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New Natural Hybrid, *Alpinia* × *ilanensis* (Zingiberaceae) in Taiwan

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ABSTRACT: The genus *Alpinia* in Taiwan was very impressed by its frequent hybridization. Four out of 6 indigenous species in Taiwan proper have been reported to be involved in a reticulate hybridization. This paper describes and illustrates a new natural hybrid *A.* × *ilanensis*, putatively derived from *A. japonica* and *A. pricei*, which is supported by morphological and ecogeographical evidences. Based on sparse distribution mode and serious fertility reduction in these hybrid individuals, we suppose that the hybridization events between *A. japonica* and *A. pricei* have been independently occurred multiple times in field. This newly discovered hybrid reveals that all 6 independent species in this island possess the ability to cross each other.

KEY WORDS: *Alpinia*, *Alpinia* × *ilanensis*, *Alpinia japonica*, *Alpinia pricei*, natural hybridization, new hybrid, Taiwan, Zingiberaceae.

INTRODUCTION

Alpinia Roxb., the largest genus in Zingiberaceae, consists of ca. 230 species (Smith, 1990; Wu and Larsen, 2000) with the diversity center in India and Malaysia (Larsen, 1996). In Taiwan, the genus has been successively studied by Moo (1973), Yang and Wang (1998; 2000), Kuo (2006) and got rather different results. Recently, a new species *A. nantoensis* was reported by Kuo et al. (2008). However, the status of this species is very doubtful because the diagnostic characters are erroneously indicated in their photos. Here we adopted the treatment of Flora of Taiwan 2nd edition (Yang and Wang, 2000) in which 10 species and 2 varieties were recognized in Taiwan proper excluding the cultivated *A. galanga* and *A. flabellate* found in Lanyu Islet. Besides taxonomic controversy, the prevalent inter-specific hybridization of Taiwanese *Alpinia* has also been intensively investigated (Yang and Wang, 1998; Liu et al., submitted). Yang and Wang (1998) firstly proposed a hypothesis of reticulate hybridization of *Alpinia* in which 4 natural hybrids (*A. formosana*, *A. kusshakuensis*, *A. mesanthera*, and *A. tonrokuensis*) were discerned by morphological, phenological, and ecological data. Subsequently, the relationship between these hybrids and their parental species was further verified by using both nuclear and chloroplast DNA markers. Not only the parentage but reciprocal and introgressive hybridization among these plants was disclosed (Liu et al., submitted). So far, four taxa, namely *A. intermedia*, *A. shimadai*, *A. uraiensis*, and *A. zerumbet*, out of six indigenous species in Taiwan proper have known to involve in hybridization events.

Both extrinsic and intrinsic reproductive isolations in Taiwanese *Alpinia* could be not so strong that natural hybridizations occur time after time. The reticulate species pairing indicated that inter-specific hybridization in *Alpinia* is extensive and is not confined to particular species groups. The four parental species involved in the reticulate hybridization belong to three different subsections within section *Alpinia* according to the system of Smith (1990). Secondary contact could be the major cause for these inter-subsectional hybridization events. This feature suggests that almost all species within section even genus possess the ability to cross each other. Novel *Alpinia* found lately with intermediate morphology is reasonably speculated to be a natural hybrid.

Several unknown *Alpinia* plants resembling in appearance were sequentially found in northeastern Taiwan during the past years. Judging from the intermediate morphology, they are proposed to be the natural hybrids between *A. japonica* and *A. pricei*, both have never been mentioned to cross each other or with other taxa. This study aims to explicitly determine the parentage of these putative hybrids based on ecogeographical and morphological evidences. A good indicator for *Alpinia* hybrid, pollen fertility, represented by stainability, was also assessed by using 0.5% acetocarmine. A new natural hybrid *A.* × *ilanensis* is consequently described and illustrated as follows.

