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SYSTEMATICS

Impatiens qingchengshanica (Balsaminaceae), a unique new species from China and its phylogenetic position

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ABSTRACT. *Impatiens qingchengshanica* Y.-M. Yuan, Y. Song & X.-J. Ge, sp. nov. is described and illustrated. It was collected from a broad-leaved forest on Sichuan Province's Qingcheng Shan, Southwestern China. This species is unique in the genus for its specialized nodular (moniliform) and horizontal rootstock with conspicuously enlarged knots (1-3 cm in diameter) and long (3-5 cm), thin (2-3 mm in diameter) string. It resembles *I. clavigera* Hook. f. in terms of gross floral morphology. *Impatiens qingchengshanica* has oblong, elliptic or widely elliptic leaves and showy pink flowers. The lower sepal is funnel-form, ca. 4-4.5 cm deep, abruptly narrowed into a subulate spur ca. 2.5-3 cm long, straight, and only occasionally incurved in young buds. The left and right pairs of the lateral united petals are unequal in size thus the whole flower is oblique and asymmetrical. The lower petals of the lateral united petals are oblong and oblique unlike *I. clavigera,* which has obovate, lanceolate or oblanceolate leaves and bright yellow flowers. Its lower sepal is subsaccate, 2-3 cm deep, abruptly contracted into a narrow tubular spur which is 5-6 mm long, conspicuously incurved when flowering. The left and right pairs of the lateral united petals are almost equal in size, thus the whole flower is nearly symmetrical. The lower petals of the lateral united petals are dolabriform. The new species is also similar to *I. omeiana* Hook. f. and *I. pritzelii* Hook. f. in terms of rhizome, leaf and stem morphology, but the flower shape and bauplan are conspicuously different. *Impatiens omeiana* has enlarged tuberous rhizomes, yellow or pale yellow flowers with subsaccate to saccate lower sepals that gradually narrow into a short incurved spur, and dolabriform lower petals of the lateral united petals. *Impatiens pritzelii* has a procumbent tortuous subterranean stem with enlarged nodes, yellow or yellow-white flowers with saccate to widely saccate lower sepals which gradually narrow into a short incurved spur, and oblong or subdolabriform lower petals having a rounded apex. The new species is nested in the basal clade of the phylogentic tree of the genus, and thus represents one of the ancestral forms with important implications for understanding the evolution within the genus. Molecular phylogeny further indicated that nodular (moniliform) and tuberose rootstocks may have undergone multiple independent origins and parallel evolution within the genus adaptive to the seasonal dry habitats of the species.

Keywords: Balsaminaceae; Evolution; *Impatiens qingchengshanica*; New species.

INTRODUCTION

The Balsaminaceae are annual or perennial herbs with flowers that exhibit a remarkable diversity. The family consists of two genera, the monotypic genus *Hydrocera* and *Impatiens*. *Hydrocera* has a single species, *H. triflora* (L.) Wight. et Arn., distributed in the broad Indo-Malaysian countries including Sri Lanka, India, Indonesia, Malaysia, Thailand, Cambodia, Laos, Vietnam, and southern China (Hainan Island). *Impatiens* has over 1000 species worldwide, with most species concentrated in five hotspots: Southeast Asia and southwestern China, eastern to central Himalayas, southern India, tropical Africa, and Madagascar (Grey-Wilson, 1980). About 240 species have been reported from China (Chen, 2001; Huang et al., 2003; Morgan et al., 2005; Cong et al., 2008; Jin et al., 2008; Yu et al., 2007; Yu et al., 2009). The mountainous regions in southwestern China, particularly Sichuan and Yunnan provinces, harbor diversified species including the most ancestral types of species of the genus (Janssens et al., 2006; Song, 2006).

We recently studied the morphology, taxonomy, karyology, molecular phylogeny and biogeography of Balsaminaceae (Song et al., 2003, 2005; Yuan et al., 2004; Janssens et al., 2006). Extensive collections were gathered from various species hot spots, including some types never before described. One of these is *I. namchabarwensis* R.

