Kalanchoe (Crassulaceae) as invasive aliens in China – new records, and actual and potential distribution

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[Abstract]

Kalanchoe daigremontiana and *K. delagoensis* are reported for the first time from Sichuan and Hainan (China), respectively. For the first, a new population located in Chengdu downtown has been found, being the first one in western China and thus representing a significant range extension of this species within the country. For *K. delagoensis*, a new population has been observed in the Old Quarter of Haikou, being the southernmost population of this species in China. The distribution area of both species in China is updated through review of the literature, as well as that of their putative hybrid, *K.* × *houghtonii*. For the case of *K. delagoensis*, its potential range has also been estimated through a niche-based modelling approach. Finally, a key to taxa of *Kalanchoe* in China is provided.

Introduction

The genus *Kalanchoe* (including *Bryophyllum*) has nearly 150 species distributed in Madagascar (its center of diversity), E and S Africa, Arabia, and tropical and SE Asia (Descoigns 2003). A few species, however, have spread beyond their native areas given their use as ornamentals, and today are global invaders. The best known examples are, in addition to *K. pinnata* (the 'air plant'), *K. daigremontiana* and *K. delagoensis*. These two latter are regarded as serious pests in several countries such as Australia, South Africa, and the United States (Moran 2009, Walters et al. 2011, Palmer and Rafter 2012). The invasion capabilities of both *K. daigremontiana* and *K. delagoensis* are enhanced by a vigorous clonal growth through pseudobulbils that arise from the margin of their leaves (hence the popular name 'mother of millions' or 'mother of thousands'); this strategy is also shared by their hybrid form, *K.* × *houghtonii* (Guerra-García et al. 2015). This hybrid taxon was firstly noted by A. D. Houghton in the 1930s, and arises spontaneously when these two species occur together (Akulova-Barlow 2009). In southern Europe, this hybrid is even more invasive than its parental species, and in some cities such as Barcelona it has already become a common component of the urban landscape (Guillot et al. 2014).

According to *Flora of China*, only six taxa belonging to the genus *Kalanchoe* are present in China (including Taiwan): *K. ceratophylla*, *K. garambiensis*, *K. integra*, *K. pinnata*, *K. spathulata* var. *annamica*, and *K. tashiroi* (Fu and Ohba 2001). In addition, only *K. pinnata* was generally included in the lists or compendiums on naturalized and invasive plants in China published during the last decade (e.g. Wu et al. 2004, 2010a, Lin et al. 2007, Weber et al. 2008, Xu et al. 2012). However, *K. delagoensis* was already included in the list of invasive plants for the whole China of Fang and Wan (2009), in the list of naturalized plants for Taiwan (Wu et al. 2010a), and in the list of naturalized plants of China of Jiang et al. (2011). In addition, *K. daigremontiana* is also listed, together with *K. delagoensis*, in the most recent list of invasive alien plants in China (Yan et al. 2014).

In the course of a field investigation in tropical and subtropical areas of China, we observed one population of *K. daigremontiana* in the city of Chengdu (Sichuan Province, SW China) and one population of *K. delagoensis* in the city of Haikou (Hainan Island, S China). The objectives of this work were to (i) evaluate the

significance of these findings within the context of the Chinese alien flora, (ii) estimate the current distribution area of *K. daigremontiana*, *K. delagoensis*, and its hybrid form *K.* × *houghtonii*, and know if the new findings constitute substantial range extensions in China, (iii) estimate the potential range of *K. delagoensis* through a niche-based modeling approach, and (iv) provide a key to taxa of *Kalanchoe* in China given that the three species studied here (*K. daigremontiana*, *K. delagoensis* and *K.* × *houghtonii*) seem to be well established and, thus, they should be regarded as members of the flora of China.

Material and Methods

The new localities were photographed (using a digital camera Finepix HS50 EXR; Fujifilm, Tokyo, Japan) and georeferenced. Dried herbarium specimens were deposited at the reference regional herbaria (SZ for the population of *K. daigremontiana* from Chengdu; HUTB for the population of *K. delagoensis* from Haikou). Co-occurring species (if present) were also recorded.

To estimate the range of the three species of *Kalanchoe* (*K. daigremontiana*, *K. delagoensis*, *K.* × *houghtonii*) in China and, thus, to evaluate the significance of the newly discovered populations, an extensive literature search was conducted and included all major regional taxonomic works (*Flora of China*, *Flora Reipublicae Popularis Sinicae*, *Flora of Taiwan*, *Flora of Hong Kong*), checklists (both at national and regional levels), lists and catalogues of naturalized and invasive plants, research articles, and grey literature. Major databases and information systems were also checked, including citizen science projects: *Global Biodiversity Information Facility* (GBIF; www.gbif.org/), *Chinese Virtual Herbarium* (CVH; www.cvh.ac.cn), *Taiwan Biodiversity Information Facility* (TaiBIF; www.taibif.tw), *iNaturalist* (www.inaturalist.org), *Chinese Field Herbarium* (CFH; www.cfh.ac.cn), and *Plant Photo Bank of China* (PPBC; www.plantphoto.cn).