TAXONOMIC TREATMENT

Alpinia* × *ilanensis S.-C. Liu & J.-C. Wang *hyb. nov.*

TYPE: TAIWAN. Ilan County: Chiaohsi Township, Wufengchi, along a trail to Mt. Sheng-mu-feng (Mt. Madonna) (121°43'E, 24°51'N), 700-800 m alt., Apr. 22, 2006, *S.-C. Liu 2631* (holotype: TNU; isotype: TAIF). 宜蘭月桃 Figs. 1 & 2

Hybrida naturalis e *Alpinia japonica* et *A. pricei*. Folia chartaceus vel subcoriaceus margine sericeus

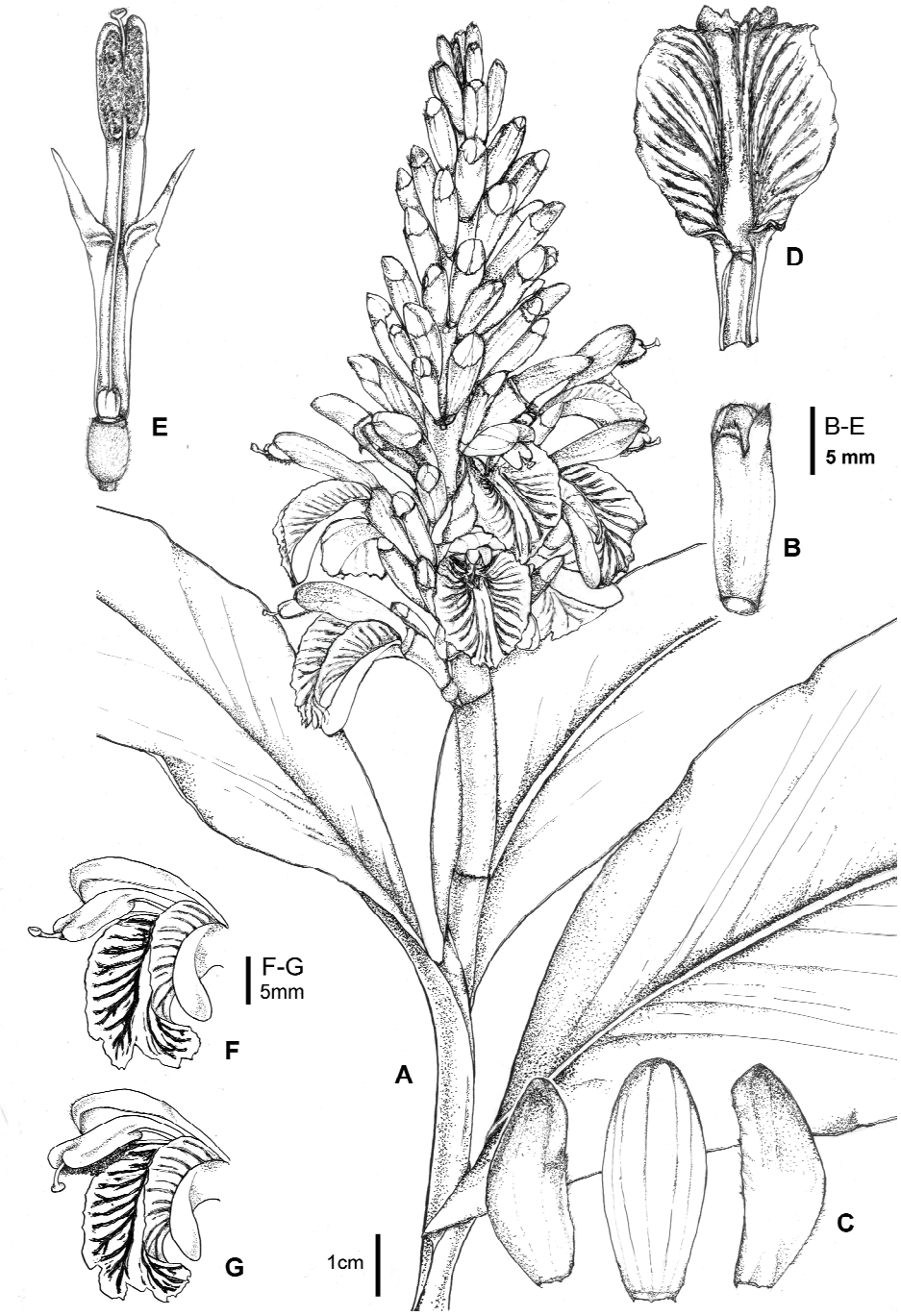

Fig. 1. *Alpinia* × *ilanensis* S.-C. Liu & J.-C. Wang. A: Flowering branch. B: Calyx. C: Dorsal and lateral lobes of corolla. D: Labellum, connecting to corolla-tube. E: Stamen, staminodes, epigynous glands, and pistil. F, G: Anaflexistylous flower during the pistillate stage in the morning (F) and the staminate stage in the afternoon (G).

utroque pagine parce vel dense tomentosus. Panicula 12-18 cm longum, floribus 1-2-fasciculatim situs fere sessilibus vel breve pedicellatis. Bracteolae minutus vel absens; labellum obovatus concavus 1.4-1.8 cm longum apice emarginato vel rotundatum margine crispatus.

