Taxonomic Identity of *Carpinus dayongina* Franchet (Betulaceae)

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Abstract

*Carpinus polyneura* and *C. dayongina* are recognised as separate species in *Flora of China*. In this study, the results of an examination of literature, morphological comparison and phenetic clustering of nuclear ITS sequences suggest that *C. dayongina* is conspecific with *C. polyneura*. Thus, we propose reducing *C. dayongina* to a synonym of *C. polyneura*.

Keywords

Hornbeam, new synonym, taxonomy

Introduction

*Carpinus* (Linnaeus 1753) is a large genus in the family Betulaceae. It contains about 50 species distributed across the Northern Hemisphere (Asia, Europe, North America) (Li and Skvortsov 1999; Holstein and Weigend 2017), 36 of which occur in China (including 30 endemic species) (Li and Skvortsov 1999; Tong et al. 2014; Lu et al. 2017; Lu et al. 2018; Lu 2020). Although some *Carpinus* species have been studied (Hu 1948; Hu 1964; Li 1979; Ill and Chang 1997; Li and Skvortsov 1999), this genus...
is still taxonomically problematic because of the lack of comprehensive field investigations and analyses of morphological characters for some species.

*Carpinus polyneura* Franchet was described, based on collections (Farges, s.n.) (Fig. 1A) from Chengkou County, Sichuan Province (now Chengkou County, Chongqing City) (Franchet 1899). Although there are some morphological variations amongst populations of this species due to its wide distribution, the higher density of leaf veins and setiform serrate leaf margin make it clearly distinguishable from the other species of *Carpinus* (Hu 1964).

In the protologue, *Carpinus polyneura* is described as having lanceolate or ovate-lanceolate with a long-acuminate apex and simply serrate margin and nutlets that are mainly villous at the apex. *Carpinus dayongina* K. W. Liu & Q. Z. Lin was described, based on several collections (Fig. 1B–D) from Tianmenshan, Dayong County, Hunan Province (now Tianmenshan, Zhangjiajie City, Hunan Province) (Liu and Lin 1986). Liu and Lin (1986) stated that *C. dayongina* was similar to *C. polyneura*, but could be distinguished by its narrower leaves, shorter infructescence, smaller bracts and narrower leaves. They cited two collections, i.e. *K. W. Liu 33359* and *Y. T. Xiao 40700*, with the former designated as holotype. The collection, *Y. T. Xiao 40700*, contains a total of six specimens (here considered as duplicates). The specimen with the barcode CSFI017465 (Fig. 1C) bears leaves that are clearly wider in shape (ovate-lanceolate) than those of the other five specimens (narrow-lanceolate) and it was identified as *C. polyneura* previously (by Qi Cheng Jing in June 1984).

Li and Skvortsov (1999) pointed out that *C. polyneura* has leaves with doubly setiform serrate margin and nutlets that are pubescent, while *C. dayongina* has narrower leaf blades with simply setiform serrate margin and nutlets that are only villous at the apex (Table 1).

When revising the species of *Carpinus* in China, we noticed that these two species are very similar to each other. This made us speculate that the two are possibly conspecific, although Li and Skvortsov (1999) followed Liu and Lin (1986) and treated them as separate species in *Flora of China*.

**Materials and methods**

**Morphological analysis**

Specimens of *C. polyneura* and *C. dayongina* deposited in the herbaria CSFI, HHBG, HIB, HNWP, IBK, IBSC, IFP, KUN, LBG, NAS, P, PE, SHM, SZ and WUK were studied and field investigations in Guizhou, Hubei, Hunan and Zhejiang to study *C. polyneura* and *C. dayongina* had been conducted in recent years. The morphological characteristics of the two species were also documented via photography and some of the physical features were measured (Table 2). Abbreviations for the names of herbaria in this study refer to the Herbarium Index Database (http://sweetgum.nybg.org/science/ih/).
Table 1. Differences between *Carpinus polyneura* and *C. dayongina* indicated by Li and Skvortsov (1999).

| Species     | Leaf                                  | Length × width (cm) | Margin of leaf   | Nutlet                  |
|-------------|---------------------------------------|---------------------|-------------------|-------------------------|
| *C. polyneura* | Elliptic-lanceolate or oblong-lanceolate | 4–8 × 1.5–2.5        | Doubly setiform serrate | Pubescent               |
| *C. dayongina* | Lanceolate or ovate-lanceolate         | 2.5–4.5 × 1–1.5      | Simply setiform serrate | Only villous at apex   |