The potential range was only determined for *K. delagoensis* because for the other two taxa the number of georeferenced wild occurrences in China were not enough to get reliable models centered in the country (<5; see Pearson et al. 2007). To do it, we employed the maximum entropy algorithm, as implemented in MaxEnt v. 3.3 (Phillips

et al. 2006). In total, we obtained 39 presence records (wild occurrences) for *K. delagoensis* (Supplementary material Appendix 1, Table A1). A set of 19 bioclimatic variables at 30 arc-sec (~1 km) resolution covering the distribution range (and neighboring areas) under current conditions (1950–2000) were downloaded from the WorldClim website (www.worldclim.org; Hijmans et al. 2005). Given that the establishment and spread of *K. delagoensis* is often facilitated by human disturbance (Queensland Government 2007, Walters et al. 2011, Guerra-García et al. 2015), an additional variable, the Human Footprint (an index of anthropogenic impacts on the environment; Sanderson et al. 2002) was added to the set of studied variables (and downloaded from the Center for International Earth Science Information Network at Columbia University; http://sedac.ciesin.columbia.edu). After a correlation analysis in a random sample of 1000 points within the study area, we selected a smaller set of eight not highly correlated variables ($r < 0.8$): annual mean temperature (bio1), mean diurnal temperature range (bio2), isothermality (bio3), temperature annual range (bio7), annual precipitation (bio12), precipitation of driest month (bio14), precipitation seasonality (bio15), and human footprint. The selection of variables from pairs or groups of highly correlated ($r \geq 0.8$) ones was done on the basis of their relative contribution to the model (percent contribution, jackknife tests of variable importance).

Replicate runs (50) of MaxEnt (using the 'subsampling' method) were performed to ensure reliable results. Model performance was assessed using the area under the curve (AUC) of the receiver operating characteristic plot, with 20% of the localities randomly selected to test the model. AUC scores may range between 0.5 (randomness) and 1 (exact match), with those above 0.9 indicating a good performance of the model (Swets 1988). Ecological niche modelling (ENM) prediction was visualized in ArcGIS v. 9.3 (ESRI, Redlands, CA, USA), with the aid of Hawth's Analysis Tools (Beyer 2004).

Results and Discussion

***Kalanchoe daigremontiana* Raym.-Hamet & H. Perrier (1914, p. 128)**

Based on the same type: *Bryophyllum daigremontianum* A. Berger (1930, p. 412).

Voucher specimens: China. Sichuan: Chengdu, Wuhou District, on a building façade, growing together with *Crassula ovata*, several individuals (some flowering), 495 m a.s.l., 30.64ºN, 104.08ºE, 4 June 2015, Z.-Q. Wang and J. López-Pujol (SZ 00356561, SZ 00356562) (Supplementary material Appendix 1, Fig. A1).

This species is a biennial diploid ($2n$ = 34; Baldwin 1949) herb, that is easily distinguishable from the other taxa of the genus that are present in China by having simple leaves that are ovate, oblong-ovate to long-triangular, with dentate margins, and strongly auriculate to strongly cordate leaf base (rarely sub-peltate; see the identification key, below, and Supplementary material Appendix 1, Fig. A1). *Kalanchoe daigremontiana* is native to SW Magadascar (Descoigns 2003), although at present it is widely naturalized in several tropical, subtropical or dry-climate countries (Invasive Species Compendium 2015a). In some areas is regarded as invasive, such as in Australia (Weeds Australia 2015) and in SE United States (Moran 2009). In recent years it has been detected in some locations of southern Europe, including Italy (Celesti-Grapow et al. 2009), Portugal (Almeida and Freitas 2006), and Spain (Sanz et al. 2004, 2011, Guillot et al. 2015b).