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Morgen, Y.-M. Yuan & X.-J. Ge, a new species we recently described having showy and truly blue flowers (Morgan et al., 2005). This species is considered to have such great horticultural potential that it was named 'Blue Diamond Impatiens' by those in the horticulture trade (Wikipedia, http://en.wikipedia.org/wiki/Impatiens_namchabarwensis). This paper describes another unique new species with showy flowers, which we found during our 2004 expedition in the Qingchengshan Mountains, ca. 80 kilometres northwest of the Chengdu city, Sichuan province, China.

NEW SPECIES

Impatiens qingchengshanica Y.-M. Yuan, Y. Song & X.-J. Ge, sp. nov.—TYPE: CHINA. Sichuan Province, Qingchengshan Mountains; alt. 700-1,400 m, N30°56', E103°28'; in broad-leaved forest, 1st August 2004, *Yuan Y.-M. 2004-16* (holotype: IBSC; isotype: NEU).

青城山鳳仙花 Figures 1-3

Species rhizomatibus noduliformibus a congeneribus diversa; differt a I. clavigera Hook. f. foliis oblongis, ellipticis vel late ellipticis, floribus roseis, asymmestricis, obliquis, sepalis infundibularibus, circa 4-4.5 cm longis, basi in calcar sublatum rectum usque ad 2.5-3.0 cm longum abrupte contractis, petalorum lobis inferioribus oblongis obliquis; etiam similis I. omeianae Hook. f., quae floribus flavis vel flavidis, sepalis inferioribus subsaccatis vel saccatis, basi in calcar breve incurvatum gradatim contractis, petalorum lobis lateralibus brevioribus, aequalibus, dolabriformibus differt; etiam similis I. pritzelii, quae caulibus subterrraneis tortuosis procumbentibus, nodis auctis, floribus flavis vel flavo-albis, sepalis inferioribus saccatis usque late saccatis in calcar brevem incurvatum gradatim angustatis, petalorum lobis lateralibus oblongis vel subdolabriformibus differt.

Diagnosis. This new species is unique in the genus for its specialized nodular (moniliform) and horizontal rootstock having conspicuously enlarged knots (1-3 cm in

