of leaf* | 2.0 ± 0.5 × 0.9 ± 0.2 (0.8–3 × 0.6–1.5) cm | 5.8 ± 2.2 × 2.4 ± 0.8 (3.1–10.8 × 1.4–4.4) cm | 4.1 ± 1.1 × 1.8 ± 0.5 (1.8–5.8 × 1–3) cm |
| Flowering stem | 5–15 cm, pubescent | 20–36, pubescent | 15–23, pubescent |
| No. of flowers | 5 ± 2 (2–7) | 10 ± 3 (7–17) | 8 ± 4 (6–12) |
| Flower width | 1.1–1.6 cm | 1.2–1.6 | 1.6–1.8 |
| Petal, | 8.5–9.5 × 2.1–3 mm, with 2 round spots at apex | 11–14 × 4.5–4.8 mm, with 2 round spots at apex | 9–12 × 3.5 mm, with 2 round spots at apex |
| Sepal | 8–10.5 × 3–3.5 mm, pubescent | 10.8–15 × 3.2–5 mm, pubescent | 9–14 × 4.3–4.5 mm, pubescent |
| Lip length | 6–9 × 2.9–3.5 mm, white, **no** spot at apex | 9–10 mm, white, with **1** spot at apex | 8–10 × 3.8 mm, white, with **1** spot at apex |
| Column | 2.8–3.5 mm | 6.8–8 mm | 6–7 mm |
| Elevation | 1800–3000 m | 900–2100 m | 1500–2500 m |

* Only the largest leaf of each plant was measured. Boldface text emphasizes important differences among species.

Reichenbach 37474) who collected it from Japan, I tried to collect images of *G. schlechtendaliana* from internet websites and found that *G. maculata* does not occur in Japan. *Goodyera schlechtendaliana* of Japan is characterized by a whitish rectangular tessellation network on the leaf surface just like the images in Fig. 2E and 2F. The only available digital specimen from Japan was collected by R. Oldham from Kino Ahosima in Oct. 1861 (K000363096) and stored under the name *Goodyera japonica* Blume. But this herbarium specimen is difficult to diagnose, because several species have similar images, i.e., *G. schlechtendaliana*, *G. kwangtungensis,* and *G. maculata*.

I found some minor differences between a lower-elevation population (1800 m) (TAI289826) and an alpine population (2400–3000 m) (TAI288180). The lower-elevation plants in Taoyuan City grow on mossy trunks and often have lighter markings on the leaf surface (Fig. 1R), and the column is shorter and almost free from the lip (Fig. 1S). What are differences among 3 related plants of *G. schlechtendaliana*, *G. daibuzanensis,* and *G. maculata*? The height of the flowering plant, leaf number, leaf size, and flower number were measured in numerous specimens in TAIF, HAST, and TAI. Leaf surface markings on fresh leaves are definitely the most important feature for differentiating these 3 species. The green upper surface of *G. maculata* has white spots or blotches, but longitudinal lines/veins are hardly ever seen; the green surface of *G. daibuzanensis* is decorated with longitudinal green lines/veins and whitish-green blotches (Fig. 2I); the tessellated network of *G. schlechtendaliana* exhibits longitudinal and horizontal whitish lines which are mostly absent in the other 2 species. These 3 species have preferences for certain habitat qualities, because no mixed growth was found between them. *Goodyera maculata* prefers mossy surfaces of rocks or horizontal trunks in the shade, or along roadsides in alpine forests, while *G. schlechtendaliana* is always found on slopes under pine or oak forests at 1500–2000 m. *Goodyera daibuzanensis* favors a drier habitat and grows either in bushes just above a steep slope or on a slope surface covered with dry debris along a roadside.

***Goodyera schlechtendaliana*** Rchb. f., Linnaea 22: 861. 1849; *Peramium schlechtendalianum* (Rchb. f.) Makino, J. Jpn. Bot. 6(12): 37. 1929. **Type**: Japan: *Göring s.n.* (W. Herb. Reichenbach 37474).