According to our literature search, the species is present as wild in at least two provinces of China (Fig. 1). As shown in the Supplementary material Appendix 1 (Table A1), the species has been reported from two nearby locations in Fujian Province (SE China) and from Bawangling Nature Reserve in Hainan Island. There are also doubtful old herbarium records from another location in Fujian (Gulangyu Island) as well as from Guizhou and Yunnan. However, we cannot attribute them to *K. daigremontiana* with certainty, as the specimens are incomplete or badly preserved (Supplementary material Appendix 1, Table A1). The species has also been included in the *Check List of Hong Kong Plants* (Hong Kong Herbarium 2004), although we have failed to find herbarium specimens or other references providing precise locations within this special administrative region of China. The population of *K. daigremontiana* detected by us should be regarded as the first one in western China (or, at least, the first of Sichuan) and, thus, represents a significant range extension of this species within the country (Fig. 1). It is a small population located in the downtown of the city of Chengdu (on a small roof at a building façade), and it seems to be well-established [it contains several mature (flowering) individuals along with many juvenile (vegetative) ones and

seedlings; Supplementary material Appendix 1, Fig. A1]. Although *K. daigremontiana* is probably the least invasive of the three taxa of *Kalanchoe* studied here, it may become naturalized in many areas of the country as it is widely cultivated (Fig. 1 and Supplementary material Appendix 1, Table A1).

***Kalanchoe delagoensis* Eckl. & Zeyh. (1837, p. 305)**

Based on the same type: *Bryophyllum delagoense* (Eckl. & Zeyh.) Schinz (1900, p. 38).

Taxonomic synonyms: *Bryophyllum tubiflorum* Harv. (1862, p. 380) – *Kalanchoe verticillata* Scott Elliot (1891, p. 14) – *Kalanchoe tubiflora* (Harvey) Raym.-Hamet (1912, p. 41) – *Bryophyllum verticillatum* A. Berger (1930, p. 411).

Voucher specimens: China. Hainan: Haikou, Old Quarter, at the façade of some old houses, 10 m a.s.l., 20.04ºN, 110.34ºE 7 August 2015, J. López-Pujol and M.-X. Ren K1 (HUTB) (Supplementary material Appendix 1, Fig. A2).

This species is a biennial or a short perennial tetraploid ($2n = 68$; Baldwin 1949), that can be distinguished by its narrowly linear leaves from the other taxa of the genus (Supplementary material Appendix 1, Fig. A2). Another characteristic trait is that bulbils can be found only in the apex (see the identification key, below). As for *K. daigremontiana*, *K. delagoensis* is native to Madagascar (to the central and southern parts of the island). It is the most widely distributed among the three species of *Kalanchoe* studied here, as it occurs throughout the Americas (including the Caribbean islands), southern Europe, most of Africa, several locations in Asia (China, India), and Oceania (Micronesia, Melanesia, Polynesia, Australia, and New Zealand) (Guillot et al., 2015a, Invasive Species Compendium, 2015b). *Kalanchoe delagoensis* is behaving as invasive in some regions, including Australia (Queensland Government 2007, Palmer and Rafter 2012), China (Yan et al. 2014), South Africa (Walters et al. 2011), and SE United States (Moran 2009).

In contrast to *K. daigremontiana*, *K. delagoensis* is a relatively common plant in China. Our search for occurrences in the literature has indicated that this succulent plant

is present as wild in at least four provinces of the mainland: Anhui, Fujian, Guangdong, and Guangxi (Fig. 1 and Supplementary material Appendix 1, Table A1). In addition, it is present in many locations throughout Taiwan Island (where it arrived in the 1960s; Wu et al. 2010b), as well as in Hong Kong (as for *K. daigremontiana*, the species has also been included in the *Check List of Hong Kong Plants*; Hong Kong Herbarium 2004). To our knowledge, the population discovered by us in Haikou City is the first one for Hainan Island and, thus, the southernmost population of *K. delagoensis* in China (Fig. 1). The population is composed by dozens of vegetative individuals located at the façade (in wall cracks or on cornices) of several old two-storey buildings located on the Old Quarter of Haikou City (Supplementary material Appendix 1, Fig. A2), sometimes accompanied by *Talinum paniculatum* (Jacq.) Gaertn. Like in Haikou, most of the pictures hosted in the checked databases (such as PPBC or CFH) are showing *K. delagoensis* naturally growing on roofs and other parts of the buildings (in some cases forming dense monospecific carpets). It seems that it was already a common element of the roofs of Guangzhou City (Canton) more than one decade ago (Jian et al. 2004). The fact that most of the observations of the species are within urban environments indicates that the species in China is still in the first stages of invasion, as probably occurs with the other two taxa of *Kalanchoe* (see above and below).