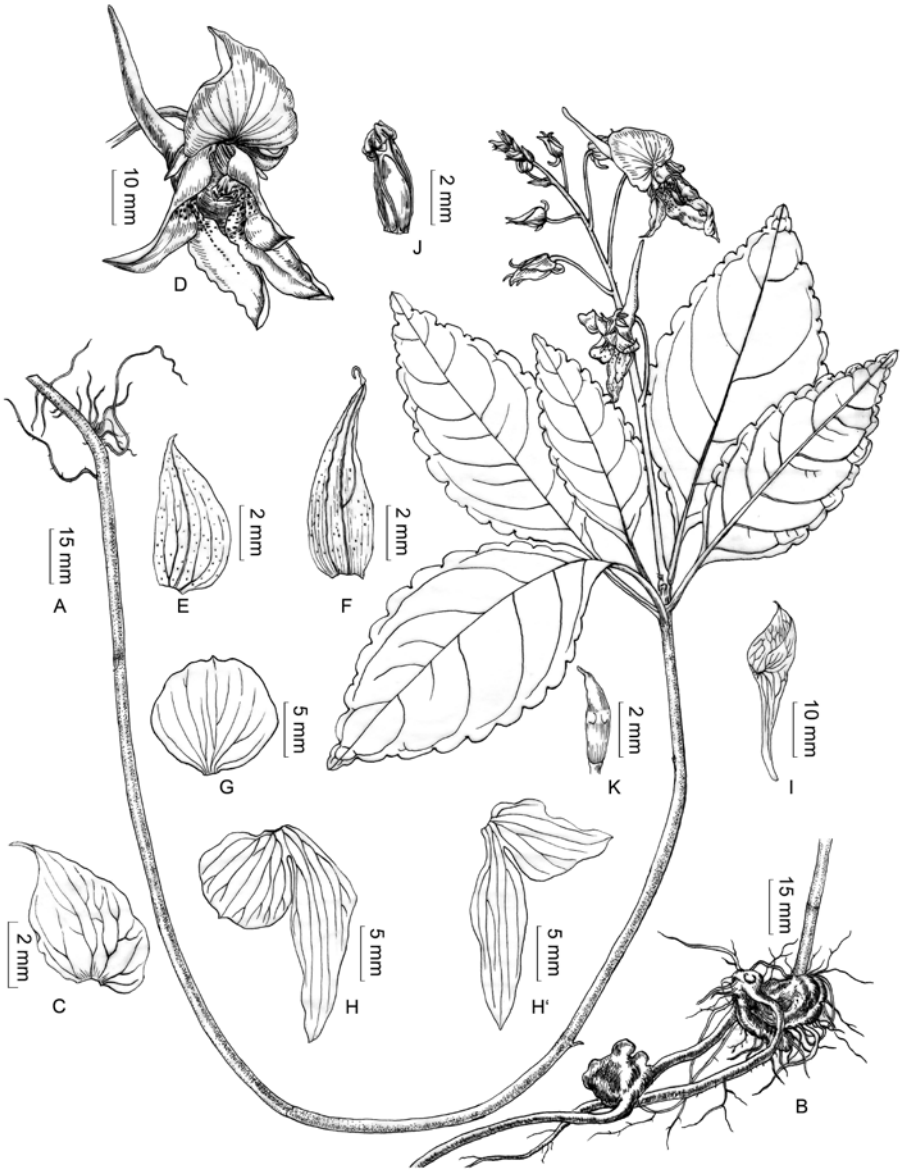

Figure 1. Illustrations of *Impatiens qingchengshanica*. A, flowering plant; B, roots and rhizomes; C, bract; D, flower; E, outer sepal; F, inner sepal; G, dorsal petal; H & H' lateral united petals (shown at upper position are upper petals which are orbicular or ovate; shown at lower position are lower petals which are oblong, oblique, and incurved, much longer than the upper petals); I, lower sepal and spur; J, ovary surrounded by stamens; K, developing ovary. (Drawn by Yun-Xiao Liu)

diameter) and long (3-5 cm), thin (2-3 mm in diameter) string. In terms of gross floral morphology *I. qingchengshanica* resembles *I. clavigera* Hook. f., which is native to Guangxi and Yunnan provinces of China and neighbouring north Vietnam. The new species has oblong, elliptic or widely elliptic leaves, showy pink flowers with funnelform lower sepals, ca. 4-4.5 cm deep, abruptly narrowing into a subulate spur which is ca. 2.5-3 cm long, straight, and only occasionally incurved in young buds, the left and right pairs of the lateral united petals unequal in size thus the whole flower oblique and asymmetrical, the lower petals of the lateral united petals oblong and oblique; whereas *I. clavigera* has obovate, lanceolate or oblanceolate leaves, bright yellow flowers with lower sepal subsaccate, 2-3 cm deep, abruptly contracted into a narrow tubular spur which is 5-6 mm long, conspicuously incurved when flowering,

