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A taxonomic revision on *Isotrema* (Aristolochiaceae) in Taiwan, including one new species

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ABSTRACT: The genus *Isotrema* (Aristolochiaceae) in East Asia had been intensely revised in the recent decade. However, the classification of Taiwanese *Isotrema* has not been reviewed since 1996. In current study, we examine the habit, leaf shape, and flower morphology and conducted morphometrical analyses in order to revise the classification of Taiwanese *Isotrema*. As a result, we recognized five species in Taiwan, including one new species, *I. pahsienshanianum*. Additionally, *I. hohuanense*, an overlooked species, which was omitted from the Flora of Taiwan is recovered.

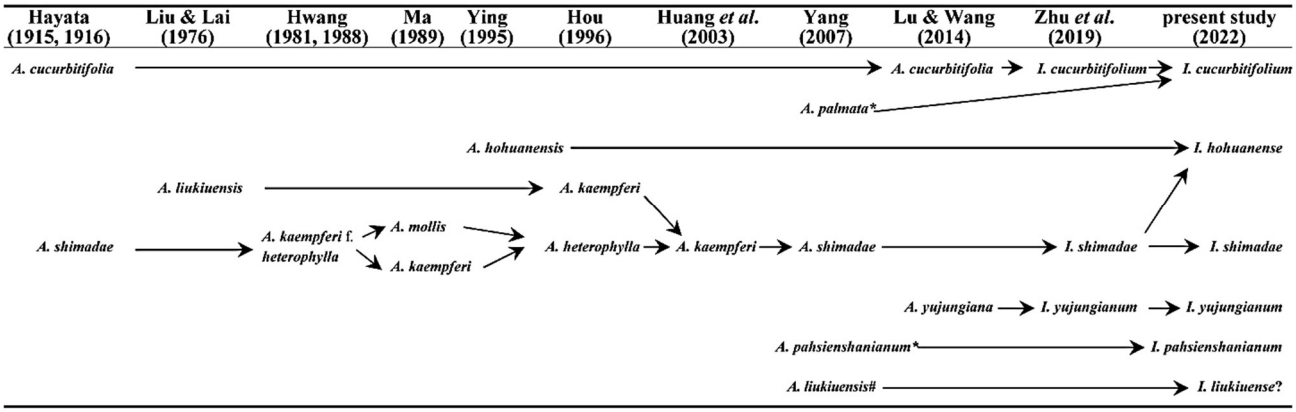
KEY WORDS: Aristolochiaceae, *Isotrema hohuanense*, *I. pahsienshanianum*, Taiwan, taxonomy.

INTRODUCTION

Aristolochia L. sensu lato (s.l.) is the largest and most widespread genus of Aristolochiaceae, composed of approximately 500 species (Wagner *et al.*, 2014). Some researchers proposed that *Aristolochia* s.l. is a single genus (*Aristolochia* s.l.), comprising of three subgenera, *Aristolochia*, *Pararistolochia* (Hutch. & Dalziel) Schmidt, and *Siphisia* (Duch.) Schmidt (Wanke *et al*., 2006; Do *et al*., 2015b). However, others suggested that it should be separated into four genera in two subtribes (Aristolochiinae and Isotrematinae Huber), i.e. *Aristolochia* (s.s.) and *Pararistolochia* Hutch. & Dalziel in Aristolochiinae; *Endodeca* Raf. and *Isotrema* Raf. in Isotrematinae (Huber, 1993; González and Stevenson, 2002; Kelly and González, 2003; Neinhuis *et al*., 2005; Ohi-Toma *et al*., 2006; Ohi-Toma and Murata, 2016). *Aristolochia* subgen. *Siphisia* in Wanke *et al*. (2006) is equivalent to subtribe Isotrematinae in Huber (1993) comprising of 98 species. This entity is mainly distributed in East and South Asia, with some scattered in North and Central America (Zhu *et al*., 2019a). Zhu *et al*. (2019a) reinstated the *Aristolochia* subgen. *Siphisia* as an independent genus *Isotrema* Raf. Herein, we follow their treatment and use the generic name *Isotrema* for our study.

The genus *Isotrema* has been intensely revised in East Asian regions during past decade, such as Japan (Watanabe-Toma *et al*., 2012; Ohi-Toma *et al*., 2014; Watanabe-Toma and Ohi-Toma, 2016), China (Zhu *et al*., 2016, 2017a, 2017b, 2018a, 2019a, 2019b, 2019c, 2019d) and Vietnam (Do *et al*., 2015b; Do and Nghiem, 2017). Many new species have been published and some taxonomic treatments has been revamped (Zhu *et al*., 2015, 2016, 2017a, 2017b, 2018a, 2018b, 2019a, 2019b, 2019c, 2019d; Gong *et al*., 2018; Peng *et al*., 2019; Cai *et al*., 2020; Li *et al*., 2019; Luo *et al.*, 2020; Wang *et al*., 2020; Huong *et al.*, 2014; Do *et al*., 2015a, 2015b, 2016, 2017, 2019, 2021; Lai *et al*., 2019). There were only two taxonomic studies on Taiwanese *Aristolochia* recently (Yang, 2007; Lu and Wang, 2014). According to Zhu *et al*. (2019a), historically considered as genus *Aristolochia* in Taiwan should include genus *Aristolochia* s.s. and genus *Isotrema*. The former has a rather straight or slightly oblique perianth, 1-lipped limb, style column 6-lobed at apex, and fruits dehiscing from the base toward apex, including *A. foveolata* and *A. zollingeriana*; the other species belong to the latter, which has a bent nearly U-shaped perianth, shallowly 3- lobed limb, style column 3-lobed at apex and fruits dehiscing from the apex toward base. The classification of Taiwanese *Isotrema* has not been reviewed since Hou (1996) account in the Flora of Taiwan (Second Edition). Besides, the highly variable folia and floral morphologies of Taiwanese *Isotrema* species often resulted in the conflictive taxonomic treatments in some species. For example, the populations with entire, cordate leaves at higher elevation of Taiwan were sometimes treated as *I. kaempferi* (Willd.) H. Huber; regarded as *I. shimadae* (Hayata) X.X. Zhu, S. Liao & J.S. Ma, or considered as a new species (e.g. Ying, 1995). Yang (2007) separated *I. cucurbitifolium* (Hayata) X.X. Zhu, S. Liao & J.S. Ma into two species based on the color of flowers. Therefore, a taxonomic revision of *Isotrema* in Taiwan is needed. In this paper, we perform morphological comparison, with special reference to morphometric analysis, to revise the taxonomy of *Isotrema* in Taiwan.

Table 1. The taxonomic history of genus ***Isotrema*** of Taiwan.



*. *nom ined.*; # new record; ?. uncertain.

Table 2. Morphometric characters used in this study.

Character acronym (abbreviation)	Detailed description of the character
Utricle length (Ul)	from the base of the utricle to the lowest part of the utricle
Tube length (Tl)	from the connective range of tube and utricle to the most up edge of mouth
Perianth length (Pl)	from the lowest part of the utricle to the most up edge of mouth
Utricle width (Uw)	from the edge of the base of tube to the edge of the utricle
Perianth length/Utricle width (Pl/Uw)	the ratio of Pl above Uw
Utricle length/Perianth length (Ul/Pl)	the ratio of Ul above Pl

MATERIALS AND METHODS

Defining* a priori *morphological groups: To distinguish the herbarium samples into distinct morphological groups, we classify the specimens using characters like habit, the size and shape of leaf lamina, as well as the color and shape of flowers. These were the characters used to differentiate species of *Isotrema* following previous taxonomic treatments (Ying, 1995; Yang, 2007; Lu and Wang, 2014). Based on this preliminary classification, we distinguish the specimens into six distinct morphological "*a priori* groups" (Table 1):

I. cucurbitifolium (Hayata) X.X. Zhu, S. Liao & J.S. Ma =*Aristolochia cucurbitifolia* Hayata (CU)
I. hohuanense =*A. hohuanensis* Ying (HO)
I. pahsienshanianum =*A. pahsienshanianum* Yang *nom. ined*. (PA),
I. palmatum =*A. palmata* Yang *nom. ined*. (PM),
I. shimadae (Hayata) X.X. Zhu, S. Liao & J.S. Ma =*A. shimadae* Hayata (SM)
I. yujungianum (Lu & Wang) X.X. Zhu, S. Liao & J.S. Ma, =*A. yujungiana* Lu & Wang (YJ). We used these *a priori* groups throughout the study.

Yang (2007) has recoded *I. liukiuense* (Hatusima) X.X. Zhu, S. Liao & J.S. Ma in Taiwan. Because we didn't find more specimens and fresh materials, we didn't include in this study.

Morphological comparison: Fresh samples were collected from the field and preserved at TNU herbarium. Also, we examined other herbarium specimens or digital images of specimens available online from herbaria HAST, PPI, TAI, TAIF, TI, TNS, TNU, and K.

Morphometric analyses of perianth shape and size: We applied objective multivariate analyses (discriminant analysis) and univariate statistical tests (analysis of variance, ANOVA) on quantitative morphological traits to test whether the *a priori* morphological groups correspond to distinct taxa. Quantitative morphological traits analyzed include perianth length (Pl), utricle width (Uw), utricle length (Ul), tube length (Tl), the ratio of utricle length/ utricle width (Ul/Uw) and utricle length/perianth length (Ul/Pl) (Table 2, Fig. 1). 89 flowering samples that represent the different *a priori* groups were selected (see supplement materials Table 1). We made longitudinal sections of the perianth and photographed all dissected flowers with a scale. Subsequently, we applied Fiji (Schindelin *et al*., 2012) to measure the perianth length, perianth width, utricle length, and tube length (Fig. 1B). We conducted multivariate analyses (discriminant analysis) and univariate statistical tests (ANOVA) to project and visualize trends in perianth morphological variability across our samples. We further tested whether quantitative traits differed significantly between *a priori* groups using a Tukey's pairwise test. All statistical analyses were performed on PAST 4.09 (Hammer *et al*., 2001).

Proposed IUCN conservation status assessment: Conservation status of each species was assessed, based on field observations in accordance with the IUCN Red list Categories and Criteria version 3.1 (IUCN, 2019). The extent of occurrence (EOO) and the area of occupancy (AOO) were estimated using the web Geospatial Conservation Assessment Tool (GeoCAT, http://geocat.kew.org/editor) with an auto-value cell width of 2 km (Bachman *et al*., 2011).