Regarding the ENM model, the AUC score averaged across 50 runs was very high (mean ± SD, 0.990 ± 0.006), which supported the predictive power of the model. According to the jackknife tests, mean diurnal temperature range (bio2), temperature annual range (bio7), and annual mean temperature (bio1) were the most informative for predicting the niche of the species in China. The ENM model (Fig. 1) shows that the potential distribution of *K. delagoensis* in China is limited to the coastal southern region (from southern Jiangsu to Guangxi), including the two large islands of China (Hainan and Taiwan) and also a region in Sichuan/Chongqing. Some small areas throughout subtropical and tropical China are also suitable. It should be noted that *K. delagoensis* is cultivated in some areas where it does not occur in the wild but that contain suitable habitat (e.g. Nanning in southern Guangxi; Supplementary material Appendix 1, Table A1), paving thus the way for new invasions. To some extent, we believe that the ENM model of *K. delagoensis* can be extrapolated to the other two conspecific taxa studied here, as they are usually found in the same habitats (pavement cracks, building roofs, waste places, fence lines, vacant lots, disturbed grasslands/woodlands) and, in fact, they often co-occur (e.g. Ward 2006, Guerra-García et al. 2015). Moreover, for the Iberian

Peninsula, the ENMs of the three *Kalanchoe* taxa were almost identical (Guillot et al. 2014, 2015a, b).

***Kalanchoe* × *houghtonii* D. B. Ward (2006, p. 94)**

Based on the same type: *Bryophyllum houghtonii* (D. B. Ward) P. I. Forst. (2006, p. 383).

This species is a monocarpic short perennial herb, morphologically relatively similar to *K. daigremontiana* but distinguishable by the leaf base (usually neither auriculate nor cordate in *K.* × *houghtonii*). However, as leaves of *K.* × *houghtonii* may rarely present small auricules or can be weakly cordate (see the identification key, below), confusions with *K. daigremontiana* are relatively common. In fact, until the species was not formally described in 2006 (Ward 2006), many of its occurrences were assigned erroneously to *K. daigremontiana* (e.g. Moran 2009). This hybrid taxa was firstly described by A. D. Houghton in the 1930s (obtained by experimental crosses in his nursery in California); although it was named by him as *Kalanchoe tubimontanum* (Houghton 1935), it was not validly published. According to Shaw (2008), there were originally two clones in cultivation, a fertile tetraploid and a sterile triploid, but it seems that the original plants were triploid ($2n = 51$; Baldwin 1949). *Kalanchoe* × *houghtonii* was observed in the wild in Australia as soon as 1965 (AVH 2015), and the plant has been reported throughout America (including the Caribbean islands), southern Europe, Asia (India), and Oceania (apart from Australia, in some Polynesian islands and in New Zealand) (Guillot et al. 2014). In some of these areas it has become a strong invader, such as in Queensland, Australia (Queensland Government 2007) and Venezuela (erroneously identified as *K. daigremontiana*; Herrera et al. 2012).

Until now, there were no records of *K.* × *houghtonii* in China contained in floras or in articles in scientific journals. Our extensive research including grey literature, internet databases, and citizen science sites has evidenced that the hybrid is present in, at least, three different regions (Fig. 1); in the mainland, there is one PPBC record from Jinjiang City (Quanzhou, Fujian Province); interestingly, in this same location the PPBC also hosts pictures of *K. daigremontiana* (Supplementary material Appendix 1,

Table A1), supporting our hypothesis that the ENM of *K. delagoensis* may be partly extrapolated to the other two *Kalanchoe* taxa. *Kalanchoe* × *houghtonii* is also present in Taiwan Island, in an urban park of Taichung City; finally, the species has also been observed at least in two different locations in Hong Kong SAR (Fig. 1). In addition, the two doubtful occurrences of *K. daigremontiana* from Guizhou and Yunnan might be actually *K.* × *houghtonii* (see Supplementary material Appendix 1, Table A1), although the antiquity of the records (1960 and 1936, respectively) makes this possibility unlikely (as this hybrid was firstly noted in the 1930s in the United States). Since *K.* × *houghtonii* is cultivated in several areas of southern and eastern China (Fig. 1 and Supplementary material Appendix 1, Table A1), the list of occurrences may increase in the coming years.

Key to species of *Kalanchoe* in China

1. Leaves first simple, later pinnate to 3- to 5-foliate or at middle of stem pinnately lobed.....2

– Leaves not pinnate……..…….....…….……3

2. Leaflets linear to linear-lanceolate, corolla yellow, styles 2–4 mm…….....….*K. ceratophylla*

– Leaflets ovate to oblong or oblong-circular; corolla green below, red to greenish-reddish above; styles 22–30 mm…….....…….……..*K. pinnata*

3. Leaves narrowly linear, terete; bulbils only at the apex…….....……*K. delagoensis*

– Leaves ovate, oblong, triangular, deltoid, spatulate or linear-oblong, elliptic or obovate; bulbils absent or bulbils appearing along the margins…….....……4

4. Leaves linear-oblong; flowers yellow with linear spots.....…

…….....……..……..…….....….*K. spathulata* var. *annamica* (*K. annamica*)