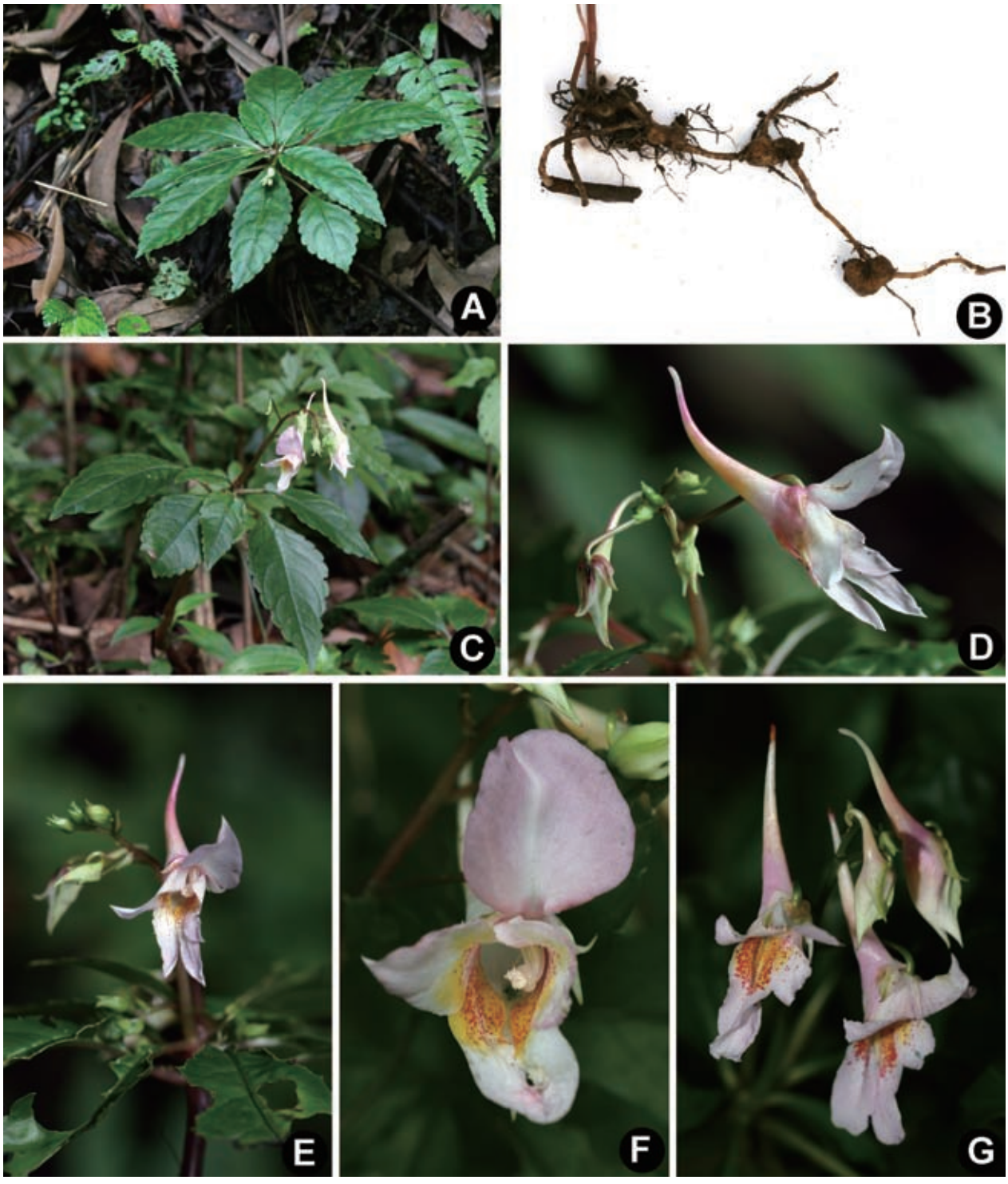

Figure 2. Photos *Impatiens qingchengshanica*. A, young plant; B, roots and rhizomes; C, flowering plant; D, flower, lateral view; E, flower, front view; F, flower details; G, flowers. (Photos by Yong-Ming Yuan)

Figure 3. Map of Sichuan and China, showing the location of Qingcheng Shan where *Impatiens qingchengshanica* was found. (Drawn by Yong-Ming Yuan)

the left and right pairs of the lateral united petals almost equal in size thus the whole flower nearly symmetrical, the lower petals of the lateral united petals dolabriform. The new species is similar to *I. omeiana* Hook. f. and *I. pritzelii* Hook. f. in rhizome, leaf and stem morphology, but the flower shape and bauplan are conspicuously different, particularly the shape of the lower sepal. *Impatiens omeiana* has enlarged tuberous rhizome, yellow or pale yellow flowers with the lower sepal subsaccate to saccate and gradually narrowed into a short incurved spur, the lower petals of the lateral united petals dolabriform. *Impatiens pritzelii* has procumbent tortuous subterranean stem with enlarged nodes, yellow or yellow-white flower with saccate to widely saccate lower sepal which gradually narrowed into a short incurved spur, the lower petals of the lateral united petals oblong or subdolabriform, apex rounded.