**Fig. 2D-F 斑葉蘭**

*Goodyera kwangtungensis* C.L. Tso, Sunyatsenia 1: 134. 1933; Lin, Native Orch. Taiwan 2: 168, photos 78, 79. 1977, Lin, Orch. Fl. Taiwan 144. Fig. 56; Pl. 7. 2016. ***Type***: China: Kwangtung: Lochong, Tatung, Nov. 16, 1931, *N.K. Chun 42963* (IBSC0005433). ***syn. nov.***
*Goodyera rontabunensis* T. Chow., Taiwan Orch. 66. 1968. *nom. nud.*

The type for the *G. kwangtungensis* C.L. Tso (IBSC0005433) can be found in the iPlant.cn. without a virtual image. The description by Tso well agrees with that of *G. schlechtendaliana*.

***Flowering time***: Mainly July–September.

***Distribution***: China, Japan, Taiwan: Found in forests at elevations of 1500–2500 m.

***Note***: The name *Goodyera kwangtungensis* C.L. Tso was used in previous work (Su, 2000; Lin *et al*., 2016), without knowing it was the true *G. schlechtendaliana*. Herbarium specimens from Southeast Asia labeled as *G. schlechtendaliana* may be mistaken identifications of *G. daibuzanensis*. Again, fresh leaves and flowers are required for diagnosis.