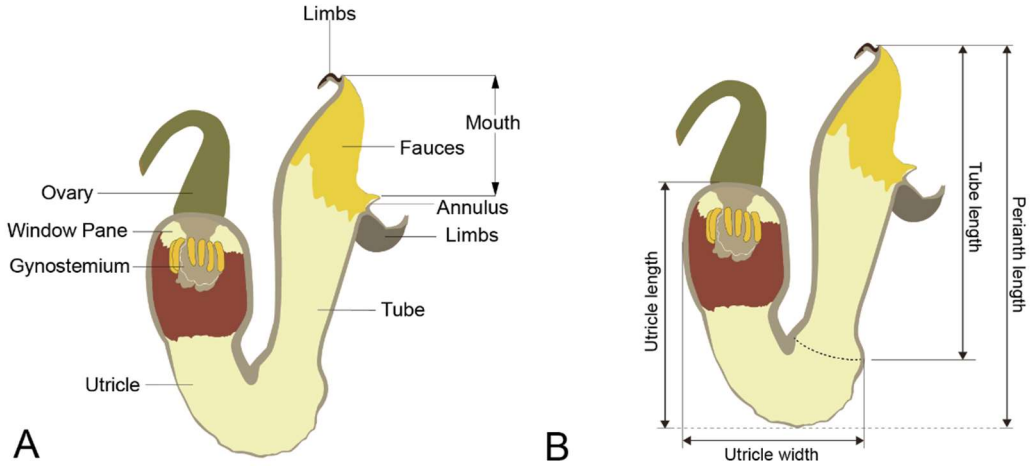


Fig. 1. Perianth terminology and the measured characters used in this study. **A**. Showing the terminology of each part of the perianth; **B**. The measured length in this study: utricle length (Ul), tube length (Tl), perianth length (Ll) and utricle width (Uw). The dashline show the connective range of tube and utricle.

RESULTS AND DISCUSSION

Morphological comparison

1. Habit

Most species of the genus *Isotrema* in Taiwan, such as *I. cucurbitifolium*, *I. hohuanense*, *I. palmatum, I. shimadae*, and *I. yujungianum* are perennial twining vines. They twinned their branches around a support and blossomed at the upper part of the supports (Figs. 6A, 7A, 7L). While *I. pahsienshanianum* is a scandent vine, its branches usually creep on the ground without twining around a support and flowered near the ground (Fig. 6F). Furthermore, the former five taxa usually appeared on the forest margin, but the latter always grew understory.

2. Leaves shape

The leaf lamina shape of species of *Isotrema* in Taiwan are broadly ovate to linear (Fig. 2). Our study reveals that leaf shapes within species are quite stable. *I. cucurbitifolium* and *I. palmatum* have a 5–7(–9)-lobed palmately leaf (Fig. 2A); *I. pahseinshanianum* has an ovate to ovate-lanceolate leaf (Fig. 2C); *A. yujungianum* has a lanceolate to linear leaf (Fig. 2E); *I. hohuenense* have a broadly ovate to broadly cordate leaves (Fig. 2B). But leaf shape of *I. shimadae* is variable from ovate, broadly ovate to 3–5 lobed (Fig. 2D). Additionally, *I. hohuanense* (Fig. 2B) and *I. pahsienshanianum* (Fig. 2C) always have entire leaves, while the others have lobed leaves (Figs. 2A, D, E).

During our field observation, we found that the leaves in the understory are entire, and those in the sunny places are lobed. This phenotypic plasticity of leaves shape might due to the boundary layer effect of leaf surface (Smith and Smith, 2015). The boundary layer is different depending on the surrounding environment because of the heat, water vapor and CO_2 diffusing from the leaf surface. If there is no air or water flow, the boundary layer increases in thickness, which will reduce the transfer of heat, water and CO_2 between the leaf and the environment. Therefore, in order to reduce the boundary layer, plant will become smaller leaves, deeply lobed leaves, or compound leaves in hot and dry environments. That explained why the leaves of *I. cucurbitifolium* are shallowly lobed in shady habitat, and are deeply lobed in sunny place. The case also found in the leaves of *I. shimadae*. Its leaves are entire or shallowly trilobed in shaded places, and deeply trilobed in sunny places.

3. Flower color

(1). The color of fauces and inner surface of perianth tube can be divided into two types. (i) fauces green-yellowish with purple dots or inner surface wholly purple, tube and utricle creamy with purple strips or dots as seen in *I. cucurbitifolium* (Fig. 5E–H), *I. pahsienshanianum* (Fig. 6G), *I. shimadae* (Fig. 7E–G) and *I. yujungianum* (Fig. 7O, P); (ii) fauces fresh yellow without purple dots, tube yellow, and utricle creamy characterizing *I. hohuanense* (Fig. 6B, D), *I. palmatum* (Fig. 5K), and *I. shimadae* (occasionally has yellowish with purple dots fauces in some individuals) (Fig. 7B–F).

(2). Limb color was considered to be a consistent and good character to distinguish most species in this group (Murata, 2006; Watanabe *et al*., 2006). However, this character is hard to recognize in dry specimens and, therefore, confused many former taxonomists. Our field observation revealed that the color of limb in this group can be separated into two patterns: (i) limb green yellowish, with fine purple strips: *I. cucurbitifolium* (Figure 5E–H), and *I. pahsienshanianum* (Fig. 6G); (ii) Limb purple reddish to purplish brown without any strips: *I. hohuanense* (Fig. 6B), *I. palmatum* (Fig. 5K), *I. shimadae* (Fig. 7A-D) and *I. yujungianum* (Fig. 7O, P).

Sometimes we will find that the fauces of flowers are greenish-yellow with purple dots or full purple, turning

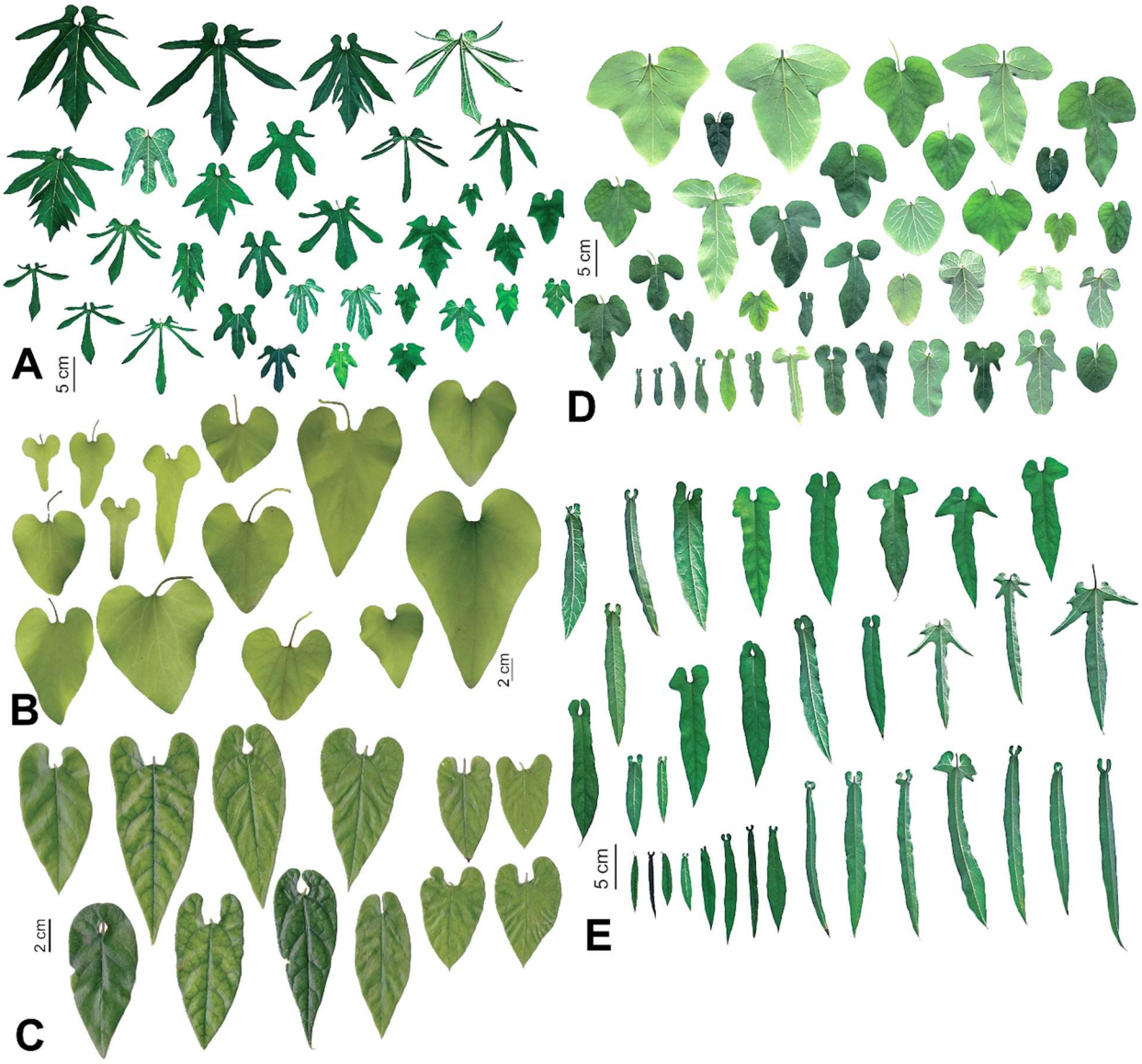


Fig. 2. Leaf variation of ***Isotrema*** inTaiwan. **A**. ***I. cucurbitifolium***, **B**. ***I. hohuanense***. **C**. ***I. pahsienshanianum***, **D**. ***I. shimadae***, **E**. ***I. yujungianum***

into bright yellow without purple dots, such as flowers in some culture individuals of *I. pahsienshanianum* (Fig. 6H, I), or vice versa, for example flowers in *I. shimadae* (Fig. 7E, F). Plants frequently display variability in flower coloration that is underlain by anthocyanin pigmentation. Anthocyanin pigmentation was negatively associated with temperature and positively associated with vapor pressure deficit (a metric of aridity) across taxa (Arista *et al*., 2013; Koski and Galloway, 2020; Sullivan and Koski, 2021). Species experiencing larger temperature increases over time displayed reductions in pigmentation, while those experiencing increases in aridity displayed increases in pigmentation (Koski and Galloway, 2018; Sullivan and Koski, 2021). For example, *I. pahsienshanianum* often grows at cooler environment at middle elevation of Taiwan. When it was transplanted to hotter environment, the newborn flower will become light color (Fig. 6H, I). This change also can be observed in some individuals of *I. shimadae* in the different aridity conditions. *I. shimadae* always occurred in the low elevation of Taiwan. It has light flower color in the wetter place (Fig. 7D), while it show darker flower color in the arid place (Fig. 7G).