Description. Perennial herb, erect, 20-50 cm tall, glabrous. *Rootstock* horizontal, with fleshy nodular, flagellate or moniliform rhizome, which is horizontal with conspicuously enlarged knots (1-3 cm in diameter) and long (3-5 cm) and thin (2-3 mm in diameter) string. *Stem* robust and simple, naked in lower part, fleshy and reddish brown. *Leaves* alternate, 5-10 crowded at terminal part of stem; petiole 1-2 cm long; blade dark green adaxially, pale green abaxially, oblong, elliptic or widely elliptic, 4-10 × 3-6 cm, midvein prominent abaxially, lateral veins 5 or 6 pairs, curved, membranous, base cuneate, attenuate into petiole, margin coarsely crenate-serrate, teeth mucronulate, apex acuminate. *Inflorescence* terminal, racemose, 5-10-flowered; peduncles equal to or shorter than leaves, 6-8 cm. Pedicels 1-2 cm, bracteate at base; bracts caducous, ovate, 4-6 × 3-5 mm, herbaceous, apex acuminate. *Flowers* pendulous, large, 4-5 cm deep, showy, bright pink, yellow with red dots at throat. Lateral sepals 4; outer 2, obliquely ovate, 4-8 × 2-5 mm, apex acute or acuminate, inner 2, longer, linear-lanceolate, falcate-curved, 4-8 × 1.5-3 mm, apex acuminate. Lower sepal funnel-form, ca. 4-4.5 cm deep, abruptly narrowed into a subulate spur which is ca. 2.5-3.0 cm long, straight, and occasionally incurved in young buds; mouth oblique, ca. 1 cm wide. Dorsal petal obovate or round, 1-2 × 1.5-2 cm, apex rounded or mucronulate; abaxial midvein thickened, carinate at upper part to middle,