Table 2. Specimens used for measurement of morphological characters of *Carpinus polyneura* and *C. dayongina*.

| Species     | Collector              | Collection number | Collection site  | Herbarium |
|-------------|------------------------|-------------------|------------------|-----------|
| *C. polyneura* | T. L. Dai              | 104469             | Chengkou, Chongqing | PE        |
|             | H. F. Zhou             | 26421              | Fengjie, Chongqing | KUN       |
|             | H. F. Zhou             | 26317              | Fengjie, Chongqing | KUN       |
|             | Z. R. Zhang            | 25054              | Fengjie, Chongqing | KUN       |
|             | Y. Liu                 | 668                | Shennongjia, Hubei | KUN       |
|             | P. C. Cai              | 20297              | Shimen, Hunan     | CSFI      |
|             | C. L. Long             | 87290              | Shimen, Hunan     | CSFI      |
|             | J. R. Zheng            | 80108              | Shimen, Hunan     | CSFI      |
|             | P. C. Cai              | 20442              | Zhangjiajie, Hunan | CSFI      |
|             | P. Y. Li               | 8277               | Langao, Shaanxi   | KUN       |
|             | T. P. Soong            | 39145              | Baoxing, Sichuan  | KUN       |
|             | G. H. Yang             | 57149              | Emeishan, Sichuan | KUN       |
|             | W. P. Fang             | 7546               | Emeishan, Sichuan | PE        |
|             | W. P. Fang et al.      | 31110              | Emeishan, Sichuan | IBK       |
|             | W. P. Fang et al.      | 32888              | Emeishan, Sichuan | IBSC      |
|             | G. H. Yang             | 54569              | Emeishan, Sichuan | IBSC      |
|             | S. G. Wu               | 394                | Sichuan           | KUN       |
|             | G. R. Chen             | 2383               | Tiantai, Zhejiang | KUN       |
|             | Anonymous              | 2759               | Without precise locality | KUN       |
|             | S. Y. Hu               | 1906               | Without precise locality | KUN       |
| *C. dayongina* | Y. T. Xiao             | 40700              | Tianmenshan, Hunan | CSFI      |
|             | K.W. Liu               | 33559              | Tianmenshan, Hunan | CSFI, PE  |
|             | Q. P. Zhang            | 2020072801          | Tianmenshan, Hunan | NF        |
|             | Q. P. Zhang            | 2020072802          | Tianmenshan, Hunan | NF        |

Molecular analysis based on nuclear ribosomal ITS sequences

Twelve individuals from five populations of the two species (Table 3), including nine individuals of *C. polyneura* (P1–P9) and three individuals from the type locality of *C. dayongina* (D1–D3), respectively, were sampled. Fresh leaves were collected from each individual. Coordinates and altitude information were recorded by using a hand-held GPS. All voucher specimens were stored in Nanjing Forestry University (NF).

DNA was extracted using the modified CTAB method (Doyle and Doyle 1990). PCR amplifying and sequencing of the ITS fragment refer to Lu et al. (2016). We made an alignment of 12 newly-sequenced ITS fragments and 10 ITS sequences of *C. polyneura*, *C. mollicoma* (Hu 1949), *C. rupestris* (Camus 1929) and *C. tschonoskii* (Maximowicz 1881b) that were downloaded from NCBI (Table 4). We used Mega X (Kumar et al. 2018) to construct a neighbor-joining (NJ) tree (Saitou and Nei 1987) using pairwise deletion and the P-distance model. Bootstrap values were set to 1000 to calculate the support values.
**Results and discussion**

Re-collections of material from the type localities and further field investigation showed that the leaf shapes are quite variable in the same area, from ovate-lanceolate to lanceolate, then narrow-lanceolate (Fig. 2). After a thorough examination of more specimens, we found that, not only leaf blade shape, but also infructescence length and bract size of *C. dayongina*, are all within the limits of *C. polyneura* (Table 5). After review of the type specimens, we found the leaf margins of *C. polyneura* and *C. dayongina* have both simply and doubly setiform serration (Table 5). In addition, by carefully searching for comprehensive and extensive groups of specimens, performing field investigations and measuring morphological characteristics, we found that the indumentum of their nutlets is also variable, from being villous at the apex and glabrous, sparsely villous or pubescent in the remaining part (Fig. 3, Table 5). Therefore, this character can also not be regarded as a useful character to differentiate these two taxa.