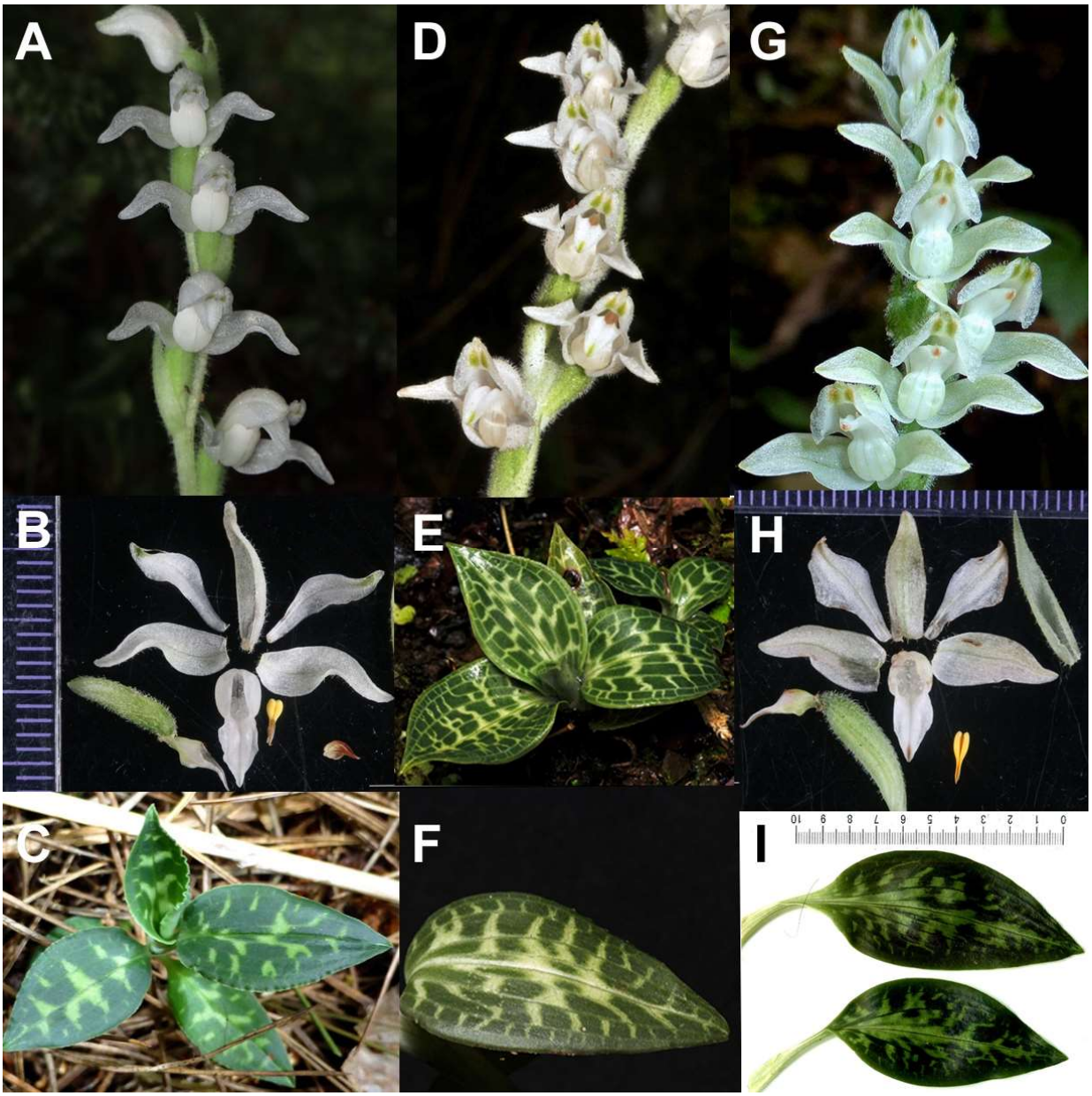


**Fig. 2**. ***Goodyera maculata*** (**A**–**C**), ***G. schlechtendaliana*** (**D**–**F**), and **G. daibuzanensis** (**G**–**I**). **A**, **D**, **G**: Inflorescence. **B**, **H**: Dissected flower. **C**, **E**, **F**, **I**: Leaf.. **A**, **D** and **E** taken by Jin-Yuan Wang; **C** and **G** taken by Da-Ming Huang.

***Additional herbarium specimens examined*: *G. schlechtendaliana***: **TAIWAN**: **TAIF**-168220, 168408, 168618, 183944, 190832, 190833, 193083, 220737, 233429, 233905, 456679, 408569, and 311199; **HAST**: 104466, 104758, 104783, 104784, and 118837; ***G. daibuzanensis***: **TAIWAN**: **TAIF**-118451, 118446, 123824, 123881, 159046, 220593, 231657, 233939, 254994, 255082, 362727, 374508, 374723, 391656, 413474, 413475, 442353, 449095, 465520, and 469110; **HAST**-14561, 14589, 23226, 24306, 25142, 31300, 32995, 35730, 116532, 14561, 14589, 14785, 25142, and 131912; **TAI**-148535 and **KPM**-G00410 (digital image in Plants of Taiwan (tai2.ntu.edu.tw)). ***G. kwangtungensis***: **JAPAN**: Kino Ahosima. Oct. 1861, *R. Oldham 358* (**K**000363096) stored under *Goodyera japonica* Blume. **TAIWAN**: **TAIF**-154705, 190843, 220752, 233965, 255134, 373908, 408598, 413644, 446496, 469820, 507659, 509720, and 298296; **HAST**-125938, 19047, 106418, 104507, 104513, 104681, 104780, 104781, 104782, 104789, 19047, and 78432; **TAI**-284557 and 283137.

***Cheirostylis chinensis*** Rolfe ex Hemsl. var. ***takeoi*** (Hayata) T.P. Lin, ***comb. & stat. nov.***

**全唇指柱蘭 Fig. 3A & B**

*Arisanorchis takeoi* Hayata, Icon. Pl. Formosan. 4: 110, pl. 57. 1914; *Cheirostylis takeoi* (Hayata) Schltr., Repert. Spec. Nov. Regni Veg. Beih. 4: 171. 1919. ***Type***: Taiwan: Chiayi: Mt. Ali, inter Karapin et Suisharyo, 3300 ped., Mar. 28, 1914, *Takeo Ito s.n.* (TI, photo T00906 in https://tai2.ntu.edu.tw/).

*Cheirostylis takeoi* is a relatively common *Cheirostylis* species in Taiwan, and is also found in China, the Ryukyus (of Japan), Thailand, and Vietnam, and is characterized by a simple or petalized labellum (Lin, 2019). A mutated labellum of *C. takeoi* (Fig. 3A) has been