– Leaves ovate, oblong, long-triangular, deltoid, elliptic, obovate or spatulate ….……....…. 5

5. Margins dentate with numerous bulbils on the teeth …….....…….……6

– Margins entire or crenate …….....……7

6. Leaf base strongly auriculate, to strongly cordate, rarely sub-peltate…….....*K. daigremontiana*

– Leaf base without auricles, or if present, very small, not or weakly cordate, not peltate, lamina gradually narrowing into petiole…….....…….……*K.* × *houghtonii*

7. Lamina 1–2.8 × 0.3–1.3 cm, tip rounded, mucronate, margins entire…..... *K. garambiensis*

– Lamina more than 2.8 cm long × 1.3 cm wide…….....……8

8. Leaves green above, pale below, tip broadly triangular, margins irregularly crenate ….....
……..……*K. tashiroi*
– Leaves light grey-green, tip obtuse, margins entire or crenate….....….*K. integra* (*K. deficiens*)

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Supplementary material (Appendix NJBXXXXX at <www.nordicjbotany.org/readers/appendix>). Appendix 1.

Figure 1. Top (A) and bottom (C) maps, location of wild (filled circles) and cultivated (plus symbol) localities found in China of *Kalanchoe daigremontiana* and *K.* × *houghtonii*, respectively. Empty circles represent the doubtful occurrences (see Supplementary material Appendix 1, Table A1). Middle map (B), location of wild (filled circles) and cultivated (plus symbol) localities of *K. delagoensis*, and potential distribution in China as probability of occurrence. Predicted distribution probabilities are shown in each 30 arc-sec pixel. We used the maximum training sensitivity plus specificity logistic threshold (mean value = 0.0324) to discriminate between suitable and unsuitable habitat.

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Supplementary material Appendix 1

Figure A1. Detail of the population of *Kalanchoe daigremontiana* from downtown Chengdu (Sichuan Province). The inset is a close view of the leaves. Pictures: J. López-Pujol.

Figure A2. Some individuals of *Kalanchoe delagoensis* growing in a building cornice, in Haikou City (Hainan Island). The inset is showing the details of the leaves (from an individual transplanted from the population that is now cultivated in Hainan University). Pictures: J. López-Pujol (general) and M.-X. Ren (inset).

Table A1. List of wild and cultivated localities found in China of *Kalanchoe daigremontiana*, *K. delagoensis*, and *K.* × *houghtonii*.

Species	Locality	Geographic coordinates	Wild/Cultivated	Source	Additional information
K. daigremontiana	Hefei (Anhui)	31.79ºN, 117.25ºE	C	PPBC	http://www.plantphoto.cn/tu/1535078
K. daigremontiana	Beijing Botanical Garden (Chinese Academy of Sciences), Beijing (Beijing Municipality)	39.99ºN, 116.21ºE	C	J. López-Pujol, pers. obs.	Observed in 2003 and in 2015
K. daigremontiana	Fujian Normal University, Fuzhou (Fujian)	26.04ºN, 119.31ºE	C	CFH	http://www.cfh.ac.cn/album/ShowPhoto.aspx?photoid=6efbb37d-e2b8-4ff3-a91f-63386a291679
K. daigremontiana	Chongwuzhen, Quanzhou (Fujian)	24.89ºN, 118.92ºE	W	PPBC	http://www.plantphoto.cn/tu/39953
K. daigremontiana	Jinjiang, Quanzhou (Fujian)	24.57ºN, 118.60ºE	W	PPBC	http://www.plantphoto.cn/tu/1058563
K. daigremontiana?[1]	Gulangyu Island, Xiamen (Fujian)	24.45ºN, 118.06ºE	W	CVH	AU 008740 [Herbarium specimen]; labeled as "*K. gremontianum*"; http://www.cvh.ac.cn/spm/AU/008740
K. daigremontiana	Huli District, Xiamen (Fujian)	24.50ºN, 118.14ºE	C	CVH	PE 01268604 [Herbarium specimen]; http://www.cvh.ac.cn/spm/PE/01268604
K. daigremontiana?[2]	Xiamen Park, Xiamen (Fujian)	24.27ºN, 118.06ºE	C	CVH	AU 008739 [Herbarium specimen]; labeled as "*K. gremontianum*"; http://www.cvh.ac.cn/spm/AU/008739
K. daigremontiana	Lanzhou (Gansu)	36.05ºN, 103.83ºE	C	PPBC	http://www.plantphoto.cn/tu/389790
K. daigremontiana	Lutianzhen, Conghua (Guangdong)	23.81ºN, 113.95ºE	C	PPBC	http://www.plantphoto.cn/tu/296524; http://www.plantphoto.cn/tu/410442
K. daigremontiana?[3]	Former Chengguan People's Commune, Luodian (Guizhou)	25.43ºN, 106.75ºE	W	CVH	IBSC 0143086 [Herbarium specimen]; labeled as *Bryophyllum* sp.; http://www.cvh.ac.cn/spm/IBSC/0143086
K. daigremontiana	Bawangling National Nature Reserve (Hainan)	18.95–19.18ºN, 109.05–109.28ºE	W	Hu et al. (2011)	Journal article
K. daigremontiana	Kaifeng (Henan)	34.82ºN, 114.32ºE	C	PPBC	http://www.plantphoto.cn/tu/388895