### Table 3.

Geographical information of four populations of *Carpinus polyneura* and one population of *C. dayongina* used for phylogenetic analyses of ITS sequences.

| Species       | Number of individuals | Collection site | Latitude (N) / Longitude (E) | Altitude (m) |
|---------------|-----------------------|-----------------|-----------------------------|--------------|
| *C. polyneura*| 4 (P1–P4)             | Hupingshan, Hunan | 30°0′42.1″N, 110°36′20.5″E   | 350          |
| *C. polyneura*| 3 (P5–P7)             | Dapanshan, Zhejiang | 29°12′33.4″N, 120°43′56.6″E   | 600          |
| *C. polyneura*| 1 (P8)                | Liujiaaping, Hubei | 30°6′27.9″N, 110°43′56.6″E   | 1380         |
| *C. polyneura*| 1 (P9)                | Caoyuan, Guizhou  | 26°18′43.9″N, 106°54′39.6″E   | 1460         |
| *C. dayongina*| 3 (D1–D3)             | Tianmenshan, Hunan | 29°3′5.8″N, 110°28′30.3″E   | 1335         |

### Table 4. ITS sequences used in this study are from NCBI; a dash (−) indicates missing data.

| Species       | Location                  | Voucher                      | ITS from NCBI |
|---------------|---------------------------|------------------------------|---------------|
| *C. polyneura*| Hupingshan, Hunan         | Z.F. Chen 20200601           | MW882972      |
| *C. polyneura*| Hupingshan, Hunan         | Z.F. Chen 20200603           | MW882973      |
| *C. polyneura*| Hupingshan, Hunan         | Z.F. Chen 20200605           | MW882974      |
| *C. polyneura*| Hupingshan, Hunan         | Z.F. Chen 20200607           | MW882975      |
| *C. polyneura*| Dapanshan, Zhejiang       | A.G. He 20200710             | MW882976      |
| *C. polyneura*| Dapanshan, Zhejiang       | A.G. He 20200715             | MW882977      |
| *C. polyneura*| Dapanshan, Zhejiang       | A.G. He 20200717             | MW882978      |
| *C. polyneura*| Liujiaaping, Hubei        | Z.Q. Lu LJP-1                | MW882979      |
| *C. polyneura*| Caoyuan, Guizhou          | Z.Q. Lu CY-1                 | MW882980      |
| *C. polyneura*| Xingshan, Hubei           | Chen et al. 961325           | AF081517      |
| *C. dayongina*| Tianmenshan, Hunan        | Q.P. Zhang 2020072801        | MW893478      |
| *C. dayongina*| Tianmenshan, Hunan        | Q.P. Zhang 2020072802        | MW893479      |
| *C. dayongina*| Tianmenshan, Hunan        | Q. P. Zhang 2020072803       | MW893480      |
| *C. polyneura*| Xingshan, Hubei           | Chen et al. 961325           | AF081517      |
|               | Tiantai Mt., Zhejiang     | –                            | JF796533      |
|               | Qinling Mt.               | SZH 454                      | MH703152      |
|               | Qinling Mt.               | Q875                         | MH711693      |
| *C. mollicoma*| Daba Mt. Shaanxi          | –                            | KX946977      |
| *C. rupestris*| Daba Mt. Shaanxi          | –                            | KX946978      |
| *C. tschonoskii*| Hangzhou Bot. Gard., Zhejiang | W 97-30                    | AY006369      |
|               | –                         | Lee s. n.                    | FJ011733      |
|               | Qinling Mt.               | HZ 283                       | MH710986      |
Phenetic comparison of ITS sequences showed that the samples of *C. dayongina* from Tianmenshan population and those of *C. polyneura* from other regions are mixed with each other (Fig. 4).

We therefore conclude that *C. dayongina* and *C. polyneura* are conspecific. According to ICN (McNeill et al. 2018), the earlier published *C. polyneura* has priority over *C. dayongina* and thus, *C. dayongina* is reduced to a synonym of *C. polyneura* herein.