Isotrema cucurbitifolium and *I. palmatum* all have 5-7(-9)-lobed palmately leaves and resemble in the other vegetative parts, however their flower color were different: In the former, its limbs green yellowish, with fine purple strips, and fauces green-yellowish with purple dots, while in the latter, the limbs purple reddish to purplish brown without any strips and fauces fresh yellow without purple dots. Because *I. cucurbitifolium* grows at cooler environment, *I. palmatum* usually occurs at hotter

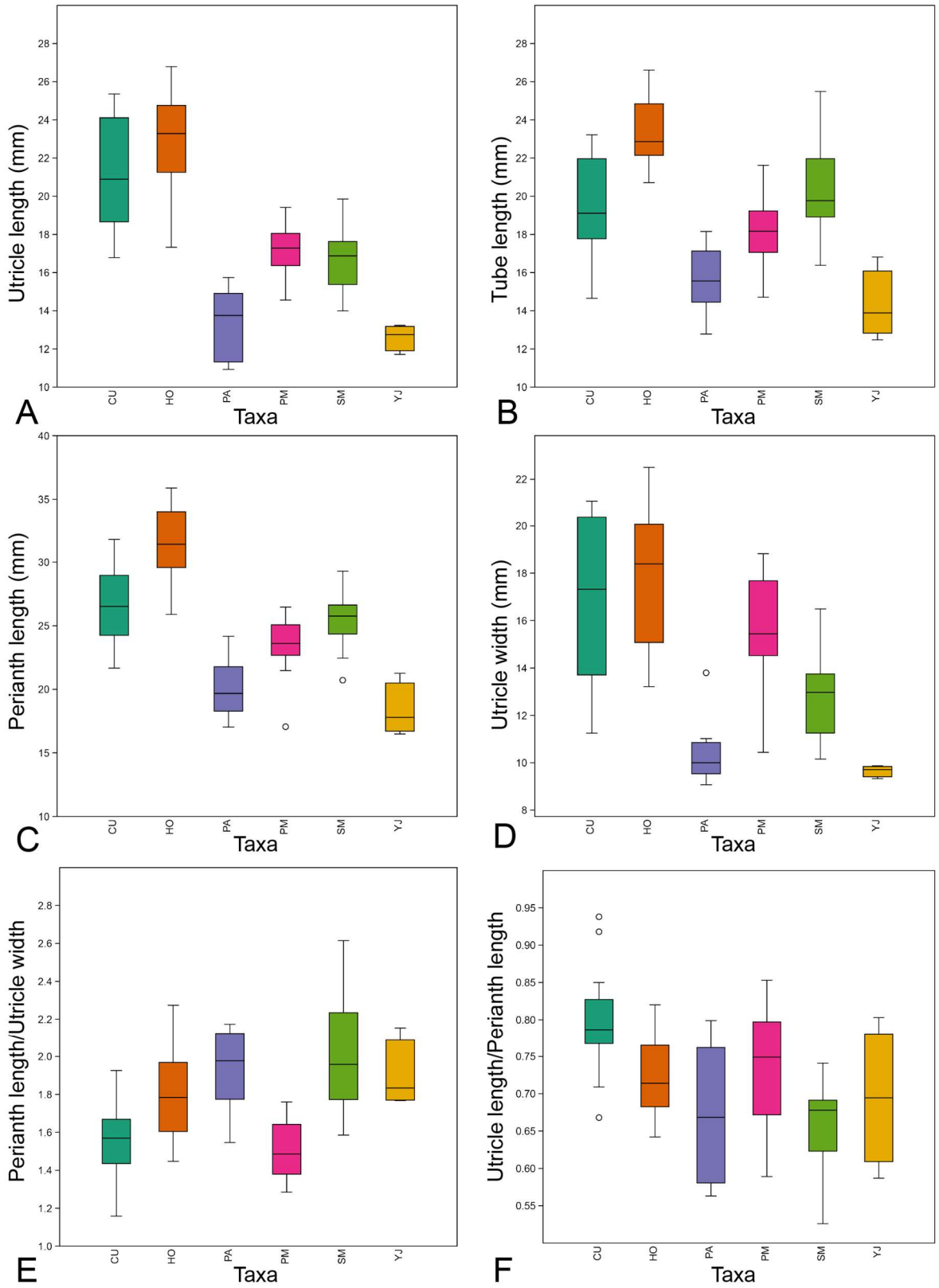


Fig. 3. Box-and-whisker plots of six floral quantitative characters of six priori taxa. **A**. Utricle length, **B**. Tube length, **C**. Perianth length, **D**. Utricle width, **E**. Perianth length/Utricle width, **F**. Utricle length/Perianth length. CU: ***I. cucurbitifolium***, HO: ***I. hohuanense***, PA: ***I. pahsienshanianum***, PM: ***I. palmatum***, SM: ***I. shimadae***, YJ: ***I. yujungianum***. Boxes incorporate 50% of values. Horizontal lines in box indicate median value. Open circles indicate extreme values.

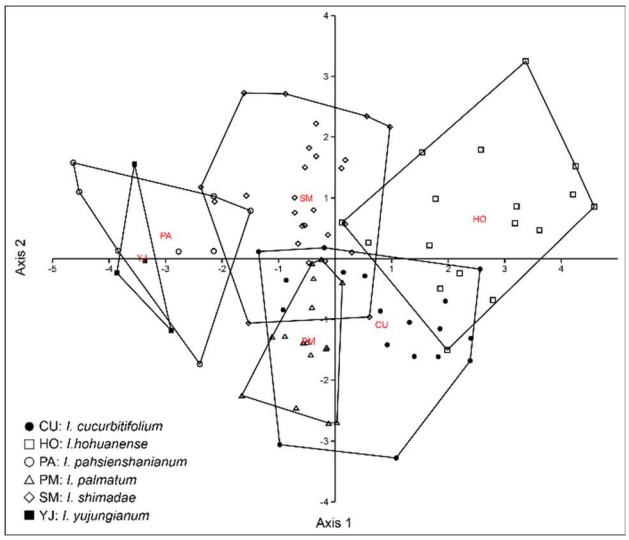


Fig. 4. Scatterplot of the first two axes in the discriminant analysis based on floral quantitative matrix of six priori taxa. The convex hulls is the smallest convex set that contains all sample of each prior species.

environment. We consider that this flower different maybe cause by the abiotic conditions that influence the display of flower coloration.

Morphometric analyses of perianth shape

All species of *Isotrema* in Taiwan have a strongly U-shaped curved perianth with utricle and tube without sharp delimitation, and glabrous inner surface, 3-lobed gynostemium (Do *et al*., 2015b). Shape of perianth has ever been considered to be taxonomically significant by some taxonomists (Watanabe-Toma *et al*., 2012; Ohi-Toma *et al*., 2014; Do *et al*., 2015b). However, this character was seldom precisely described in the previous taxonomic treatments.

The ANOVA results (see supplement Table 1) showed that most taxa had significantly different in utricle length, tube length, perianth length and utricle width. Moreover, in the Tukey's pairwise test, CU can be distinguished from HO, PA, and SM in the ratio of perianth length above utricle width, as well as utricle length above perianth length. HO and PM also can be distinguished from SM in the ratio of perianth length above utricle width, and utricle length above perianth length (see supplement Table 1).

The discriminant analysis were performed to examine whether significant differences exist among the groups. The results showed that the first two axes can explain 90.11% variance between these taxa (see supplement Table 2). The most important character is the ratio of utricle length (Ul) above perianth length (Pl) in the first two axis. The scatterplot of discriminant analysis showed most prior species separated each other but had some overlap (Fig. 4). PA can be completely separated from CU, HO, and PM, but slightly overlapped with SM. In addition, the spread range of PA and YJ as well as CU and PM were almost overlapped.

Combined with the morphological comparison and morphometric analysis, we recognized five species, i.e. *Isotrema cucurbitifolium* (Hayata) X.X. Zhu, S. Liao & J.S. Ma, *I. hohuanense* (Ying) C.T. Lu & J.C. Wang, *comb. nov.*, *I. pahsienshanianum* C.L. Yang, J.C. Wang & C.T. Lu, *sp. nov*., *I. shimadae* (Hayata) X.X. Zhu, S. Liao & J.S. Ma and *I. yujungianum* (C.T. Lu & J.C. Wang) X.X. Zhu, S. Liao & J.S. Ma. *Isotrema palmatum* (=*Aristolochia palmata* Yang *nom. ined.*) was regarded as *I. cucurbitifolium* due to their similar leaves character and flower characters. *I. pahsienshanianum* was considered as a new species to Taiwan because of its distinct leaves characters and creeping habit. Yang (2007) ever recoded that *I. liukiuense* (Hatusima) X.X. Zhu, S. Liao & J.S. Ma occurred in Taiwan. However, we didn't find further specimens and fresh materials in this study, so we treated it as an uncertain species in Taiwan.

TAXONOMIC TREATMENT

Key to the taxa of *Isotrema* in Taiwan

1. Leaf lamina ovate to ovate-lanceolate or broadly ovate, entire, without lobed. ……..… 2.
- Leaf lamina linear to widely cordate-ovate, margin lobed. …… 3.
2. Leaf lamina ovate to ovate-lanceolate, surfaces green and glabrescent adaxially, grayish green and pubescent abaxially ……..…… ……. 3. ***I. pahsienshanianum***
- Leaf lamina broadly ovate, surfaces densely gray to white tomentose abaxially, densely strigose adaxially …… 2. ***I. hohuanense***
3. Leaves deeply 5–7(–9) palmately lobed ……... 1. ***I. cucurbitifolium***
- Leaves shallowly 3–5 lobed. …….. 4
4. Leaves linear to linear-lanceolate; inside of perianth tube dotted dark purple near mouth. …… 5. ***I. yujungianum***
- Leaves ovate-lanceolate, ovate to broadly ovate; inside of perianth tube yellow near mouth. ……..…… 4. ***I. shimadae***

1. *Isotrema cucurbitifolium* (Hayata) X.X. Zhu, S. Liao & J.S. Ma. X.X. Zhu, S. Liao & J.S. Ma, Phytotaxa 401(1): 9. 2019.

瓜葉馬兜鈴 Figs. 2A & 5

Aristolochia cucurbitifolia Hayata, Icones Plantarum Formosanarum 5: 137. 1915; Hayata, Gen. Ind. Fl. Form. 61. 1917; Masamune, List Vasc. Pl. Taiwan 49.1954; Liu & Lai in T. C. Huang *et al*., Fl. Taiwan 2: 572. 1976; Hwang in Kiu & Ling, Fl. Reip. Pop. Sin. 24: 243. t. 60: 6 & 7. 1988; Ma, Acta Phytotax. Sin. 27: 343. 1989; Hou in T. C. Huang *et al*., Fl. Taiwan 2nd ed. 2: 639. *pl. 307*. 1996; Huang *et al*. in Wu & Raven, Fl. China 5: 260. 2003. ***Type*:** TAIWAN. Kagi, Baiako, Taiwan, Apr. 1, 1909, *T. Kawakami s. n.* (Holotype: TI photo!; Syntype: TAIF!).
Aristolochia palmata C.L.Yang, *nom. ined.*

***Description.* Habit:** perennial scandent lianas, woody. **Stem:** young branches terete, pubescent. **Leaf:** petiole 2–4 cm long, pubescent; leaf lamina broadly cordate to cordate, unequally 5–7(–9) lobed, 6–14 cm × 5–14 cm, chartaceous or subcoriaceous, base cordate, the middle lobe oblanceolate, apex spatulate-ensiform, the lateral lobes oblanceolate-linear, apex acute; adaxial surface glabrescent or pubescent along veins, abaxial surface