K. daigremontiana	Hong Kong SAR	22.15–22.56ºN, 113.84–114.44ºE	W	Hong Kong Herbarium (2004)	Book
K. daigremontiana	Huazhong Agricultural University, Wuhan (Hubei)	30.48ºN, 114.35ºE	C	PPBC	http://www.plantphoto.cn/tu/1823077
K. daigremontiana	Wuhan Botanical Garden, Wuhan (Hubei)	30.54ºN, 114.41ºE	C	PPBC	http://www.plantphoto.cn/tu/1754784
K. daigremontiana	Wuxi (Jiangsu)	31.49ºN, 120.31ºE	C	PPBC	http://www.plantphoto.cn/tu/471450
K. daigremontiana	Ganjingzi District, Dalian (Liaoning)	38.93ºN, 121.55ºE	C	PPBC	http://www.plantphoto.cn/tu/1085848
K. daigremontiana	Chengwu, Heze (Shandong)	34.95ºN, 115.89ºE	C	PPBC	http://www.plantphoto.cn/tu/1871865
K. daigremontiana	Licheng District, Jinan (Shandong)	36.71ºN, 117.09ºE	C	PPBC	http://www.plantphoto.cn/tu/1886293
K. daigremontiana	Zoucheng, Jining (Shandong)	35.41ºN, 116.96ºE	C	PPBC	http://www.plantphoto.cn/tu/1895968
K. daigremontiana	Shinan District, Qingdao (Shandong)	36.07ºN, 120.39ºE	C	PPBC	http://www.plantphoto.cn/tu/1502177
K. daigremontiana	Zhaozhuang University, Shizhong (Shandong)	34.90ºN, 117.53ºE	C	PPBC	http://www.plantphoto.cn/tu/254467
K. daigremontiana	Jinjiang District, Chengdu (Sichuan)	30.58ºN, 104.14ºE	C	PPBC	http://www.plantphoto.cn/tu/1785334
K. daigremontiana	**Wuhou District, Chengdu (Sichuan)**	**30.64ºN, 104.08ºE**	**W**	**This work**	**SZ-00356561, SZ-00356562 [Herbarium specimen]**
K. daigremontiana	Tianjin (Tianjin Municipality)	39.08ºN, 117.20ºE	C	PPBC	http://www.plantphoto.cn/tu/1943466
K. daigremontiana	Xiqing District, Tianjin (Tianjin Municipality)	39.14ºN, 117.01ºE	C	PPBC	http://www.plantphoto.cn/tu/1831702
K. daigremontiana?[4]	The Original Forest Park, Jinhong (Yunnan)	22.03ºN, 100.88ºE	W	CVH	NAS 00331669 [Herbarium specimen]; labeled as *Bryophyllum pinnatum*; http://www.cvh.ac.cn/spm/NAS/NAS00331669