**Taxonomic treatment**

*Carpinus polyneura* Franch., *J. Bot.* 13: 202. 1899.

≡ *Carpinus turczaninovii* var. *polyneura* (Franch.) H. J. P. Winkl., Das Pflanzenreich IV 61 (Heft 19): 38 (Winkler 1904). – Type: China, Su-tchuen [Sichuan], in District de Tchen kéou tin [Chengkou County], *P. G. Farges s. n.* (lectotype: P06811144!, designated by Holstein and Weigend 2017; isolecotypes: P06811145!, P06811146!) (Fig. 1A).

= *Carpinus dayongina* K. W. Liu & Q. Z. Lin, *Bull. Bot. Res., Harbin* 6(2): 143. 1986. syn. nov. – Type: China, Hunan, Dayong [now Zhangjiajie], Tianmenshan, 1100 m a.s.l., 28 July 1985, *K. W. Liu* [Liu Ke Wang] 33359 (holotype: CSFI050241!; isotype: PE01843387!) (Fig. 1B). – Additional original material: ibid., 25 August 1984, *Y. T. Xiao* [Xiao Yu Tan] 40700 (paratypes: CSFI017465!, CSFI017535!, CSFI017536!, CSFI017538!, CSFI017539!, CSFI017542!) (Figs. 1C and D).

**Description.** A deciduous tree, up to 15 m tall. Bark grey. Branchlets slender, dark purplish, covered with white roundish lenticels, densely villous and soon glabrous. Petiole 5–11 mm, 0.5–0.8 mm in diameter; leaf blade ovate-lanceolate to narrow-lanceolate, sometimes oblong or ovate, 2.5–8 × 1–3 cm, base broadly sub-rounded or slightly cordate, margin doubly setiform serrate, sometimes simply setiform serrate at the apex or simply setiform serrate, upper surface sparsely villous, densely villous along the veins, glabrescent, lower surface densely villous along the veins, sometimes bearded in axils of lateral veins, lateral veins 15–20 on each side of the mid-vein. Infructescence 1.4–6.5 cm long, pendent, peduncle slender, densely villous with white roundish lenticels; bracts semi-ovate-lanceolate, 5–15 × 3–6 mm, outer margin dentate, without basal lobe, inner margin entire with small, inflexed basal auricle. Nutlets broadly ovoid, 2–4 × 1.5–3 mm, villous at apex, glabrous or sparsely villous or pubescent on the remaining part, ribbed.

**Distribution and habitat.** China: Chongqing, Gansu, Shaanxi, Sichuan, Guizhou, Hubei, Hunan, Jiangxi and Zhejiang. This species grows in subtropical broad-leaved forests or thickets at altitudes of 400–1900 m.

**Additional specimens examined.** *Carpinus polyneura*: Chongqing, Chengkou, 5 September 1958, *T. L. Dai 104405* (IBSC, NAS, PE, SZ); Chongqing, Chengkou, 6 September 1956, *T. L. Dai 104469* (IBSC, NAS, PE, SZ); Chongqing, Chengkou, 14 September 1958, *T. L. Dai 104783* (IBSC, NAS, PE, SZ); Chongqing, Chengkou, 20 September 1958, *T. L. Dai 104961* (IBK, NAS, PE); Chongqing, Fengjie, 1 June
Figure 1. Specimens of *Carpinus polyneura* Franchet: A lectotype of *C. polyneura* (P. G. Farges s.n., P06811144) B holotype of *C. dayongina* K. W. Liu & Q. Z. Lin (K. W. Liu 33359, CSFI050241) C paratype of *C. dayongina* (Y. T. Xiao 40700, CSFI017465) D paratype of *C. dayongina* (Y. T. Xiao 40700, CSFI017535).
Figure 2. *Carpinus polyneura* A, B population from Tianmenshan, Zhangjiajie City (type locality of *C. dayongina*) (A photographed by H. Zhou B photographed by W. Q. Qin) C, D population from Wushan, Chongqing City (near the type locality of *C. polyneura*) (C, D photographed by H. L. Zhou).