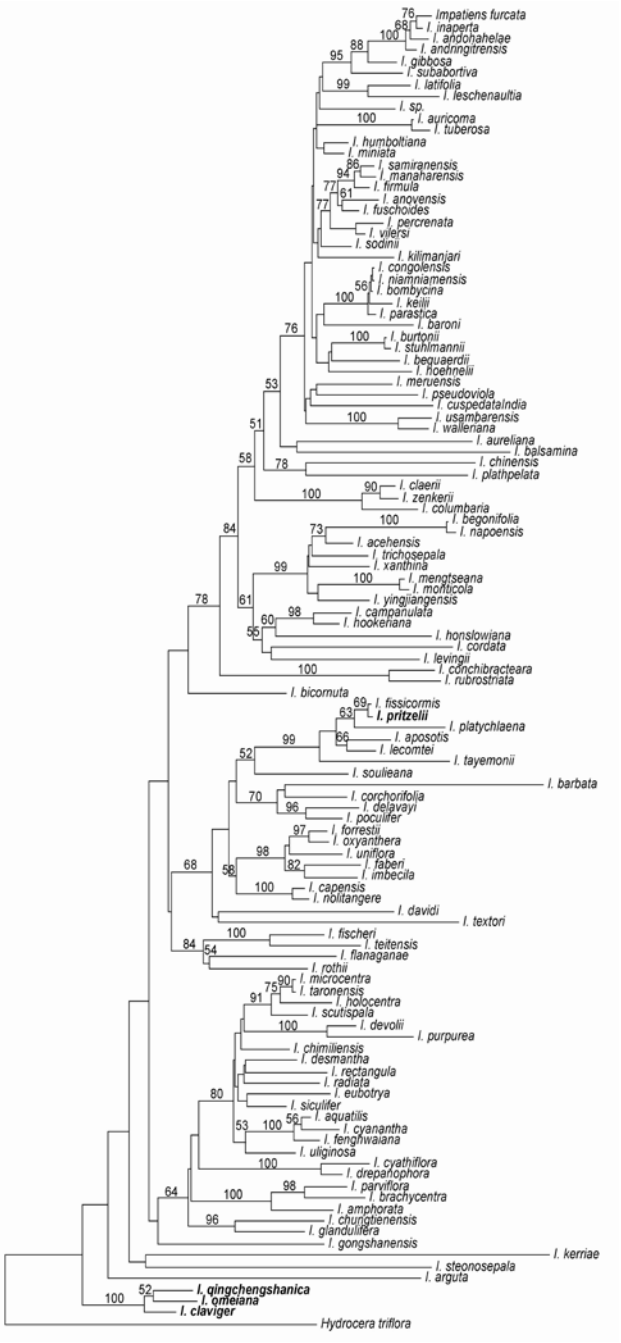

Figure 4. Neighbour-joining phylogenetic tree based on the nucleotide sequences of the internal transcribed spacers of the nuclear ribosome DNA, showing position of *Impatiens qingchengshanica*. Figures above the internal branches are bootstrap clade support percentage values when higher than 50%. *Impatiens qingchengshanica* and its putative close relatives based on morphology are shown in bold.

pink or pale pink; lateral united petals not clawed, left and right pairs unequal in size with the left pair often larger than the right pair, thus the flower being oblique and asymmetrical, pink or light pink, yellow with dense red dots at throat; upper petals of the lateral united petals of each pair unequal in size, orbicular to ovate, 8-12 × 10-16 mm, apex round or obtuse; lower petals of the lateral united petals oblong, oblique, incurved, 20-30 × 5-10 mm, much longer than the upper petals, distally ligulate. Filaments linear, swollen at upper part; anthers ovoid, apex obtuse. Ovary ovoid-oblong, glabrous. *Capsule* narrow-fusiform or clavate, 1-3 cm long, 5-8 mm wide; seeds 3-6, ca. 1 mm long, brownish.

Phenology. Flowering in July to September; fruiting in September to October.

Ecology. Under stories of sparse and dense broad-leafed forests on slopes, forest margins in moist places in valleys; 700-1,400 m.

Distribution. Sichuan, Southwestern China. It is so far known only from the type location and its vicinity, sparsely found in both front and rear hills of Qingchengshan Park.

Horticulture potential. This new species has large and showy flowers and was easy to grow in a garden due to its unique rhizome structure. Thus, it has great potential for horticultural applications.

Phylogenetic Position of the New Species. In her doctoral dissertation, Song (2006) studied the molecular phylogeny of the family Balsaminaceae based on multiple DNA markers and revealed that this new species (represented as an unidentified specimen *Isp*2004-16), together with *I. clavigera* and *I. omeiana*, was nested in the most basal clade of the gene tree of the genus *Impatiens*. In order to further confirm the phylogenetic relationships of the new species, we revisited the phylogeny of the genus *Impatiens*. The DNA sequences of the internal transcribed spacers (ITS) of the nuclear ribosome DNA of the new species *I. qingchengshanica* (DNA obtained from the type specimen, GenBank accession HQ718764), its putative close relatives based on gross morphology, *I. clavigera* (voucher specimen AF23 deposited in NEU, sample collected by A. Favre from Fannipan, Sapa, northern Vietnam at the altitude 1,500 m on 15 September 2003; GenBank accession HQ718766), and *I. omeiana* (voucher specimen Yuan Y.-M. 2004-21 deposited in NEU, collected by Y.-M. Yuan from Emeishan Mountain, Sichuan, China at the altitude 1,200 m on 13 September 2004; GenBank accession HQ718765) were acquired and analyzed together with the previously published data matrix of the ITS sequences (Yuan et al., 2004). *I. pritzelii*, another putative close relative with similar rootstock, was already included in the previous study. The three newly-acquired ITS sequences were aligned with the original ITS matrix containing 112 taxa of Balsaminaceae (Yuan et al., 2004) using Clustal X (Thompson et al., 1997). A molecular phylogenetic tree was reconstructed by PAUP* v4.0b10 (Swofford, 2000) using the neighbor-joining method. *Hydrocera triflora* was used as the outgroup. Bootstrap clade support values were calculated based on 1000 replicates of data applying the same neighbor-joining method. The resulted neighbor-joining tree, as shown in Figure 4, confirmed the previous results. The new species *I. qingchengshanica* was clustered together with *I. clavigera* and *I. omeiana* as a highly supported clade (bootstrap 100%) that was placed as the most basal clade in the ITS molecular tree of the genus *Impatiens*. *Impatiens pritzelii,* a species having rootstocks very similar to our new species, was nested inside the ITS tree and distantly related to our new species (Figure 4). However, the resolution of the relationships among the main clades did not obtain strong bootstrap support for ITS sequences. This could be due to the relative high level of homoplasy in ITS sequences because other published data of chloroplast DNA sequences obtained much higher clade supports for the same relationships (Song, 2006).