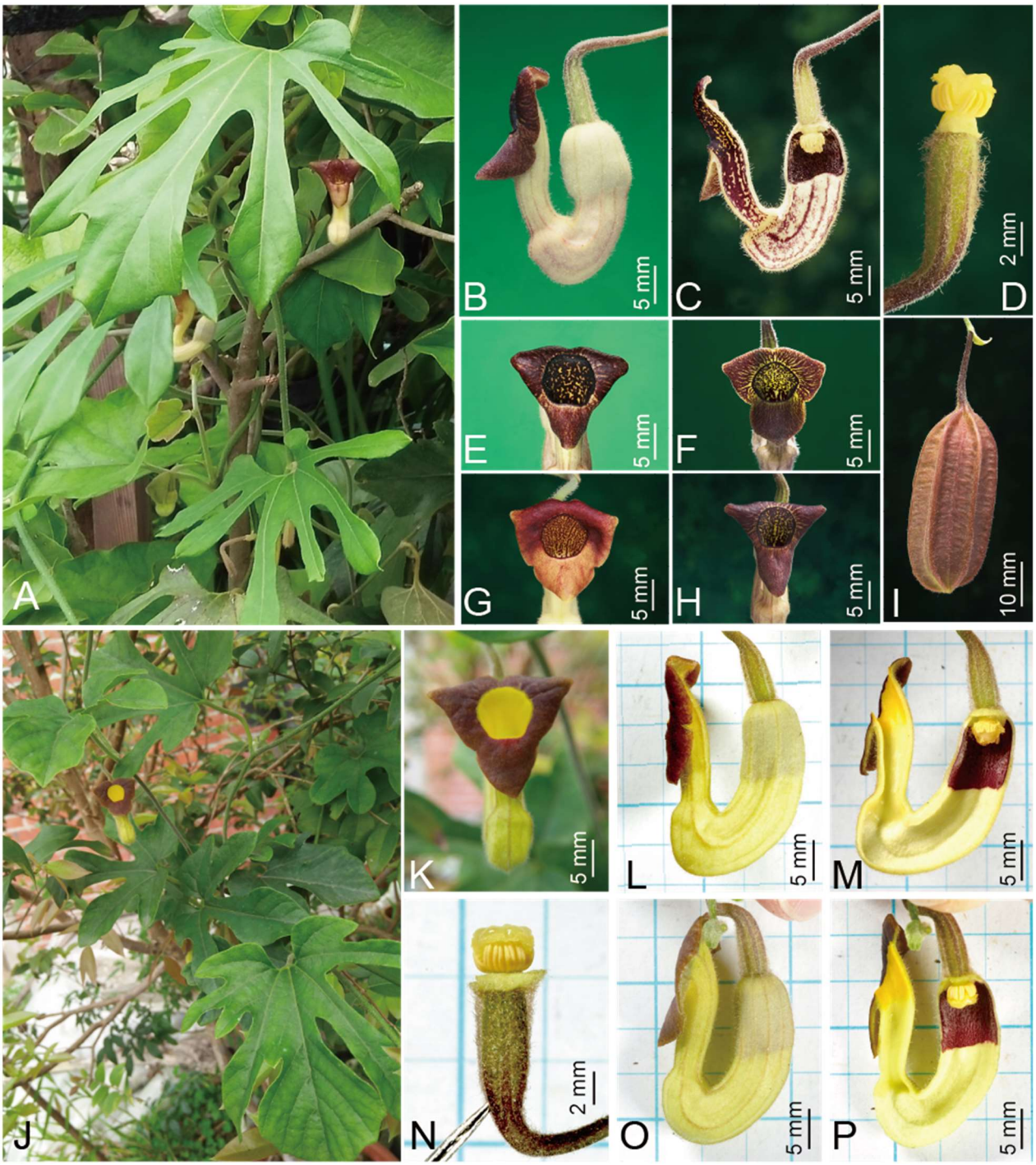


Fig. 5. ***Isotrema cucurbitifolium*** (Hayata) X.X. Zhu, S. Liao & J.S. Ma. **A**–**I**. Brown flower of ***I. cucurbitifolium***, **A**. Habit, **B**. Perianth (lateral view), **C**. Dissection of perianth, showing inner structure of perianth, **D**. Gynostemium and ovary, **E**–**H**. Perianth (front view), **I**. Capsule; **J**–**P**. Yellow flower of ***I. cucurbitifolium*** (= ***I. palmatum***). **J**. Habit, **K**. Perianth (front view), **L**, **O**. Perianth (lateral view), **M**, **P**. Dissection of perianth, showing inner structure of perianth, **N**. Gynostemium and ovary.

pubescent; venation 5–7(–9) palmately veined. **Inflorescences:** on a new growth branch, axillary, flowers solitary; pedicel 2.5–3 cm long, pubescent; bract ovate, 5–8 mm long, at base of pedicel. **Flower:** perianth tube U-shaped, ca. 2.2–3.1 cm long; utricle pendent, cylindrical, 6–8 mm wide, outside yellow, pubescent, inside of the fertile zone purple reddish, white manicate, base with white window pane, and inside of the other part of utricle creamy with purple spots or lines; tube bent and angled upward, cylindrical, outside yellow, pubescent,

inside creamy marked with purple lines and dots, glabrous; mouth subspherical, sometimes reniform; annulus distinct; fauces yellow-green with dark purple reticulum to whole purple, glabrous; limbs light brown or green yellowish marked with dark purple lines adaxially, obtriangular, deeply 3-lobed, lobes widely ovate, recurved, about 1 cm × 2 cm, glabrous or glabrescent; gynostemium 3-lobed, globose, ca. 4 mm long; lobe apex retuse to truncate; anthers 6, oblong, ca. 2 mm long; ovary inferior, conical to cylindrical, 3-locular, ca. 6–7 mm long, pubescent with grayish hairs. **Fruits:** capsule, cylindrical to narrowly ellipsoid, 5–7 cm long, hairy, with 6 ridges, dehiscent from apex. **Seeds:** flat, triangular, plano-concave, ca. 7 mm long.

Distribution: Endemic to Taiwan, from Miaoli to Pingtung and Taitung (Fig. 8A).

Habitat: *I. cucrbitifolium* always occurs in bamboo plantations, thickets and open forest at low-to-medium elevations below 1,600 m.

Phenology: Flowering from November to July, mainly from February to May.

Proposed IUCN Conservation status: *Isotrema cucurbitifolium* (Hayata) X.X. Zhu, S. Liao & J.S. Ma. is endemic to Taiwan and is restricted to the central to southern Taiwan. Mostly occurrences of this species are not in the protected areas, and are commonly found in bamboo plantations. It is easy disturbed or destroy by human activities. According to the assessments of GeoCAT (AOO ca. 128 km^2) and the IUCN Red List (IUCN 2022), we proposed that *I. cucurbitifolium* should be assigned an extinction risk of "endangered" [EN, B2b(ii)(iii)c(ii)(iv)].

Specimens examined: **TAIWAN. Miaoli County:** Tahu, elev. ca. 200–400 m, fl., 17 February 2007, *H.-Y. Hsieh 175* (PPI); **Nantou County:** Tungpu, elev. ca. 1150 m, fl., 29 March 1986, *K.C. Yang 1983* (TAI); Fenghuangshan, elev. ca. 1,200–1,300 m, fl., 29 November 1984, *C.-I Peng 7532* (HAST); Hsitou, fl., 26 March 2011, *C.T. Lu 1910* (TAIF). **Chiayi County:** Meishan, elev. ca. 980 m, fl., 24 March 1987, *M.T. Kao 10490* (TAI); Kuanyin Waterfall, elev. ca. 500 m, fl., 15 May 2006, *S.W. Chung 13094* (TAIF); Funchihu, elev. ca. 1600 m, fl., 23 March 1985, *S.F. Huang 2607* (TAI); A-li-shan Hsiang, Feng-shan, elev. ca. 700–800 m, fl., 5 February 1998, *S.D. Shen 287* (TAIF). **Tainan City:** Kuantzuling, elev. 245–300 m, fl., 23 April 1993, *T.C. Huang & S.F. Huang 15983* (TAI); Takeng, elev. ca. 80 m, fl., 5 April 2007, *C.L. Yang 507* (TNU). **Kaohsiung City:** Shanping, elev. ca. 670 m, fr., July 1986, *the summer collection team s.n.* (TNU); Ape's Hill (Tsaishan), fl. & fr., *A. Henry 719* (TAI, BM photo!); Shoushan, elev. ca. 117 m, fl., 3 March 1996, *C.S. Yang 413* (TAIF); Shoushan, fl., 6 April 1996, *C.S. Yang 455* (TAIF); Shoushan, fl., 29 March 1998, *W.-F. Ho 831* (TAIF). **Pingtung County:** Santeimon, elev. ca. 300 m, fl., 20 February 1969, *I.S. Chen 2927* (TAI); Santimen Hsiang, elev. ca. 720 m, fr., 22 May 1997, *C.-I Peng 16861* (HAST); Tahan forest road, near mileage sign 21 K, elev. ca. 1,300 m, fl., 8 July 2011, *C.-I Peng et al. 23194* (HAST); Tahanshan, elev. ca. 1,000 m, fl., 19 Apr 1986, *S.Y. Lu 19062* (TAIF); Tahan Logged Trail 8.5 km, elev. ca. 933 m, fl., 15 March 2013, *C.F. Chen 4617* (TAIF); Chinshuiying, elev. ca. 1,400–1,500 m, fl., 7 July 2011, *S.W. Chung 10382* (TAIF); Along Lilungshan hiking trail, elev. ca. 415–813 m, fr., 25 July 1997, *C.N. Wang 192* (HAST); Wutai, elev. ca. 900 m, 10 May 1986, *C.E. Chang 126, 133* (PPI); Mt. Peihulu, elev. ca. 850–1,300 m, fl., 1 Jan 2011, *P.F. Lu 21252* (TAIF). **Taitung County:** Tajen, fl., 16 March 2013, *W.Y. Wang 1666* (TAIF).

Notes: *Isotrema cucurbitifolium* is a very distinct species and can be distinguished from other congeners by its 5–7-lobed leaves. However, some populations distributed at low elevations in south and southeast Taiwan have different floral color patterns from the populations distributed at the higher elevations of central Taiwan (mainly Nantou County and Chiayi County). The flowers of the species at lower elevation have yellow fauces and dark purple limbs, while those of the species at higher elevation have yellow-green throat with dark purple reticulum or whole purple and light brown or greenish yellow marks with dark purples lines on the limbs. Yang (2007) proposed a new species, *Aristolochia palmata* without formal publication from lower elevation. The vegetative morphologies of these two taxa can not be distinguished from each other based on our morphometric study, and as we discussed above that floral color could be change from brown type to yellow type. Herein, we regarded it as *I. cucurbitifolium*.

2. *Isotrema hohuanense* (S.S. Ying) C.T. Lu & J.C. Wang, ***comb. nov.***

合歡山馬兜鈴 Figs. 2B & 6A–E

Aristolochia hohuanensis S.S. Ying, Coloured Ill. Fl. Taiwan 5: 597. *photogrs. 1280, 1280A*. 1995. ***Type*:** TAIWAN: Nantou County, Hohuanshan, elev. ca. 2,500–2,700 m, *S.S. Ying 9941* (Holotype: NTUF, n.v.)

Aristolochia liukiuensis auct. non Hatusima, Liu & Lai in T. C. Huang *et al*., Fl. Taiwan 2: 573. 1976.

Aristolochia kaemferi auct. non Willd., Hou in T. C. Huang *et al*., Fl. Taiwan 2nd ed. 2: 639. *pl. 306*. 1996. *pro parte*; Huang *et al*. in Wu & Raven, Fl. China 5: 260. 2003.