Figure 3. Nutlet trichomes of *C. polyneura* A from isotype of *C. dayongina* (K. W. Liu 33359, PE01843387) B from paratype of *C. dayongina* (Y. T. Xiao 40700, CSFI017539) C from T. L. Dai 104469, PE00818275 D from W. P. Fang 7546, PE00818253. A, C, D photographed by Q. Q. He B photographed by X. Li.
Figure 4. The neighbor-joining (NJ) tree, based on ITS sequence data. *Carpinus mollicoma*, *C. rupestris* and *C. tschonoskii* as related species; P1–P4 are samples of *C. polyneura* from Hupingshan (HPS), Shimen, Hunan, China; P5–P7 are samples of *C. polyneura* from Dapanshan (DPS), Panan, Zhejiang, China; P8 is a sample of *C. polyneura* from Liujiaping (LJP), Wufeng, Hubei, China; P9 is a sample of *C. polyneura* from Caoyuan (CY), Longli, Guizhou, China; D1–D3 are samples of *C. dayongina* from Tianmenshan (TMS), Zhangjiajie, Hunan, China. The numbers above the branch are bootstrap values (%), and the numbers below the branch are branch length.
Table 5. Measurements of morphological characteristics of *Carpinus polyneura* and *C. dayongina*. A dash (–) indicates missing data.