Plants 0.7-1.0 m high, more or less tomentose. Leaves petiolate; ligule 4-8 mm long, bilobed; leaf blade oblong to lanceolate, 20-50 cm long, 4-9 cm wide, base oblique or cuneate, apex acuminate, chartaceous to subcoriaceous, sparsely to densely tomentose on both

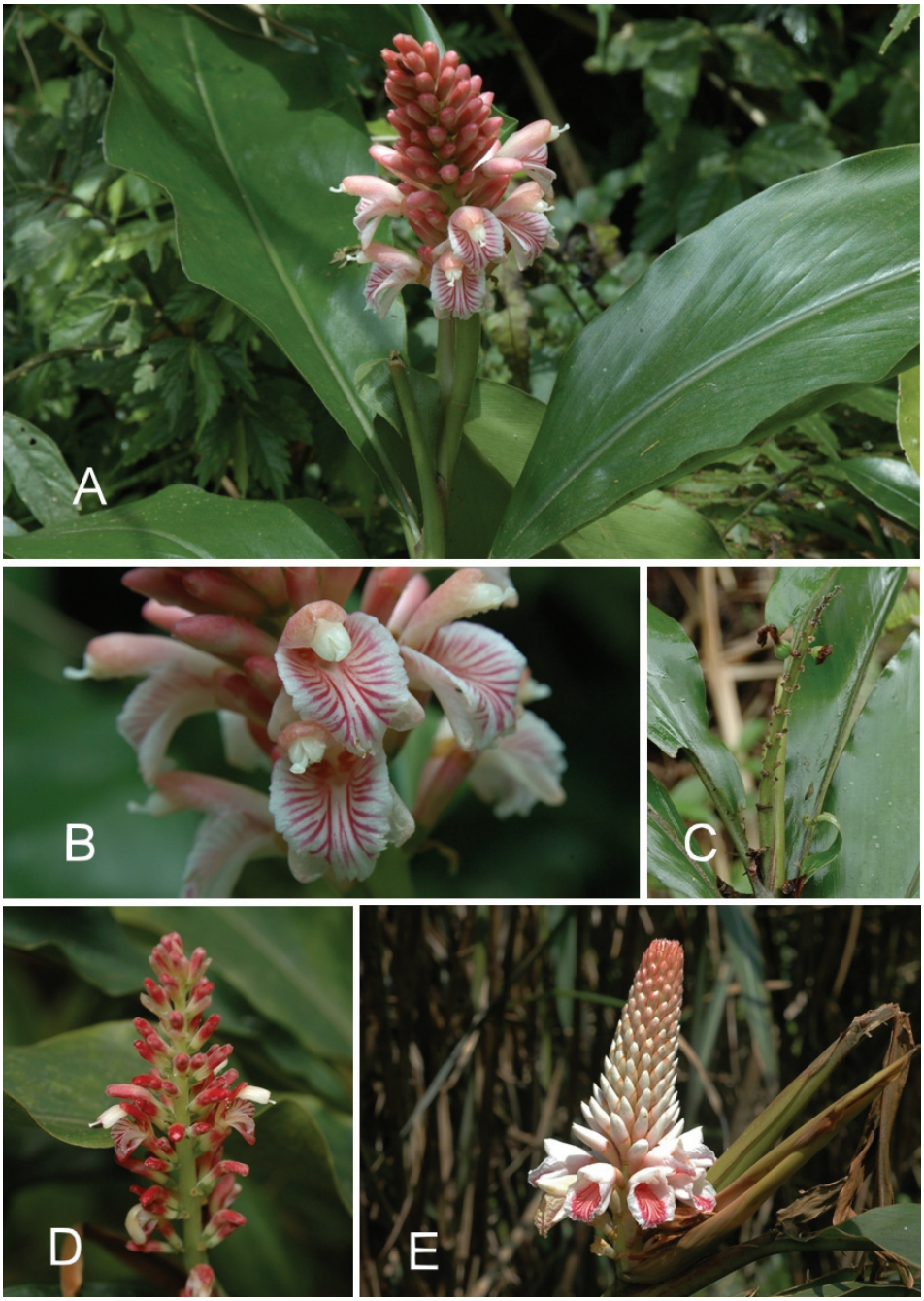

Fig. 2. *Alpinia* × *ilanensis* (A-C) and its putative parental species *A. japonica* (D), *A. pricei* (E). A: Flowering branch. B: Partial inflorescence. C: Fruiting branch.

surfaces, sericeous at margin and below midrib, lateral veins indistinct. Panicles erect, 12-18 cm long, rachis and branches tomentose, each branch with 1-2 flowers; bracts minute, deciduous. Flowers sessile or shortly pedicellate; bracteoles minute, oblong, glabrous, deciduous, or absent; calyx light red, tubular, 9-13 mm long, shortly 3-lobed; corolla- tube white mingled with light red, 10-13 mm long, lobes oblong, light red, dorsal lobe 13-15 × 7-9 mm, laterals 10-13 × 5-7 mm; labellum obovate, white to pinkish with red stripes at center and margin, 14-18 × 12-15 mm, slightly concave, apex emarginate or rounded, margin crispate; staminodes linear to lanceolate, red, 5-6 mm long; anther 8-9 mm long; thecae parallel; filament 8 mm long; stigma expanded,

Table 1. Morphological comparison of *Alpinia* × *ilanensis* with its putative parents, *A. japonica* and *A. pricei*.

Characters	*A. japonica*	*A.* × *ilanensis*	*A. pricei*
Plant height	0.5-0.7 m	0.7-1.0 m	0.8-2 m
Leaf			
Texture	chartaceous	chartaceous to subcoriaceous	subcoriaceous