***Description*. Habit:** perennial climbing liana. **Stem:** young stem terete, sparsely short hairs; stem elongate, 3–5 m long, 3–4 mm in diameter, green, terete, nodose, nearly glabrous, much branched; the nodes usually swelled, 5–6 mm across. **Leaves:** alternative, elongate-ovate to broadly ovate, 8–18 cm long, 7–15 cm wide, acute to obtuse at apex, deeply cordate at base, chartaceous, entire, 5-nerved; nerves and nervules slightly elevated surface and prominently elevated beneath; slightly villose surface and densely villose along nerves and nervules beneath; nervules reticulate; petioles 5–8 cm long, villose. **Inflorescences:** on a new growth branch, axillary, flower solitary, 9–13 mm in diameter when open; the pedicels 4–6 cm long, 1-bracteate at base, 4–5 mm long, serico-villose outside and subglabrous inside. **Flower:** perianth villose outside and glabrous inside; the tube U-formed, 2.6–3.6 cm long, 6–7 mm in diameter, pale yellow outside and cream inside; the limb triangular, purplish, fauce yellow, annulus distinct; ovary inferior, cylindrical, 4–5 mm long, 2–3 mm wide, deeply 6-sulcated, 6-celled; stamens 6 connated with style, sessile; anther oblong, 2 mm long, 0.5 mm wide; style column-like 3 mm long, 1.5 mm across, 3-lobed at apex. **Fruit:** capsule, narrowly ellipsoid, ca. 7 cm long, with 6 ridges, dehiscent from apex.

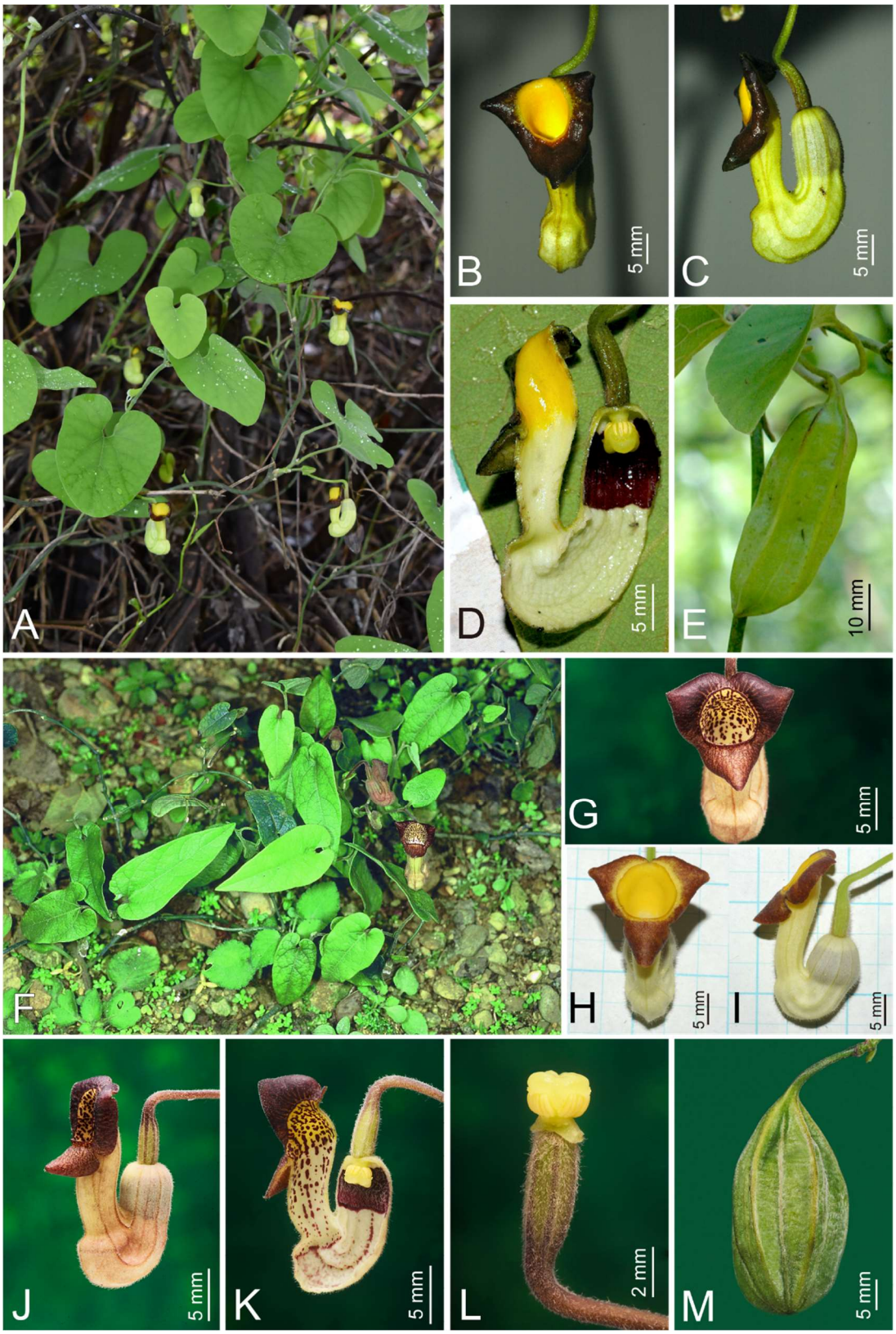


Fig. 6. ***Isotrema hohuanense*** (Ying) C.T. Lu & J.C. Wang and I.. **A**–**E**. ***I. pahsienshanianum*** C.T. Lu, C.L. Yang, & J.C.Wang: **A**. Habit, **B**. Perianth (front view), **C**. Perianth (Lateral view), **D**. Dissection of perianth, showing inner structure of perianth, **E**. Capsule. **F**–**M**. ***I. pahsienshanianum***: **F**. Habit, **G**, **H**. Perianth (front view), **I**, **J**. Perianth (lateral view), **K**. Dissection of perianth, showing inner structure of perianth, **L**. Gynostemium and ovary, **M**. Immature capsule.

Distribution. Endemic to Taiwan (Hsinchu, Taichung and Nantou) (Fig. 8B).

Habitat: This species always occurs in thickets and forest margin at medium to high elevations above 1,500 m.

Phenology. Flowering of *I. hohuanense* has been recorded in March to June.

Proposed IUCN Conservation status: *Isotrema hohuanense* (S.S. Ying) C.T. Lu & J.C. Wang is endemic to Taiwan and is restricted to the central mountain range of Taiwan. The occurrences of this species are mostly in the National Parks. No obviously threaten is observed.. According to the assessments of GeoCAT (EOO ca. 1,584 km^2, AOO ca. 52 km^2) and the IUCN Red List (IUCN 2022), we proposed that *I. hohuanense* should be assigned an extinction risk of "endangered" [EN, B1+B2b(ii)(iii)c(ii)(iii)].

Specimens examined. **TAIWAN: Hsinchu County:** Kuanwu, Dalu logged trail, elev. 1,950–2,000 m, fl., 16 May 2000, *S.W. Chung 2371* (TAIF); Mt. Litung, elev. ca. 1,600–1,900 m, fl., 1 May 2005, *P.F. Lu 9578* (TAIF). **Taichung City:** Ssuyuan, fl., 9 April 1997, *S.Y. Lu & M.F. Lou s.n.* (TAIF); Ssuyuanyakou to Wuling, elev. ca. 1,550–1,650 m, fl., 14 March 2009, *P.F. Lu 17918* (TAIF); Hoping Hsiang, Lishan, elev. ca. 2,000 m, fl., 17 April 2002, *H.L. Chiang 2907* (TAIF); Huanshan, Provincial Rd. 7A 48.4K, elev. ca. 1,850 m, fl., 4 May 2000, *C.H. Lin 261* (HAST); Huanshan, Provincial Rd. 7A, elev. ca. 1,700–1,800 m, fl. & fr., 16 April 2000, *S.-C. Liu & C.-C. Lu 397* (HAST, TAIF); At road marker 52.3 km on Prov. Hwy 7A, near ShengKuang, elev. ca. 1,765 m, fl., 10 April 2011, *C.-I Huang 5147* (HAST); Central Cross-Island Hwy 103.2 K, elev. ca. 2,250 m, fl., 16 April 2002, *C.M. Wang 5474* (HAST, TAIF); At WuLing Farm, elev. ca. 1,765 m, fl., 20 April 2012, *C.-I Huang 5639* (HAST); Wuling, Wuling Farm, elev. ca. 1,650 m, fl., 1 April 1985, *S.-Y. Lu 15630* (TAIF); Wuling Farm, elev. ca. 1,700–1,900 m, fl., 19 April 2015, *S.-W. Chung 12120* (TAIF); Wuling farm, elev. ca. 1,700 m, fr., 19 May 1987, *J.C. Wang 4329* (TAI); Wuling farm, elev. ca. 1,600 m, fr., 24 April 1993, *K.C. Yang & T.H. Hsieh 4117* (TAI); Wuling farm, elev. ca. 1,700 m, fl., 19 May 1987, *J.C. Wang 4328* (TAI); Wuling Farm, elev. ca. 2,000 m, fr., 4 July 2000, *Y.P. Cheng 3106* (TAIF); Wuling Farm, elev. ca. 1,700–1,800 m, fl. 19 April 2015, *S.W. Chung 12120* (TAIF); Wuling, elev. ca. 1,800–1,900 m, fl., 27 March 2003, *S.-H. Liu & C.-W. Chen 708* (TAIF); Hsuehshan, Wuling to Chika, elev. 1,700–2,400 m, fl., 11 June 1987, *J.C. Wang et al. 4372* (TAI); Heping Farm, elev. ca. 1,500–1,700 m, fl., 1 April 2009, *P.-F. Lu 18051* (TAIF); Wuling to Chingchuan Bridge, elev. ca. 2,000 m, fl., 18 May 2010, *S.W. Chung 9895* (TAIF); Mt. Shuan, fl., 14 July 1983, *T.T. Lin & T.H. Hsieh s.n.* (TAIF). **Nantou County:** Provinvial Rd. No 8: 91-93 K, fl., 14 June 2011, *C.T. Lu 1861* (TAIF); Provinvial Rd. No 8: 90 K, elev. ca. 2,000 m, fl., 4 June 2012, *C.F. Chen 3537* (TAIF) Jenai Hsiang, en route from Puli, via. Wushe to Chingchin Farm, elev. 1,000–1,800 m, 23 August 1968, *Namba et al. 2551* (TI); Kuanyang-Yuanfeng, elev. ca. 2,700–3,000 m, fl., 9 April 1988, *J.C. Wang 5092* (TAI); Meifeng to Tsuifeng, elev. 2000–2300 m, fl., 21 May 2005, *J.H. Lii 1181* (TAI); Meifeng to Tsuifeng, elev. ca. 2,200 m, fl., 29 May 1998, *C.M.Wang et al. 3261* (HAST); Meifeng, elev. ca. 2,155 m, fr., 4 July 2003, *C.M. Wang & M.M. Yang 7025* (PPI); Meifeng, fl., 19 April 1980, *Ou & Kao 9348* (TAI); Meifeng, fl., 21 March 2005, *J.-L. Hsiao s.n.* (TAI); Meifeng, elev. ca. 2,100 m, fl., 26 April 1985, *S.-Y. Lu 15934* (TAIF); Meifeng, Sanchiaofeng (a mountain), elev. ca. 2,350 m, fl., 12 May 2004, *C.-C. Wu 563* (HAST); Piluhsi Working Station, elev. ca. 2,350 m, fl., 11 May 2004, *W.L. Chiou 15012* (TAIF, TNU); Piluchi Forestry Station, elev. ca. 2,080 m, fr., 11 Oct. 1997, *T.Y.A. Yang et al. 9626* (HAST, TAIF); Pilushi, elev. ca. 2,500 m, fl., 24 April 1975, *S.-Y. Lu 4117* (TAIF); Chingching, elev. ca. 1,800 m, fl., 23 April 1986, *S.Y. Lu 18875* (TAIF); Tunyuan, elev. 1,900–2,100 m, 22 April 2000, *C.H. Chen 3201* (TAIF, TNM, TNU, HAST); Yunhai to Tunyuan, elev. ca. 2,000 m, fr., 9 September 2001, *T.Y.A. Yang et al. 13993* (HAST); Yunhai-Tienchih, fr., 4 July 1971, *I.S. Chen 1973* (TAI); Yuanfeng, elev. ca. 2,200 m, fl., 13 May 2000, *C.W. Chen 1499* (TAIF); along Central Cross-Island Hwy, from Tsuifeng to Hsinjenkang, elev. ca. 2,500 m, fl., 8 June 2004, *C.-I Huang 1749* (HAST); Tsuifeng to Hsinjenkang, elev. ca. 2,500 m, fl., 28 May 2006, *T.-C. Hsu 518* (TAIF); Yunhai, elev. 2,360–2,830 m, fr., 31 July 1998, *C.H. Chen 2420* (TNU); Hohuanshan, fl., 19 May 1997, *C.-C. Hsu 254* (HAST); Chihyuanchuang, fl., 5 May 1985, *W.S. Tang 444* (TAI), same loc., fl., 9 May 1986, *W.S. Tang 1773* (TAI); Nengkaoyuehling, elev. 2,200–2,400 m, fl., 6 June 2004, *C.F. Chen 718* (PPI); Hetso Village, elev. ca. 2,200–2,300 m, fl., 17 April 2004, *H.-Y. Chen et al. s.n.* (TAIF); Wangshianshan, fl., 12 May 1978, *Y.-P. Yang s.n.* (TAIF).