| Species       | Specimen                  | Leaf length × width (cm) | Leaf size ratio | Leaf margin                             | Infructescence length (cm) | Bract size (cm) | Nutlet indumentum |
|---------------|---------------------------|--------------------------|-----------------|----------------------------------------|----------------------------|-----------------|-------------------|
| *C. polyneura*| T. L. Dai 104469, PE00818275 | 5.5–6.2 × 1.7–1.9        | 3–3.4           | Simply setiform serrate at apex, doubly setiform serrate in the rest | 1.8–3.2                    | 1.2 × 0.45       | Villous at apex |
|               | H. F. Zhou 26317, KUN0590809 | 5.1–5.9 × 1.9–2.3        | 2.5–2.8         | Simply setiform serrate                | 3.2–5.6                    | 1.3 × 0.5        | Villous at apex |
|               | Z. R. Zhang 25054, KUN0590804 | 5.8–6.5 × 2.1–2.5        | 2.3–3.1         | Simply setiform serrate                | 4.4–4.9                    | 1.5 × 0.6        | Villous at apex |
|               | Y. F. Zhou 26421, KUN0590808 | 5.1–5.9 × 1.9–2.3        | 2.5–2.8         | Simply setiform serrate                | 3.2–5.6                    | 1.3 × 0.5        | Villous at apex |
|               | P. C. Cai 20297, CSFI017457 | 5.3–6 × 1.8–2.1          | 2.8–3           | Doubly setiform serrate                | 2.6–3.9                    | 1.2 × 0.4        | Pubescent         |
|               | C. L. Long 87290, CSFI017461 | 5.4–6.1 × 1.6–2.2        | 2.5–3.4         | Doubly setiform serrate                | 3.9–4.3                    | 1.2 × 0.5        | Villous at apex |
|               | J. R. Zheng 80108, CSFI017456 | 6.7–7.1 × 2.3–2.5        | 2.8–3           | Doubly setiform serrate                | –                          | –               | –                 |
|               | P. C. Cai 20442, CSFI017455 | 5.1–5.7 × 1.8–1.9        | 2.7–3           | Simply setiform serrate at apex, doubly setiform serrate in the rest | 2.2–2.7                    | 1.2 × 0.5        | Villous at apex |
|               | Y. Y. Li 8277, KUN0590814   | 5.9–7.3 × 2.2–2.7        | 2.4–3           | Simply setiform serrate                | 4.4–4.8                    | 1.4 × 0.6        | Villous at apex |
|               | T. P. Soong 39145, KUN0590798 | 5.5–6.5 × 2.4–2.7        | 2.2–2.7         | Doubly setiform serrate                | 2–3.6                      | 1.2 × 0.4        | Villous at apex |
|               | G. H. Yang 57149, KUN0590811 | 6–7.4 × 2.1–2.5          | 2.8–3           | Simply setiform serrate, sometimes doubly setiform serrate          | 4.1–5.5                    | 1.4 × 0.5        | Pubescent         |
|               | W. P. Fang 7546, PE00818253 | 5–6.2 × 1.8–2.5          | 2.5–2.8         | Simply setiform serrate                | 2.8                        | 1.2 × 0.5        | Villous at apex |
|               | W. P. Fang et al. 31110, IBK00079496 | 6.7–7.5 × 1.9–2.1 | 3.2–3.7         | Simply setiform serrate                | 3.1                        | 1 × 0.3          | Pubescent         |
|               | W. P. Fang et al. 32888, IBSC0368122 | 5.4–6.6 × 2.5–3         | 2.2–3           | Doubly setiform serrate                | 3.2                        | 1.5 × 0.5        | Villous at apex |
|               | G. H. Yang 54569, IBSC0368131 | 6–7.2 × 2.2–2.5          | 2.4–3           | Doubly setiform serrate                | 3.9                        | 1.4 × 0.5        | Villous at apex |
|               | S. G. Wu 394, KUN0590803    | 4.8–5.6 × 1.5–1.8        | 2.7–3           | Simply setiform serrate                | 2.2–3.5                    | 1.1 × 0.4        | Villous at apex |
|               | G. R. Chen 2383, KUN0590815 | 5.1–5.8 × 1.7–1.9        | 2.8–3           | Simply setiform serrate                | 2.8–4.1                    | 1.1 × 0.4        | Pubescent         |
|               | Anonymous 2759, KUN0590800  | 5.7–6.4 × 1.8–2.1        | 2.9–3.5         | Doubly setiform serrate                | 3.1                        | 1.3 × 0.4        | Pubescent         |
|               | S. Y. Hu 1906, KUN0590797   | 6–6.6 × 2.2–2.2          | 2.7–3           | Simply setiform serrate, sometimes doubly setiform serrate          | 5–6.5                      | 1.5 × 0.6        | Villous at apex |
| *C. dayongina*| Y. T. Xiao 40700, CSFI017539 | 5.1–5.7 × 1.2–1.5        | 3.4–3.8 | Simply setiform serrate                | 3.5–4.2                    | 1.1 × 0.35       | Villous at apex |