K. daigremontiana	Kunming Botanical Garden, Kunming (Yunnan)	25.14ºN, 102.74ºE	C	PPBC	http://www.plantphoto.cn/tu/2039405
K. daigremontiana	Garden of Forestry Bureau, Urumqi (Xinjiang)?[5]	43.80ºN, 87.60ºE	C	CVH	XJBI 00015178 [Herbarium specimen]; http://www.cvh.ac.cn/spm/XJBI/00015178
K. daigremontiana	Xihu District, Hangzhou (Zhejiang)	30.23ºN, 120.14ºE	C	PPBC	http://www.plantphoto.cn/tu/1338852
K. daigremontiana	Qingyuan, Lishui (Zhejiang)	27.62ºN, 119.06ºE	C	PPBC	http://www.plantphoto.cn/tu/1343882
K. daigremontiana	Linhai, Taizhou (Zhejiang)	28.86ºN, 121.15ºE	C	PPBC	http://www.plantphoto.cn/tu/1377683
K. × *houghtonii*	Jinjiang, Quanzhou (Fujian)	24.57ºN, 118.60ºE	W	PPBC	http://www.plantphoto.cn/tu/1089955
K. × *houghtonii*	Hanyingcun, Zhangzhou (Fujian)	23.66ºN, 117.20ºE	C	CFH	http://www.cfh.ac.cn/album/ShowPhoto.aspx?photoid=bb15159c-0aa6-48cb-8f05-9c138ad42b3f
K. × *houghtonii*	Huazhou, Maoming (Guangdong)	21.73ºN, 110.72ºE	C	PPBC	http://www.plantphoto.cn/tu/970321
K. × *houghtonii*	Kadoorie Farm and Botanical Garden, New Territories (Hong Kong SAR)	22.43ºN, 114.12ºE	C	PPBC	http://www.plantphoto.cn/tu/1535926
K. × *houghtonii*	Sai Kung Country Park, New Territories (Hong Kong SAR)	22.40ºN, 114.35ºE	W	PPBC	http://www.plantphoto.cn/tu/2031813
K. × *houghtonii*	Yuen Long District, New Territories (Hong Kong SAR)	22.42ºN, 114.08ºE	W	iNaturalist	https://www.inaturalist.org/observations/907947
K. × *houghtonii*	Nanjing Botanical Garden, Nanjing (Jiangsu)	32.05ºN, 118.83ºE	C	PPBC	http://www.plantphoto.cn/tu/1825236
K. × *houghtonii*	Mudan, Heze (Shandong)	35.23ºN, 115.50ºE	C	PPBC	http://www.plantphoto.cn/tu/1869094

K. × *houghtonii*	Yuchi, Nantou (Taiwan)	23.85ºN, 120.93ºE	C	PPBC	http://www.plantphoto.cn/tu/1206796
K. × *houghtonii*	Aofengshan Park, Taichung (Taiwan)	24.27ºN, 120.59ºE	W	----	http://nc.kl.edu.tw/bbs/showthread.php?t=45086
K. × *houghtonii*	Binhai District, Tianjin (Tianjin Municipality)	39.03ºN, 117.69ºE	C	PPBC	http://www.plantphoto.cn/tu/1777115
K. × *houghtonii*	Kunming Botanical Garden, Kunming (Yunnan)	25.14ºN, 102.74ºE	C	PPBC	http://www.plantphoto.cn/tu/2039295, http://www.plantphoto.cn/tu/1023964
K. × *houghtonii*	Xishuangbanna Tropical Botanical Garden, Menglun (Yunnan)	21.93ºN, 101.25ºE	C	CVH	HITBC 103168 [Herbarium specimen]; labeled as *Kalanchoe tubiflora*; http://www.cvh.ac.cn/spm/HITBC/103168
K. × *houghtonii*	Garden of Zhejiang Agriculture and Forestry University, Lin'an (Zhejiang)	30.25ºN, 119.73ºE	C	PPBC	http://www.plantphoto.cn/tu/2007289
K. delagoensis	Huangshan Scenic Area, Huangshan (Anhui)	30.13ºN, 118.18ºE	W	Wu (2012)	Master Thesis, Anhui Agricultural University
K. delagoensis	Beijing Botanical Garden, Beijing (Beijing Municipality)	40.00ºN, 116.21ºE	C	CFH	http://www.cfh.ac.cn/album/ShowPhoto.aspx?photoid=56376eea-561a-43b2-a6a6-322bb317a633
K. delagoensis	Fujian Normal University, Fuzhou (Fujian)	26.04ºN, 119.31ºE	C	PPBC	http://www.plantphoto.cn/tu/536884; http://www.plantphoto.cn/tu/822485
K. delagoensis	Jincheng, Great Kinmen Island (Fujian)	24.43ºN, 118.32ºE	W	----	http://www.panoramio.com/photo/45911940
K. delagoensis	Jinhanxiang, Jiaocheng (Fujian)	26.68ºN, 119.51ºE	W	PPBC	http://www.plantphoto.cn/tu/455661
K. delagoensis	Shuangdi Overseas Chinese Farm, Longhai (Fujian)	24.40ºN, 117.72ºE	C	PPBC	http://www.plantphoto.cn/tu/501306
K. delagoensis	Ningde Normal University, Ningde (Fujian)	26.64ºN, 119.54ºE	W	CFH	http://www.cfh.ac.cn/album/ShowPhoto.aspx?photoid=c9a49618-2b58-4009-9b2c-dd9f05f89146