Many species of *Impatiens*, especially perennial ones, have well-developed rhizomes (Grey-Wilson, 1980); however, modified rootstock is uncommon in Balsaminaceae. Only a few species are described having tubers or nodular rhizomes, these are: *I. tuberosa* H. Perrier from Madagascar, *I. cinnabarina* Grey-Wilson from Tanzania, *I. omeiana* from Sichuan, China, and *I. pritzelii* from Hubei and Chongqing, China. These species are geographically isolated from each other. In the molecular phylogenetic tree, they are also distantly related, suggesting that their rootstock, adapted for storage, may have undergone multiple independent origins and parallel evolution within the genus. The fleshy and enlarged tuber or nodular knots of *Impatiens* species are probably adaptations to the seasonal dry conditions of their habitats.

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青城山鳳仙花：中國鳳仙花屬一獨特新種及其系統關係

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本文描述了中國四川青城山地區所特產的鳳仙花屬一獨特新種：青城山鳳仙花（*Impatiens qingchengshanica* Y.-M. Yuan, Y. Song & X.-J. Ge）。該新種生長在青城山地區海拔 700-1,400 米的闊葉林下及山谷陰濕處。青城山鳳仙花具有獨特的節結狀根狀莖而與鳳仙花屬其他所有已知種類不同。它在花的形態方面與產于廣西與雲南東南部及越南北部的棒鳳仙花（*I. clavigera* Hook. f.）相似，但它的葉片長圓形、橢圓形或闊橢圓形；花色豔麗、粉紅色；下萼片漏斗狀，急狹成鑽形、通常直伸的距；左右兩側的側生合生花瓣大小和形態不等，因此其花整體偏斜、不對稱；而棒鳳仙花的葉倒卵狀披針形或倒披針形，花亮黃色，下萼片近囊狀、急狹成細管狀且內彎的距，左右兩側的側生合生花瓣大小和形態基本相等，因此其花整體兩側對稱。青城鳳仙花在莖和葉的形態方面與產於四川峨眉山的峨眉鳳仙花（*I. omeiana* Hook. f.）及產於湖北西部和四川東部的湖北鳳仙花（*I. pritzelii* Hook. f.）相似，但在花的整體形態和構造方面明顯不同。峨眉鳳仙花的花黃色或黃白色，下萼片近囊狀或囊狀，漸狹成內彎且很短的距，側生合生花瓣較小、兩側對稱。湖北鳳仙花的花黃色或黃白色，下萼片囊狀或闊囊狀，漸狹成內彎的距，側生合生花瓣兩側對稱，下裂片長圓形，先端鈍圓。該新種在鳳仙花屬系統發育樹上處於基部位置，因此屬於鳳仙花屬中較原始的類型，在研究該屬植物的進化方面有比較重要的意義。分子系統樹表明，作為地下存儲體官，鳳仙花屬中節結狀或塊莖狀的根狀莖可能經歷了多次獨立起源和平行進化，是對季節性乾旱生境的適應。

關鍵詞：青城山鳳仙花；鳳仙花科；新種；進化。