Vestiture	densely tomentose on both surfaces	sparsely to densely tomentose on both surfaces	glabrous on upper surfaces, glabrous to pubescent below
Inflorescence	panicle, each branch with 1-3 flowers	panicle, each branch with 1-2 flowers	raceme
Bracteole	oblong, but variable in size, deciduous	minute to absent	absent
Flower			
Pedicel	0-2 mm	0-2 mm	1-3 mm
Corolla	red	white mingled with lightly red	white, sometimes mingled with pinkish
Labellum			
Shape	round, apex 2-lobed or emarginate	obovate, apex emarginate or rounded	obovate, apex rounded
Size	1.0-1.2 × 0.9-1.1cm	1.4-1.8 × 1.2-1.5 cm	2.8-3.6 × 2.7-3.5 cm
Color	white with red stripes at margin	white to pinkish with red stripes at center and margin	white with numerous red stripes at center
Fruit			
Type	berry-like	capsule, with indistinct ribs	ribbed capsule
Shape	ellipsoid	irregularly globose	globose

ciliated orifice; style slender, 28 mm long; epigynous glands columnar, yellow, ca. 3 mm long; ovary green, tomentose, 3-5 mm long. Capsule irregularly globose, indistinctly ribbed.

Additional specimens examined: Taipei County: Shuanghsi Township, Wantan (121°48'E, 24°56'N), *ca.* 450 m alt., *S.-C. Liu 2776* (TNU). Ilan County: Chiaohsi Township, Wufengchi, along a trail to Mt. Sheng-mu-feng (Mt. Madonna) (121°43'E, 24°51'N), 700-800 m alt., *P.-F. Lu 9606* (TNU, TAI, TAIF), Mt. Hongludishan (121°42'E, 24°50'N), 700-1000 m alt., *S.-C. Liu 2689* (TNU, TAIF). Hualien County: Hoping Township, *ca.* 23 Km from the entrance of Hoping logging trail (121°41'E, 24°18'N), *ca.* 1500 m alt., *S.-C. Liu 2621* (TNU).

Etymology: The specific epithet is derived from the type locality, Ilan.