|               | Y. T. Xiao 40700, CSFI017465 | 5.7–6.5 × 2.3–2.8        | 2.2–2.7         | Doubly setiform serrate                | 3.6–3.8                    | 1 × 0.4          | Villous at apex |
|               | K.W. Liu 33359, CSFI050241 (holotype of *C. dayongina*) | 4.3–4.7 × 1.4–1.6 | 2.9–3.6 | Simply setiform serrate                | 2.5                        | 0.7 × 0.4        | Pubescent         |
|               | K. W. Liu 33359, PE01843387 (isotype of *C. dayongina*) | 4.4–5 × 1.3–1.7 | 2.8–3.5 | Simply setiform serrate                | 2.1                        | 0.7 × 0.4        | Pubescent         |
|               | Q. P. Zhang 2020072801, NF  | 5–5.6 × 1.6–1.8          | 2.7–3           | Simply setiform serrate                | –                          | –               | –                 |
|               | Q. P. Zhang 2020072802, NF  | 4.5–4.9 × 1.4–1.8        | 2.7–3.7         | Simply setiform serrate, sometimes doubly setiform serrate          | 2                          | 0.9 × 0.3        | Villous at apex |
ian, 31 August 1958, Z. P. Wei 2245 (HHBG, HNWP, SZ, WUK); Guizhou Province, Tunzrte, 27 May 1930, Y. Tsang 51177 (IBSC, NAS, PE); Hubei Province, Badong, 31 October 1958, S. X. Fu 1228 (HIB); Hubei Province, Hefeng, 27 August 1958, H. J. Li 5874 (HIB, IBSC, KUN, PE, SZ); Hubei Province, Shennongjia, 29 August 1976, Hubei Shennongjia Botanical Expedition 32766 (HIB, PE); Hubei Province, Shennongjia, 10 August 1976, Hubei Shennongjia Botanical Expedition 31451 (HIB, PE); Hubei Province, Shennongjia, 19 June 1976, Hubei Shennongjia Botanical Expedition 30417 (HIB, PE); Hubei Province, Shennongjia, 12 August 1976, Hubei Shennongjia Botanical Expedition 11239 (HIB, PE); Hubei Province, Shennongjia, 26 August 1976, Hubei Shennongjia Botanical Expedition 22775 (HIB); Hubei Province, Shennongjia, 3 June 1987, Y. Liu 00668 (HIB, NAS, PE); Hubei Province, Shennongjia, August – September 1959, Z. E. Zhao 113 (HIB); Hubei Province, Xingshan, 3 June 1957, Y. Liu 668 (KUN, NAS, PE); Hunan Province, Anhua, 2 October 1978, Z. H. Shen 1669 (CSFI); Hunan Province, Baojing, 8 August 1991, X. L. Yu 91547 (CSFI); Hunan Province, Chengbu, 14 July 1981, T. R. Cao 032 (CSFI); Hunan Province, Chengbu, August 1981, Q. Z. Lin 11152 (CSFI); Hunan Province, Cili, 1 September 1984, Xiangxi Expedition 0066 (PE); Hunan Province, Longshan, 10 August 1957, B. M. Yang 2041 (IBSC, PE); Hunan Province, Luxi, 12 April 1982, K. W. Liu 30079 (CSFI); Hunan Province, Qianyang Expedition 122207 (IBK); Hunan Province, Sangzhi, 24 August 1988, Beijing Expedition 3922 (PE); Hunan Province, Sangzhi, October 1976, Sangaishi Expedition 960 (CSFI); Hunan Province, Shimen, 30 June 1979, P. C. Cai 20297 (CSFI); Hunan Province, Shimen, 24 May 1987, C. L. Long 87290 (CSFI); Hunan Province, Shimen, 4 May 1980, J. R. Zheng 80108 (CSFI); Hunan Province, Yongshun, 31 May 1988, Beijing Expedition 00571 (PE); Hunan Province, Yongshun, 5 June 1988, Beijing Expedition 01123 (PE); Hunan Province, Yongshun, 22 August 1991, X. L. Yu 91751 (CSFI); Hunan Province, Yongshun, 27 August 1991, X. L. Yu 91854 (CSFI); Hunan Province, Yuanling, 23 June 1988, Zhang et al. 512 (PE); Hunan Province, Yuanling, 23 June 1988, G. C. Zhang et al. 510 (PE); Hunan Province, Yuanling, 15 June 1988, Zhang et al. 380 (PE); Hunan Province, Zhangjiadie, 18 August 1979, P. C. Cai 20442 (CSFI); Jiangxi Province, anonymous 0470 (SHM); Jiangxi Province, Quanzhan, 27 June 1958, anonymous 01184 (PE); Jiangxi Province, Shangrao, 21 June 1982, anonymous 518 (LBG); Jiangxi Province, Xiushui, 4 September 1963, S. K. Lai 03449 (LBG, SHM); Jiangxi Province, Zixi, 11 October 1985, S. K. Lai & D. F. Huang 319 (LBG); Jiangxi Province, Zixi, 7 November 1957, M. J. Wang et al. 2561 (NAS); Shaanxi Province, Langao, 27 July 1959, P. Y. Li 8277 (KUN); Shaanxi Province, Zhenping, 13 May 1989, G. Y. Xu 4899 (WUK); Shaanxi Province, Zhenping, 20 July 1991, J. S. Ying et al. 217 (WUK); Sichuan Province, without date, anonymous 20574 (IBK); Sichuan Province, without date, anonymous 6255 (IBK); Sichuan Province, without date, E. H. Wilson 5191 (IBSC); Sichuan Province, without date, S. Y. Hu 1906 (KUN); Sichuan Province, without date, S. G. Wu 394 (KUN); Sichuan Province, 23 November 1935, W. G. Hu 8842 (IBK); Sichuan Province, 23 November 1935, W. G. Hu 8832 (IBK, SZ); Sichuan Province, Baoxing, 1954, Z. P. Song 39145 (IBSC, KUN, PE, WUK); Sichuan Province, Baoxing, 9 May 1954, Z. P.
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References