Notes. This species was regarded as *I. liukiuense* by Liu and Lai (1978) in Flora of Taiwan and as *I. kaempferi* by Hwang (1988) and Ma (1989). Ying (1995) named this species based on the specimens that collected from Mt. Hohuanshan, Taiwan. However, this name was overlooked and excluded from the Flora of Taiwan Second Edition (Hou, 1996) and Flora of China (Huang *et al*., 2003). After examining the specimens, we found that it resembled *I. kaempferi* and *I. liukiuense*: they shared similar cordate to widely cordate leaves with a round to obtuse apex. However, the flowers color of this species is similar to those of *I. shimadae*. We compared the fresh materials and specimens of *I. shimadae* and *I. hohuanense,* and found that the leaf shape of *I. hohuanense* (entire, elongate-ovate to broadly ovate) (Fig. 2B) differed from that of *I. shimadae* (3–5 shallowly lobed) (Fig. 2D). Additionally, our morphometric analyses showed these two species were different in the flower characters (Fig. 3 & Fig. 4). Thus, we treated *I. hohuanense* as a distinct species.

3. *Isotrema pahsienshanianum* C.-T. Lu, C.-L. Yang & J.-C. Wang, ***sp. nov***.

八仙山馬兜鈴 Figs. 2C & 6F–M

***Type*:** TAIWAN. Taichung City: Hoping Township, Mt. Pahsienshan, elev. ca. 1,300 m, Jan. 24, 2007, *C.-L. Yang 452* (Holotype: TNU, Isotype: TAI).

***Diagnosis*:** this new species is similar to *I. shimadae* (Hayata) X.X. Zhu, S. Liao & J.S. Ma in floral shape, but can be distinguished from *I. shimadae* by flower less than 2 cm long (vs. 2–3 cm long), lanceolate-ovate to lanceolate lamina with inward lateral lobes (vs. cordate-ovate, ovate to lanceolate lamina with outward lateral lobes in *I. shimadae*), as well as its yellowish green limb with dark purple striae, and fauces yellowish green with dotted dark purple (vs. limbs dark purple and fauces yellow without dots). Furthermore, *I. pahsienshanianum* always occurred on the forest floor, while *I. shimadae* grew on the forest margin.

Description. **Habit:** perennial herbaceous vines, creeping. **Stem:** young branches terete, pubescent. Leaf: lamina lanceolate-ovate to lanceolate, two inward lobes at base, lobes entire, base cordate, apex acuminate, chartaceous, adaxial surface green and glabrescent, up to 12 cm long, 5 cm wide, abaxial surface light green with short hairs along veins, nerves on abaxial surface elevated;

Table 3. Diagnose characters comparison of ***Isotrema pahsianshanianum*** with ***I. shimadae*** and ***I. yujungianum***

	I. pahsienshanianum	***I. shimadae***	***I. yujungianum***
Habit	creeping	twining	twining
Leaf	ovate to lanceolate-ovate with two inward lobes at base, lobes entire	cordate-ovate, ovate to lanceolate with two lateral outward lobes at base, lobes entire	linear to linear-lanceolate with two inward lobes at base, lobes entire, or occasionally 3–5 lobed at base
perianth length (cm)	2.0 (1.7–2.4)	2.55 (2.1–2.9)	1.83 (1.6–2.1)
Limbs	greenish-yellow with dark purple lines	reddish-purple to dark purple	dark-purple
Throat	greenish-yellow with dotted dark purple	yellow	dark-purple, sometimes with yellow dots
Ovary	clavate	cylindrical	cylindrical

petiole 2–7 cm long. **Inflorescence:** flower solitary in axil of prophyll at new branches; flower peduncle approximately 2 cm long, pubescent; bractate at base, ovate to narrowly ovate, 2–3 mm long. **Flower:** perianth tube U-shaped, 1.7–2.4 cm long, 4–5 mm wide at utricle, utricle outside pale green or creamy and pubescent, inside purple with hairy in fertilized zone and creamy with purple dots and smooth in other parts; mouth subspherical, annulus distinctly raised, fauces greenish yellow with dotted dark purple or rarely yellow; limbs 3-lobed, recurved at apex, obtriangular in front view, approximately 1.0–1.5 cm wide, smooth, yellowish green with fine, dark purple striae or rarely dark purple without striae. Stamens six, adnate to gynostemium, anthers oblong, approximately 2 mm long; stigma trilobed, lobes triangular; ovary inferior, clavate, 3–5 mm long, pubescent with grayish hairs. **Fruit:** capsule, hairy, short ellipsoid, with six ridges, 3–5 cm long, dehiscent from apex. **Seeds:** ovate, concave-convex, approximately 5 mm long.

Etymology: Specific epithet derived from the name of the location where the type specimen was collected.

Phenology: flowering from February to April.

Distribution: *Isotrema pahsienshanianum* is a local endemic species distributed only in the central part of Taiwan (Taichung City and Nantou County) at an elevation of approximately 800–1,400 m (Fig. 8C).

Habitat: Unlike *I. shimadae*, which grows in open forest at forest margins and sunny places, or *I. cucurbitifolum*, which occurs in bamboo plantations and open forest, *I. pahsienshanianum* always grows in moist, shady places in broad-leaved forests.

Proposed IUCN Conservation status: According to our specimen examination and fieldwork, less than five localities have been found in an area of occupancy (AOO) smaller than 20 km^2. The occurrences of this species are not in the protected areas, and most populations occur in the National Forest Recreation Area. We did not observe the threaten of land use change, but this species may be disturbed by tourists. On the basis of the guideline for using the International Union for Conservation of Nature and Natural Resources Red List categories and criteria (IUCN 2022), we proposed that this species is categorized as endangered [EN, B1+B2ab(i)(ii)].

Specimens examined: **TAIWAN**. **Taichung City:** Hoping Township: Mt. Pahsienshan, elev. ca. 1,300 m, fr., 21 July 1999, *J. C. Wang 11079* (TNU; TAIF); fl., 4 March 2007, *C. L. Yang 468* (TNU); fl., 24 February 2006, *C. L. Yang 329* (TNU); Chiapaotai, elev. 500–1,000 m, fl., 28 April 2001, *S.-Y. Huang et al. 307* (TAI). **Nantou County:** Jenai Township, Huisun Forest Recreation Area, elev. ca. 980 m, fl., 10 April, 2000, *T. Y. Hsieh s.n.* (TNM); Hetso Village, elev. ca. 1,400 m, fl., 26 March 2011, *C. T. Lu. 1909* (TAIF).

Notes. *I. pahsienshanianum* and *I. shimadae* are morphologically closely related, but they can be easily distinguished by habit (scandent vs. twining), leaf shape (lamina lanceolate-ovate to lanceolate, base cordate, lobes inward, entire vs. lamina cordate-ovate, ovate to lanceolate with two lateral outward lobes at base, usually shallowly trilobed) (Fig. 2C & 2D), and flower color (creamy vs. yellowish green) (Figs. 6 & 7). It also resembles *I. yujungianum* in flower characters, but differs from the latter in leaves shape (lamina lanceolate-ovate to lanceolate, base lobes entire vs. linear to linear-lanceolate, base lobes occasionally 3–5 lobed) (Fig. 2C & 2E). Additionally, the habit of these species are different.

A detailed comparison of the morphologies and distributions of *I. pahsienshanianum* and similar species is provided in Table 3.

4. *Isotrema shimadae* (Hayata) X.X. Zhu, S. Liao & J.S. Ma, Phytotaxa 401(1): 14. 2019.

臺灣馬兜鈴 Figs. 2D & 7A–K

Aristolochia shimadae Hayata, Icon. Pl. Form. 6: 36. 1916, ditto 8: 110. *pl. 13*. 1919. (as 'shimadai'); et Gen. Ind. Fl. Form. 61. 1917; Kudo & Masamune, Ann. Rep. Taihoku Bot. Gard. 2: 47. 1932; Liu & Lai in H. L. Li *et al*., Fl. Taiwan 2: 576. 1976; Murata in Iwatsuki *et al*., Fl. Jap 2a: 368. 2006. ***Type*:** TAIWAN. Shimpo, Shinchikucho, fl., 15 December 1915, *Y. Shimada s.n.* (holotype: TI, photo!).

Aristolochia heterophylla auct. non Hemsl., Hou in Fl. Taiwan 2nd ed. 2: 637, pl. 305, 1996.

Aristolochia kaempferi auct. non Willd., Hwang in Acta Phytotax. Sin. 19: 229, 1981; Hwang in Kiu and Ling, Fl. Reip. Pop. Sin. 24: 206, 1988; Huang *et al*. in Wu and Raven, Fl. China 5: 261, 2003. *pro parte.*

Aristolochia mollis auct. non Dunn., Ma, Acta Phytotax. Sin. 27: 359. 1989 (quoad syn. *A. shimadae* Hayata).