circulating on the internet among amateurs for the past 3 years. Recently, many populations of *C. takeoi* containing mutated flowers were found, and usually only 1 or rarely 2 of the flowers in an inflorescence are mutated. Transformation into an irregularly toothed or laciniate labellum from a simple one only occurs to one-half of the labellum (Fig. 3A). I think that perhaps the lip of *C. takeoi* must have petalized from an unknown progenitor, but have no idea which progenitor. Molecular tools should be able to answer this question if we were to study DNA patterns of all species in Taiwan. Here I found morphological evidence to be useful. There are 5 species of *Cheirostylis* with a laciniate lip in Taiwan, but only *C. chinensis* and *C. cochinchinensis* have a similar laciniation or fringe as the mutated *C. takeoi*. Additionally, all 5 of these species have different calli inside the lip sac, viz., a row of 2–5 papilla-like calli on each side in *C. chinensis*, 6–8 branched calli in *C. cochinchinensis*, bifurcate or trifurcate calli in *C. liukiuensis*, 8–10 randomized papilla-like calli in *C. octodactyla*, and 1 bifurcate or trifurcate papilla in *C. tortilacinia*. The calli of mutated *C. takeoi* show 4 calli arranged in a row (Fig. 3B), which is identical to *C. chinensis*. Furthermore, leaves of *C. takeoi* are ovate or ovate-cordate with grayish-green or deeper-green along prominent veins, which is also identical to that of *C. chinensis*, a relatively common *Cheirostylis* species in central and southern Taiwan. Based on these observations, I propose that *C. takeoi* may have mutated from *C. chinensis*. I therefore have made an adjustment to the name as shown above to show the relationship between *C. takeoi* and *C. chinensis*.

***Additional specimens***: **Mutated flowers**: Taiwan: Nantou Co. 600 m, Mar. 15, 2021, P.N. *Shen s.n.* (TAI289867), Taiwan: Taoyuan City, Baling, 600 m, Mar. 13, 2021, *D.M. Huang s.n.* (TAI289868).

## NEW TAXONOMIC OBERVATIONS

**Dimorphic flower in *Gastrodia flexistyla***

*Gastrodia flexistyla*, a mycoheterotrophic orchid (Fig. 3C), is characterized by a strongly inflexed column (gynostemium) and anther developmentally embedded in the ovary, thus forming an exclusively self-pollinating flower (Fig. 3E, right; Lin, 2019). This structure ensures that the pollinia matures and germinates inside the ovary without going through the stigma. Not only is the pollinia intact, but the anther cap is also found in the top chamber inside the ovary, which is the norm for *G. flexistyla*. At this point, it seems that the stigma and open perianth are functionless to the flower of *G. flexistyla*.

This however dramatically changed by observations of Dr. Ching-Hwang Liu who found a straight column in flowers of *G. flexistyla* in a Yangminshan (northern Taiwan) population in 2020 (Fig. 3D, E, left). The number of flowers with a straight column was much less than that with an inflexed column (at least 2 of 30 individuals). The straight column is always accompanied by an open perianth tube, but the inflexed column can have either open or closed perianth tubes. This is the first instance in which we saw *G. flexistyla* with a round anther cap, a basal rounded stigma, and a well-developed rostellum. Dr. Liu also noted that the inflorescence always consists of some cleistogamous flowers and the more-common chasmogamous flowers (Fig. 3C). Both cleistogamous and chasmogamous flowers always have a colorful lip and shiny calli at the lip claw. This may explain why a flower with an inflexed column still needs an open perianth tube and colorful lip. This ensures that pollinators will be attracted and visit the flower to benefit the few flowers with a straight column.

Cleistogamy is generally present in angiosperms, but the known genera and families are still limited (Culley and Klooster, 2007). Although cleistogamy may provide reproductive assurance, reduce the reproductive energy investment, and facilitate local adaptation, completely cleistogamous species are rare (Culley and Klooster, 2007). However, it does not seem to be uncommon in the Orchidaceae, especially in *Gastrodia*. *Gastrodia clausa* (Hsu, 2012; Lin, 2019) and *G. takeshimensis* (Suetsugu, 2013) are other cases reported to be completely cleistogamous and that self-pollinate with pollinia shaded on the stigma by gravity. *Gastrodia peichatieniana*, a native of Taiwan, produces both cleistogamous and chasmogamous flowers in different individuals. *Gastrodia flexistyloides* (Suetsugu, 2014) from Japan has an identical flower structure as that of *G. flexistyla*, but can be distinguished by its smaller-sized cleistogamous flowers. Based on the new observations described above, I see no reason to separate *G. flexistyloides* from *G. flexistyla*. Cleistogamy may also have disadvantages which include inbreeding depression and reduced genetic diversity of populations.

***Taxonomic treatment***:

***Gastrodia flexistyla*** T.C. Hsu & C.M. Kuo, Taiwania 55(3): 243-244, f.1. 2010. ***Type***: Taiwan: Taipei: Beitou, Mt. Chongcheng, 700–800 m. Mar. 24, 2008, *T.C. Hsu 1300* (holo. TAI; iso. TAIF440367).