Camus A (1929) Espèces asiatiques nouvelles du genre *Carpinus*. Bulletin de la Société botanique de France 76: 966–969. https://doi.org/10.1080/00378941.1929.10836320

Doyle JJ, Doyle JL (1990) Isolation of plant DNA from fresh tissue. Focus 12: 13–15. https://doi.org/10.2307/2419362

Franchet A (1899) Plantarum sinensium ecloge tertia. Le Journal de Botanique 13(7): 198–208.

Holstein N, Weigend M (2017) No taxon left behind? – a critical taxonomic checklist of *Carpinus* and *Ostrya* (Coryloideae, Betulaceae). European Journal of Taxonomy 375: 1–52. https://doi.org/10.5852/ejt.2017.375

Hu HH (1948) The silva of China (Vol. 2). The Fan Memorial Institute of Biology and the National Forestry Research Bureau Ministry of Agriculture and Forestry, Beijing, 83–197.

Hu HH (1949) Four new species of *Carpinus* from Yunnan. Bulletin of the Fan Memorial Institute of Biology n.s. 1(3): 213–218.

Hu HH (1964) The materials on the monography of gen. *Carpinus* Linn. of China. Acta Phytotaxonomica Sinica 9(3): 281–298.

Ill JJ, Chang SC (1997) Reconsideration of *Carpinus* L. (Betulaceae) of Korea primarily based on quantitative characters. Korean Journal of Plant Taxonomy 27(2): 157–187. https://doi.org/10.11110/kjprt.1997.27.2.157

Kumar S, Stecher G, Li M, Knyaz C, Tamura K (2018) MEGA X: Molecular Evolutionary Genetics Analysis across computing platforms. Molecular Biology and Evolution 35(6): 1547–1549. https://doi.org/10.1093/molbev/msy096

Li PC (1979) Betulaceae (Vol. 21). Science Press, Beijing, 58–89. https://doi.org/10.2307/25157899

Li PC, Skvortsov AK (1999) Betulaceae. In: Wu ZY, Raven PH (Eds) Flora of China (Vol. 4). Science Press, Beijing, and Missouri Botanical Garden Press, St. Louis.

Linnaeus C (1753) Species Plantarum. Laurentius Salvius, Stockholm 2: 998. https://www.biodiversitylibrary.org/page/358012

Liu KW, Lin QZ (1986) A new species of *Carpinus* from Hunan. Bulletin of Botanical Research, Harbin 6(2): 143–145.

Lu ZQ (2020) *Carpinus gigabracteatus*, a new species from southeast Yunnan, China. PhytoKeys 145: 47–56. https://doi.org/10.3897/phytokeys.145.49488

Lu ZQ, Zhang D, Liu SY, Yang XY, Liu X, Liu JQ (2016) Species delimitation of Chinese hop-hornbeams based on molecular and morphological evidence. Ecology and Evolution 6(14): 4731–4740. https://doi.org/10.1002/ece3.2251

Lu ZQ, Liu SY, Yang XY, Liang QL, Yang YZ, Zhang D, Milne R, Liu JQ (2017) *Carpinus langaoensis* (Betulaceae), a new hornbeam species from the Daba Mountains in Shaanxi, China. Phytotaxa 295(2): 185–193. https://doi.org/10.11646/phytotaxa.295.2.6

Lu ZQ, Li Y, Yang XY, Liu JQ (2018) *Carpinus tibetana* (Betulaceae), a new species from south-east Tibet, China. PhytoKeys 98: 1–13. https://doi.org/10.3897/phytokeys.98.23639

Maximowicz CJ (1881b) Diagnoses plantarum novarum asiaticarum IV. Bulletin de l’Academie impériale des sciences de St.-Pétersbourg 27: 425–460.
McNeill J, Barrie FR, Buck WR, Demoulin V, Greuter W, Hawksworth DL, Herendeen PS, Knapp S, Marhold K, Prado J, Prud’Homme Van Reine WF, Smith GF, Wiersema JH, Turland NJ (2018) International Code of Nomenclature for algae, fungi, and plants (Shenzhen Code).

Saitou N, Nei M (1987) The Neighbor-joining method: A new method for reconstructing phylogenetic trees. Molecular Biology and Evolution 4(4): 406–425. https://doi.org/10.1093/oxfordjournals.molbev.a040454

Tong YH, Pang KS, Xia NH (2014) *Carpinus insularis* (Betulaceae) A new species from Hong Kong, China. Journal of Tropical and Subtropical Botany 22(2): 121–124.

Winkler HJP (1904) Betulaceae. In: Engler HGA (Ed.) Das Pflanzenreich IV 61 (Heft 19). Wilhelm Engelmann, Berlin.