Aristolochia onoei Franch. et Sav. ex Koidzumi in Acta Phytotax. Geobot. 8: 50 (1939). ***Type***: JAPAN, *Savatier 2920* (Isotype: P photo!)

Description: **Habit:** perennial twining liana. **Stem:** young branches terete, pubescent, hair spreading. **Leaf:** petiole 2–7 cm long, pubescent; leaf lamina cordate-ovate, ovate to lanceolate with two lateral outward lobes at base, 6–18 cm long, 2–14 cm wide, herbaceous to papery, base

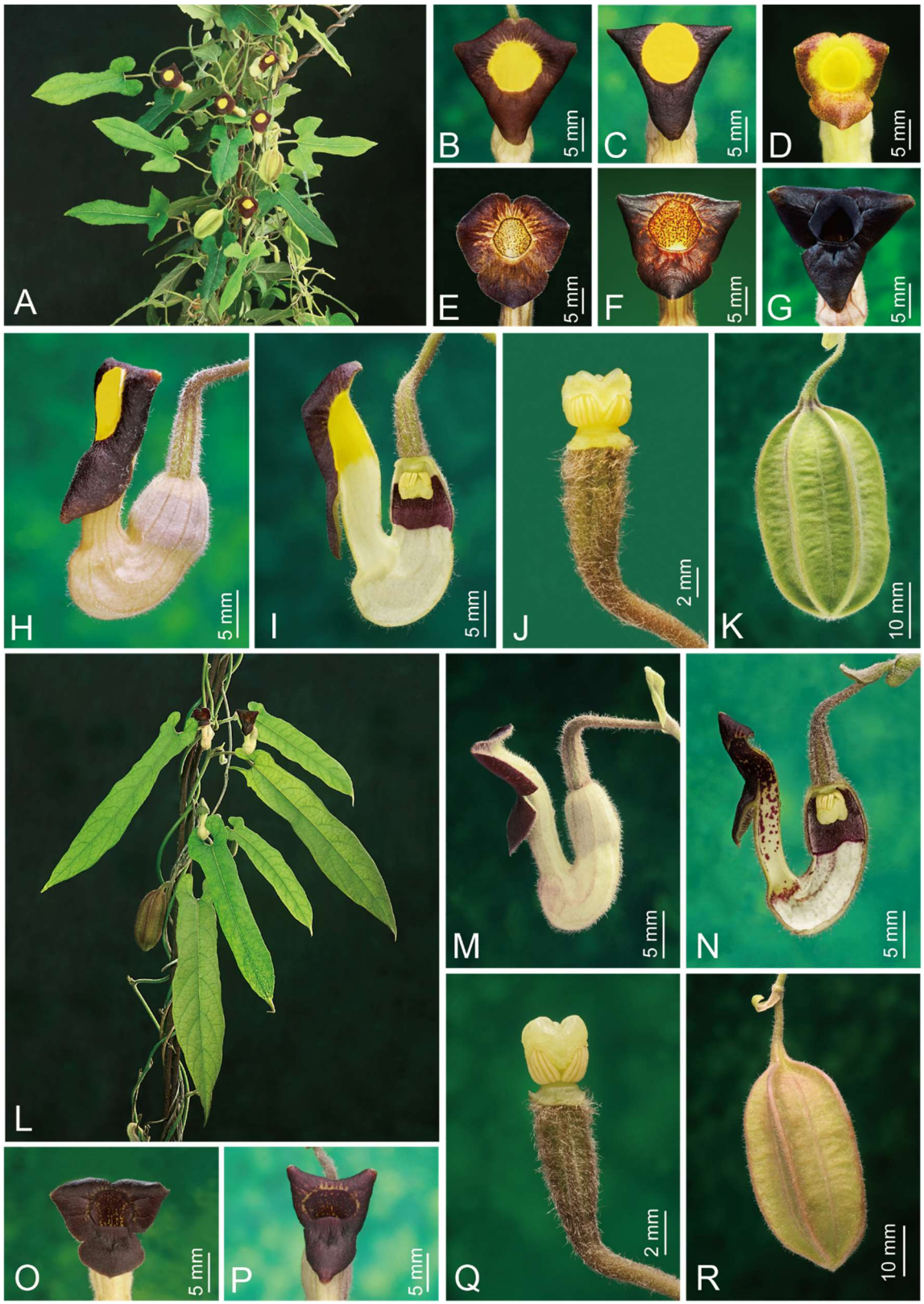


Fig. 7. ***Isotrema shimadae*** (Hayata) X.X. Zhu, S. Liao & J.S. Ma and ***I. yujungianum*** (Lu & Wang) X.X. Zhu, S. Liao & J.S. Ma. **A**–**K.** ***I. shimadae***, **A**. Habit; **B**–**G**. Perianth (front view); **H**. Perianth (lateral view); **I**. Dissection of perianth, showing the gynostemium and the color of inner surface on the perianth; **J**. Gynostemium and ovary, **K**. Capsule; **L**–**R**. ***I. yujungianum***. **L**. Habit, **M**. Perianth (lateral view), **N**. Dissection of perianth, showing inner structure of perianth, **O**, **P**. Perianth (front view), **Q**. Gynostemium and ovary, **R**. Capsule.

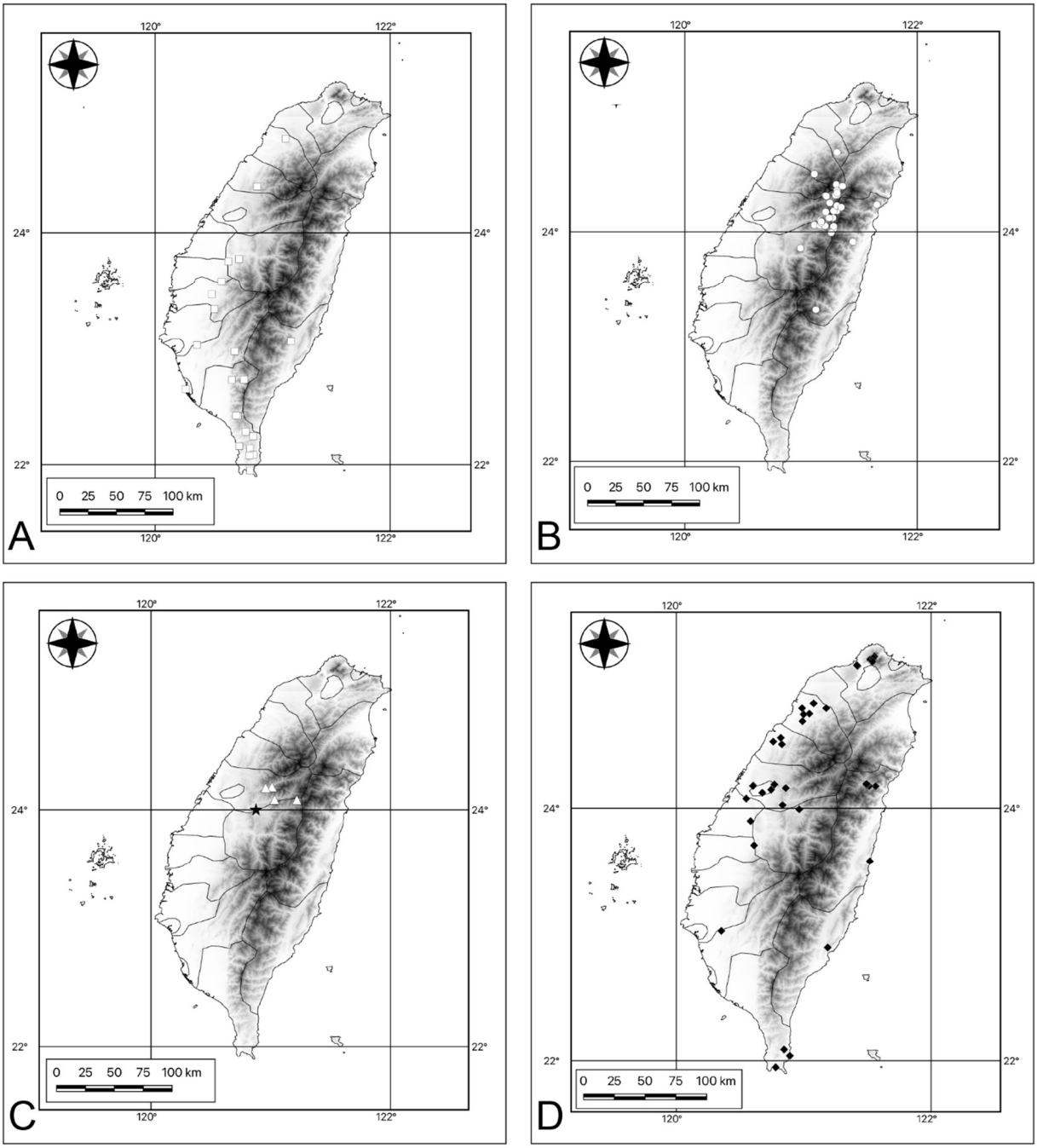


Fig. 8. Geographical distribution of ***Isotrema*** species in Taiwan. **A**. ***I. cucurbitifolium***; **B**. ***I. hohuanense***; **C**. ***I. pahsienshanianum*** (triangulate) and ***I. yujungianum*** (star); **D**. ***I. shimadae***.

cordate, apex obtuse to acuminate; adaxial surface green and glabrescent, abaxial surface grayish green and pubescent; nerves on abaxial surface elevated, with spreading hairy along nerves. **Inflorescences:** on a new growth branch, axillary, flowers solitary or 2; peduncle pendulous, 3–5 cm, pubescent; bract ovate, 2–5 mm, inserted at base of pedicle, sessile and amplexicaul. **Flower:** perianth tube U-shaped, 2.1–2.9 cm long; utricle pendent, cylindrical, 6–10 mm wide, outside pale green or creamy and pubescent, inside of fertile zone purple-reddish and manicate, base with white window pane, and inside of the other part of utricle creamy, glabrous; tube bent upward, outside pubescent, inside glabrous; mouth spherical to subspherical; annulus distinct; fauces yellow or rarely with brown dots, glabrous; limb dark purple adaxially, obtriangular, ca. 2 cm in diameter, deeply 3-lobed, lobes broadly ovate, recurved, glabrous; gynostemium 3-lobed, lobe apex retuse; anthers 6, oblong,

2–3 mm; ovary inferior, conical to cylindrical, ca. 10 mm long, pubescent with densely grayish brown hairs. **Fruits:** capsule, cylindrical, with 6 ridges, 4–7 cm long, hairy, dehiscent from apex. **Seeds:** ovoid, concave-convex, ca. 5 mm long.

Distribution: Japan [Kinki (Hyogo), north Kyushu, and southern Ryukyu Islands (south of Kume jima)] and Taiwan (Watanabe-Toma and Ohi-Toma, 2016).

Habitat: In Taiwan, *I. shimadae* occurs in thickets, forest edges, or open forest, at an elevation of 10–1,100 m (Fig. 8D).

Phenology: Flowering from November to May.