*Gastrodia flexistyloides* Suetsugu, Phytotaxa 175(5): 270–274. 2014. ***Type***: Japan: Kyushu: Takashima Island, March 25, 2014, *K. Suetsugu s.n.* (holo. KYO; iso. TNS). ***syn. nov.***

**Trimorphic flowers in *Calanthe lyroglossa***

*Calanthe lyroglossa* Rchb. f. is one of the common *Calanthe* species in lowland hills of Taiwan and often shows mixed growth with *C. speciosum*, which also has small yellow flowers but a different flowering season. Hayata presented a line drawing with an inflorescence with an open flower under *Calanthe forsythiiflora* Hayata (Hayata 1914, synonym of *C. lyroglossum*) (Fig. 3F), but he did not report the structure of the column. I also presented a line drawing with an inflorescence with a

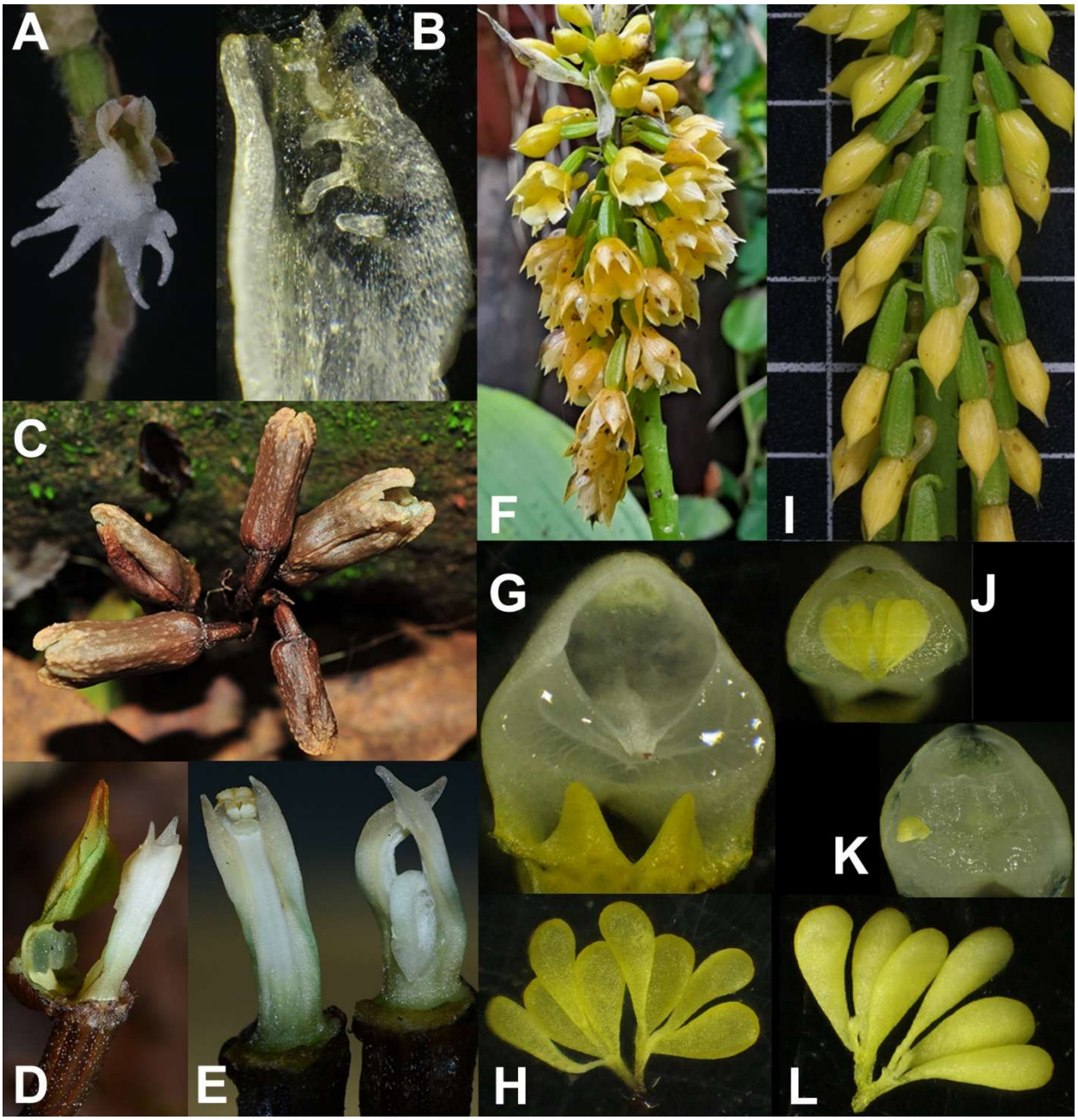


**Fig. 3**. **A**, **B**: ***Cheirostylis takeoi***, **C–E**: ***Gastrodia flexistyla***, **F–L**: ***Calanthe lyroglossum*** (**F–H**: Chasmogamous flowers and **I–L**: Cleistogamous flowers)). **A**: Laciniate lip of mutant flower of *Cheirostylis takeoi*, frontal view. **B**: Basal sac of lip showing 4 calli in a row. **C**: Inflorescence of *Gastrodia flexistyla*, view from above. **D**: Straight column and lip, side view. **E**: Straight (left) and inflexed columns (right). **F**: Inflorescence of *Calanthe lyroglossum*, with open flowers. **G**: Column with pollinia removed, frontal view showing triangular rostellum. **H**: Pollinia and viscidium. **I**: Inflorescence of *Calanthe lyroglossum* with closed flowers. **J**: Column, frontal view showing stigma with pollinia attached. **K**: Column of J with pollinia removed, frontal view showing stigma lacking rostellum. **L**: Pollinia without viscidium, with 2 pollinia aborted. C, D, and E taken by Ching-Hwang Liu; F taken by Liang-Zu Chang.

closed flower under *C. lyroglossa* in my early work (Lin, 1975, Fig. 3I), also without information on the column. However, I later published a line drawing and color image of *C. lyroglossum* to demonstrate that the column of a closed flower does not have a rostellum or viscidium (Fig. 3J, K) (Lin, 2019). In the previous flowering season of *C. lyroglossum* (Feb.