Morphological comparison and pollen fertility of putative hybrids and parental species

Morphological comparison of twelve discriminative characters between *A.* × *ilanensis* and its putative parents, *A. japonica* and *A. pricei*, is displayed in Table 1. The characteristics of *A.* × *ilanensis* are variable but wholly in the range between their putative parents'. Several qualitative characters, e.g. texture of leaf, presence of bracteole, position of stripes on labellum, and type of fruit, are so different between two parental species that practical to discern the intermediate, but not exactly middle, state of hybrids. Floral quantitative characteristics, such as size and color of labellum, are also very substantial in diagnosing hybrids (Fig. 2). Variations among hybrid individuals may straightly come from intraspecific differences within their parental species. Because *A. japonica* has some impressively distinctive characters among Taiwanese *Alpinia*, e.g. the leaves densely tomentose, chartaceous and the inflorescence chiefly colored in red, its hybrids were more easily recognized according to these characteristics. Therefore, the hybrids were ever misidentified as *A. japonica*.

The pollen grains of *A.* × *ilanensis* revealed low fertility (Table 2, Fig. 3). Sterile pollen in hybrid was determined by notably abnormal shape and low stainability rate (9-42%) contrast to rather high in two parental species (92% & 94%, Yang and Wang, 1998). Even though only one immature infructescence was collected in our study, its low fruit and seed setting rates were consistent with the expectation for hybrid of which sexual reproduction usually has serious problem. Therefore, the spread of hybrid was considered to be limited but the perennial habit and vigorous propagation by rhizome provide their persistence for a long span of time.

Ecogeography of putative hybrids and parental species

Both parental species are common but regional-distributed in Taiwan. *Alpinia japonica* is considered to be a temperate ginger and 24°N is almost the south limit of its distribution in Taiwan. *Alpinia pricei* is an endemic species distributed in the mountain region below 2,000 m in altitude around the island except the western part. *Alpinia* × *ilanensis* was found in four separate locations scattered in the superimposed region of *A. japonica* and *A. pricei*, northeastern Taiwan (Fig. 4). Single individual or few individuals grown very closely were found within a location and usually only a few meters away from any putative parent. Within these locations, *A. pricei* is generally more abundant than *A. japonica*.

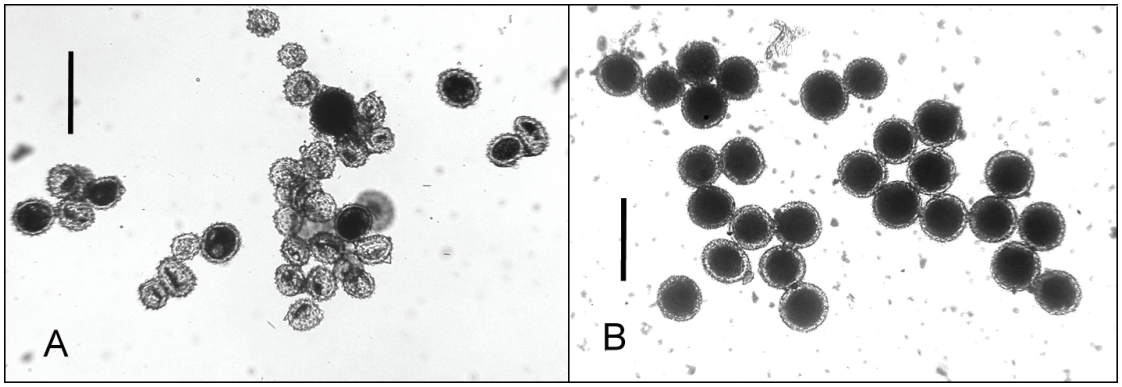

Fig. 3. A: Aberrant and unstainable pollen grains of *Alpinia ×ilanensis.* B: Mostly normal-shaped and stainable pollen grains of *A. japonica*.

Table 2. The percentage of stainable and normal-shaped pollen grains of *Alpinia* × *ilanensis* determined by using 0.5% acetocarmine.

Location	Stainability (%)	Voucher specimen
Ilan: Wufengchi	33	*S.-C. Liu 2631*
Ilan: Wufengchi	42	*P.-F. Lu 9606*
Ilan: Mt. Hongludishan	9	*S.-C. Liu 2689*
Hualien: Hoping logging trail	11	*S.-C. Liu 2621*

Ecologically, both putative parental species grow under broad-leaf forests, but each has its own preference: *A. pricei* grows typically along hillsides while *A. japonica* inhabits near mountain ridges. *Alpinia* × *ilanensis* appears in the contact zones of these two species. In addition, the sympatric-distributed parental species blooms simultaneously from April to May.