Proposed IUCN Conservation status: *Isotrema shimadae* (Hayata) X.X. Zhu, S. Liao & J.S. Ma distributed from Taiwan, along the Ryukyu Islands to Japan. Most populations of this species occur in the low altitude mountain range and not in the protection areas. It is usually disturbed and destroy by human activities. According to the assessments of GeoCAT (AOO ca. 204 km^2) and the IUCN Red List (IUCN 2022), we proposed that *I. shimadae* should be assigned an extinction risk of "endangered" [EN, B2b(ii)(iii)c(iii)(iv)].

Specimens examined: **JAPAN.** Hyogo Pref., Kobe city, Arima-do, fl., 23 June 1937, *Ishikawa s.n.* (TI); Settsu, Arima, fl., 25 June 1940, *Huroi s.n.* (TI); Hyogo, Kawabe Distr., Inagawa, elev. ca. 160 m, fl., 29 May 2003, *T. Ushijima 21801* (TNS). **TAIWAN: Taipei City:** Mt. Tatunshan, fl., 27 April 1932, *S. Suzuki 10219* (TAI); Kuanyinshan, fl., 10 May 1975, *W.C. Hwa et al. 129* (TAI); Kuan-yin shan, elev. ca. 100 m, fl., 29 March 1974, *S.-Y. Lu 1326, 1330* (TAIF); Hsiaokuanyinshan, elev. ca. 1,070 m, fl., 21 April 1935, *H. Simada 1363* (TAI); Yang-ming-shan, Chingshan road, elev. ca. 240 m, fl., 3 May 1996, *S.C. Wu 977* (TAIF, TNM, HAST); Mt. Yangming, fl., 25 March 1984, *S.F. Huang 1663* (TAI); Erhtzuping to Hsiangtien Pond, elev. 750–800 m, fl., 1 May 2009, *S.W. Chung 9591* (TAIF); Tienmu Ancient Trail, elev. ca. 350 m, fl,. 9 January 2011, *P.F. Lu 21330* (TAIF). **Taoyuan County:** Tsaotzuchi, elev. 50–100 m, fl., 02, Nov. 2003, *C.C. Wang 588* (TAIF); **Hsinchu County:** Shintiku, Shinpo, fr., 20 September 1917, *Shimada s.n.* (TI, photo!, fruit voucher of *A. shimadae* in Icon. Pl. Form. 8: 110, 1919, TAIF); Shinpo, fr., 5 August 1917, *Y. Shimada s.n.* (TAIF); Shinpo, fr., October 1907, *Y. Shimada s.n.* (TAIF); Sanwan, fl., 12 March 1923, *Y. Shimada 1683D, 1683F* (TAI), *1683B* (TAIF); Sanwan, fr., 3 July 1923, *Y. Shimada 1684D, 1984F* (TAI); Kuanhsi Town, No. 16 county Rd. 6.3 Km, Minan Bridge-Nanho, elev. ca. 102 m, 28 June 2003, *C.M. Wang 7005* (TNM); Paoshan, fl., 16 February 1986, *M.T. Kao 10186* (TAI); Tatungkeng, fl. & fr., 31 March 2012, *S.Y. Tsai TSY250* (TAIF). **Miaoli County:** Tunghsiao, elev. ca. 380 m, fr., 7 June 1940, *T. Suzuki ST20035* (TAI); Kungkuan, fl., 4 April 1973, *I.S. Chen 2929* (TAI); Tonglo to Tunghsiaom, elev. ca. 150 m, fr., 14 September 2007, *T.C. Hsu 976* (TAIF); Hsihu Township, Chinshih village, elev. ca. 138 m, 21 February 2007, C.L. Yang 460 (TNU); Shihwu Township First Cemetery, elev. ca. 180 m, fl., 10 April 2010, *P.F. Lu 20052* (TAIF); Miaoli City Cemetery, elev. ca. 150 m, fl., 18 April 2010, *P.F. Lu 20112* (TAIF); Mt. Tukanting, elev. ca. 100–150 m, fl., 30 April 2011, *T.C. Hsu 3946* (TAIF). **Taichung City:** en route from Chunghsing Ling to Takeng, elev. ca. 570 m, 2 November 1986, *C.-I Peng 9981, 9966* (HAST). **Changhua Co.:** Chingshuyen, elev. ca. 50 m, fl., 2 April 1991, *S.F. Huang 4530* (TAI); Mt. Pakua, fl., 26 March 2011, *C.T. Lu 1805* (TAIF). **Chiayi City:** Lantan, elev. ca. 50–100 m, fl., 21 April 2013, *T.C. Hsu 6498* (TAIF). **Hualien County:** Batakan, fr., 6 May 1932, *S. Sasaki s.n.* (TAI); Tabito-Tausai, fr., 7 July 1937, *H. Shimada 1306* (TAI); Lushui-Yanhai logged trail, elev. 500–1,000 m, fl., 1 April 1983, *W.L. Chiou & T.T. Lin s.n.* (TAIF); Hsinkanshan, elev. ca. 760 m, 18 February 1989, T.Y. Yang 4459 (TNM); Shakatang Trail, elev. 100–300 m, fl., 27 March 2011, *T.C. Hsu 3790* (TAIF); Walami, fl., 14 February 2013, *W.Y. Wang 1579* (TAIF). **Taitung Co.:** Tulanshan, elev. ca. 1,100 m, 8 May 2002, *S.W. Chung 5245* (TAIF); Hungshih Logged Trail, fl., 5 April 2011, *W.Y. Wang 1103* (TAIF).

Notes. *I. shimadae* (Hayata) Zhu, Liao & Ma is widely distributed from Japan to Taiwan and exhibits considerable morphological variation, causing many taxonomic inconsistencies. It was treated as synonymous with *I. kaempferi* by Hwang (1981, 1988) or *I. molle* by Ma (1989). However, on comparing the protologues and type specimens, we found that the flower shape of *I. shimadae* is quite different from that of *I. kaempferi* and *I. molle*. The former differs from the latter two with respect to the relationship of tube and utricle (tube longer than utricle vs. tube as long as utricle), limb shape (deeply 3-lobed, recurved apically, obtriangular in front view vs. shallowly 3-lobed, incurved apically, widely obovate in front view), limb color (purple reddish to purplish brown without any stripes vs. green-yellowish with fine linear purple radiating markings at the base), and color pattern on the inner surface of the perianth tube (throat fresh yellow without purple dots, tube yellow, and utricle creamy vs. throat green-yellowish with purple dots or wholly purple, tube and utricle creamy with purple stripes or dots). Therefore, we consider *A. shimadae* distinct from *I. kaempferi* and *I. molle*.

Hou (1996) regarded *I. shimadae* as a synonym of *I. heterophyllum*. However, Ma (1989) separated these two species on the basis of the gynostemium lobe: triangular without secondary lobes in *I. heterophyllum*, while obtuse to truncate with apex retuse in *I. shimadae*. Although we could not compare this character in the dry specimens, we found *I. shimadae* can be distinguished from *I. heterophyllum* based on the amplexicaul bract (smaller, 2–5 mm, and ovate to lanceolate vs. larger, approximately 5 mm, and circular), annulus (narrow unclearly vs. obviously protruded), and ovary (conical to cylindrical, pubescent vs. clavate, glabrescent) (also see Zhu *et al*., 2017a, Figs 4 and 5). In addition, their geographical distributions are disjunct. Therefore, we consider that *I. shimadae* and *I. heterophyllum* should be treated as different species.

Murata (2006) also considered *A. onoei* Fr. & Sav. ex Koidzumi to be synonymous with *A. shimadae*, based on the flower color. After examining the type specimen of *A. onoei* and some specimens from Japan, we noted that their floral characters are similar to those of *I. shimadae*, except for deeply 3-lobed leaves in *A. onoei* and the other specimens. Through molecular data, Watanabe *et al*. (2006) (by chloroplast DNA) and Watanabe *et al*. (2008) (by nuclear DNA) confirmed that *A. onoei* is closely related to *I. kaempferi*. Moreover, Watanabe *et al*. (2008) performed a reproductive experiment and showed that *I. shimadae* (=*A. onoei*) could hybridize with *I. kaempferi*. Additional studies of these species to understand these relationships are needed. Nevertheless, we follow the treatment of Murata (2006) and regard *A. onoei* a synonym of *I. shimadae*.

5. *Isotrema yujungianum* (C.T. Lu & J.C. Wang) X.X. Zhu, S. Liao & J.S. Ma, Phytotaxa 401(1): 16. 2019.
裕榮馬兜鈴 Figs. 2E & 7L–R

Aristolochia yujungiana C.T. Lu & J. C. Wang, Taiwan J. For. Sci. 29(4): 293. 2014. ***Type*:** TAIWAN. Nantou County, Yuchi Township, Peishankan, ca. 400 m, 8. Feb. 2008, *C.-T. Lu 1635* (holotype, TAIF!; isotype, TNU!).

Description. **Habit:** perennial twining liana. **Stem:** young branches terete, densely pubescent. **Leaves:** petiole 2–5 cm long; lamina herbaceous to leathery, 10–20 cm long, 2.5–3 cm wide, linear to linear-lanceolate, base cordate, with 2 small inward lobes at base, lobes entire or occasionally 3–5 lobed; apex acute to acuminate, adaxially green and glabrescent, abaxially grayish-green with pubescence along the veins, hairs appressed; nerves elevated on abaxial surface. **Inflorescences:** flower solitary in axils of prophylls of lateral branches; pedicel 4–5 cm long, bracteole ovate, ca. 3 mm long, inserted at base of pedicel. **Flower:** perianth tube U-shaped, 1.6–2.1 cm long, 5–6 mm wide at utricle; utricle outer surface creamy, pubescent, and inner yellowish-green with dark-purple speckles, smooth; mouth subspherical to elliptical, ca. 5×8 mm; annulus distinct; fauces dark-purple sometimes with yellow dots; limb obtriangulate in front view, ca. 2 cm wide, deeply 3-lobed, lobes spread, recurved apically, dark-purple, sparsely pubescent. Stamens 6, adnate to style column, anthers oblong, ca. 2 mm long. Gynostemium ca. 4 mm long; stigmatic lobes 3, lobe triangular; ovary inferior, cylindrical, ca. 8 mm long, pubescent. **Fruits:** capsule, ellipsoid to oblong, with 6 ridges, 4–5 cm long, 2.5–3 cm in diameter, and dehiscent from apex. **Seeds:** flat, widely ovate, plano-concave, 5.2–6 mm long, and 5.2–5.5 mm wide.

Distribution: *I. yujungianum,* is endemic to Taiwan and so far found only in the locality that type specimen collected (Fig. 8C).

Habitat: It usually grows along the forest edge in low-elevation mountain areas of central Taiwan.

Phenology: Flowers from December to March.

IUCN Conservation status: **C**ritically endangered (CR, B1ab(iii, iv)) (Lu and Wang, 2014; Editorial Committee of the Red List of Taiwan Plants, 2017).

Specimens examined: TAIWAN. Nantou Co: Peishankan, fl., 29. Mar. 2011, *C.-T. Lu 1911* (TAIF).

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Supplementary materials are available from Journal Website.