–Mar. 2021) I was wondering what kind of column structure the open flower has. Surprisingly, open flowers have a well-developed rostellum in *C. lyroglossum* (Fig. 3G), and a viscidium (Fig. 3H). So I realized that open flowers and closed ones represent 2 morphs within a single species. The closed morph (with cleistogamous flowers) exhibits a swollen pollinia which attaches to the stigma within a developing

flower bud (selfer, Fig. 3K), while the open morph (with chasmogamous flowers) has a triangular rostellum which separates the pollinia from the stigma in a blossoming condition (out-crosser). I also noted that 2 of the 8 pollinia in open flowers had aborted in closed flowers (Fig. 3L). Our dimorphic case differs from that of the Neotropical *Catasetum* which is well known for its sexual dioeciousness, because male and female flowers grow on different individuals (Milet-Pinheiro *et al*., 2015). Our case, however, is slightly similar to many Madagascan species of *Bulbophyllum* in which auto-pollinating morphs, either lacking a rostellum or possessing a stigmatic rostellum, coexist with their pollinator-dependent conspecifics (Gamisch *et al*., 2014).

In fact, *C. lyroglossum* shows a trimorphic flower. In addition to the 2 morphs, a third one, viz., *Calanthe actinomorpha* Fukuy. (Fukuyama, 1935) or *C. lyroglossa* var. *actinomorpha* (Fukuy.) P.J. Cribb & D.A. Clayton has a petalized lip otherwise identical to cleistogamous flowers (Lin, 1975; 2019). This variety is rare as only a few individuals were found in a normal population of *C. lyroglossum* with open flowers but not in closed flowers. This is the first Taiwanese species of orchid showing trimorphic flowers within the same species.

***Specismen examined*: Chasmogamous flowers** (Fig. 3F–H): **TAIWAN**: New Taipei City: Bolushan, c. 500 m, Mar. 22, 2021, *L.Z. Chang s.n*. cultivated (TAI289871). **Cleistogamous flowers** (Fig. 3I–L): **TAIWAN**: New Taipei City: Mt. Badaoer, c. 600 m, Mar. 15, 2021, *T.P. Lin s.n.* (TAI289868); New Taipei City: Yun-Hsien Park, c. 800 m, Mar. 17, 2021, *T.P. Lin s.n*. (TAI289870).

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