Interspecific hybridization of *Alpinia* is a general rule in Taiwan

The natural hybrid *A.* × *ilanensis* derived from *A. japonica* and *A. pricei* has been ecogeographically and morphologically proved (Table1, Figs. 2 & 4). Advanced study for demonstrating the hybrid lineage by molecular tools and elucidating its structure is in progress. After the discovery of natural hybridization between *A. japonica* and *A. pricei,* together with the formerly reported reticulate hybridization, it represents that all six independent species in this island possess the ability of being a parent of hybridization. Hybridization among Taiwanese *Alpinia* species seems to be commonplace when the plants are sympatric-distributed and flowering at the same time. Contrast to the extensive zones of other *Alpinia* hybrids reported previously, *A.* × *ilanensis* is sporadically found in very small scale under the forest with little human disturbance. It emphasizes the significance of ecogeographical reproduction isolation in *Alpinia* and also shows the diverse patterns between these hybridization cases. Ecogeographical barriers may often have the greatest contribution to total isolation

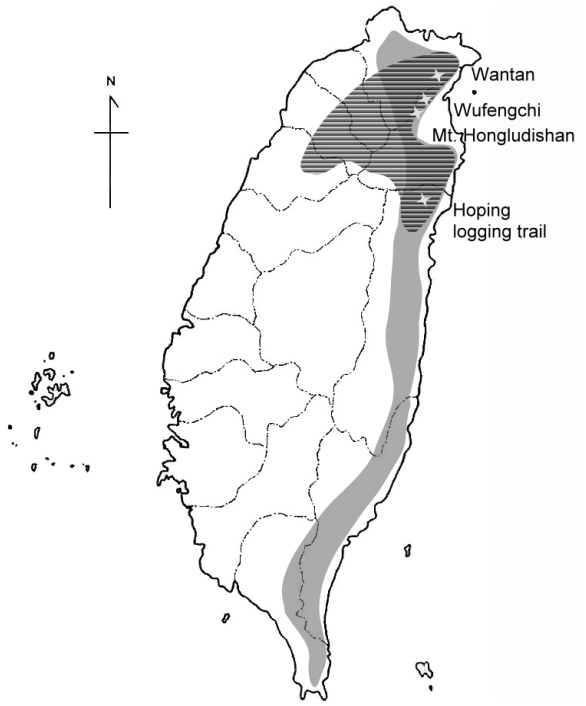

Fig. 4. Distribution of *Alpinia japonica* (slashed), *A. pricei* (shaded) and *A.* × *ilanensis* (star) in Taiwan.

because they come into play first (Schemske, 2000). The secondary contacts between species created by whether natural or anthropogenic forces are really effective in the evolution of *Alpinia*. Based on sparse distribution mode and serious fertility reduction, we suppose that these hybrid individuals are raised independently multiple times in field rather than a lasting hybrid lineage. It is tempting to generalize that interspecific hybridization in Taiwanese *Alpinia* is a rule, not exception. Based on the more clarification about the breakdown of reproduction barrier in *Alpinia*, more new hybrid from undetermined parental species pairing is deductive.

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臺灣產薑科新天然雜交—宜蘭月桃

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摘要：臺灣產薑科月桃屬植物有頻繁的種間雜交現象，在本島六個原生種中，有四種曾被報導參與了一網狀雜交關係。本文根據形態及生態地理上的證據，新描述一推斷來自山薑 (*A. japonica*) 及普萊氏月桃 (*A. pricei*) 的天然雜交－宜蘭月桃 (*A.* × *ilanensis*)，並提供其手繪圖及照片。基於這些雜交個體呈現零散分布以及孕性大幅降低的特性，作者認為此雜交為多次獨立發生的事件。此新雜交組合的發現顯示臺灣本島的六個獨立種均具有相互雜交的能力。

關鍵詞：月桃屬、宜蘭月桃、山薑、普萊氏月桃、天然雜交、新雜交、臺灣、薑科。