K. delagoensis	Jinjiang, Quanzhou (Fujian)	24.58ºN, 118.60ºE	C	PPBC	http://www.plantphoto.cn/tu/1815135
K. delagoensis	Gulangyu Island, Xiamen (Fujian)	24.45ºN, 118.06ºE	W	PPBC	http://www.plantphoto.cn/tu/806892, http://www.plantphoto.cn/tu/806870, http://www.plantphoto.cn/tu/1017265
K. delagoensis	University of Xiamen, Xiamen (Fujian)	24.44°N, 118.10°E	C	CVH	AU 008751, 008752, and 008753 [Herbarium specimen]; http://www.cvh.ac.cn/spm/AU/008751; http://www.cvh.ac.cn/spm/AU/008752; http://www.cvh.ac.cn/spm/AU/008753
K. delagoensis	Xiamen Botanical Garden, Xiamen (Fujian)	24.45ºN, 118.10ºE	C	CFH	http://www.cfh.ac.cn/album/ShowPhoto.aspx?photoid=11e08c1d-98bb-46ff-ba9e-b14d09eaa7c8
K. delagoensis	Dongzhaicun, Xianyou (Fujian)	25.26ºN, 118.82ºE	W	PPBC	http://www.plantphoto.cn/tu/651271
K. delagoensis	Longhai, Zhangzhou (Fujian)	24.31ºN, 118.01ºE	W	PPBC	http://www.plantphoto.cn/tu/1007036
K. delagoensis	Guraozhen, Chaoyang (Guangdong)	23.34ºN, 116.42ºE	W	PPBC	http://www.plantphoto.cn/tu/262996
K. delagoensis	Lutianzhen, Conghua (Guangdong)	23.81ºN, 113.95ºE	C	PPBC	http://www.plantphoto.cn/tu/1293361; http://www.plantphoto.cn/tu/296526
K. delagoensis	Gardens of Sun Yat-sen University, Guangzhou (Guangdong)	23.10ºN, 113.30ºE	C	CVH	IBSC 0143075 and PE 00842704 [Herbarium specimen]; http://www.cvh.ac.cn/spm/IBSC/0143075; http://www.cvh.ac.cn/spm/PE/00842704
K. delagoensis	Haizhu District, Guangzhou (Guangdong)	23.11ºN, 113.28ºE	W	PPBC	http://www.plantphoto.cn/tu/1391866, http://www.plantphoto.cn/tu/1288040, http://www.plantphoto.cn/tu/603408
K. delagoensis	Haizhu District, Guangzhou (Guangdong)	23.10ºN, 113.32ºE	C	PPBC	http://www.plantphoto.cn/tu/493582
K. delagoensis	Huadu District, Guangzhou (Guangdong)	23.40ºN, 113.21ºE	W	PPBC	http://www.plantphoto.cn/tu/1274375
K. delagoensis	Huangpu District,	23.09ºN, 113.39ºE	W	PPBC	http://www.plantphoto.cn/tu/1787943

	Guangzhou (Guangdong)				
K. delagoensis	South China Botanical Garden, Guangzhou (Guangdong)	23.19ºN, 113.36ºE	C	PPBC	http://www.plantphoto.cn/tu/2089973
K. delagoensis	Puning, Jieyang (Guangdong)	23.33ºN, 116.16ºE	W	PPBC	http://www.plantphoto.cn/tu/306683
K. delagoensis	South Subtropical Botanical Garden, Mazhang (Guangdong)	21.16ºN, 110.27ºE	C	CFH	http://www.cfh.ac.cn/album/ShowPhoto.aspx?photoid=4300e6cf-3a64-4835-9246-280f62448817
K. delagoensis	Jieshizhen, Shanwei (Guangdong)	22.82ºN, 115.83ºE	W	PPBC	http://www.plantphoto.cn/tu/263359
K. delagoensis	Waihu, Shanwei (Guangdong)	22.77ºN, 115.52ºE	W	PPBC	http://www.plantphoto.cn/tu/596596
K. delagoensis	Fairy Lake Botanical Garden, Shenzhen (Guangdong)	22.58ºN, 114.17ºE	C	PPBC	http://www.plantphoto.cn/tu/1531470
K. delagoensis	Longgang, Shenzhen (Guangdong)	22.62ºN, 114.41ºE	W	PPBC	http://www.plantphoto.cn/tu/148668
K. delagoensis	Longxianzhen, Wengyuan (Guangdong)	24.35ºN, 114.13ºE	W	PPBC	http://www.plantphoto.cn/tu/1703110
K. delagoensis	Huodaozhen, Zhaoqing (Guangdong)	22.86ºN, 112.41ºE	C	PPBC	http://www.plantphoto.cn/tu/1740778
K. delagoensis	Former Residence of Sun Yat-Sen, Zhongshan (Guangdong)	22.44ºN, 113.53ºE	W	PPBC	http://www.plantphoto.cn/tu/1440307
K. delagoensis	Doumen District, Zhuhai (Guangdong)	22.22ºN, 113.36ºE	W	PPBC	http://www.plantphoto.cn/tu/814064
K. delagoensis	Guantian, Lipu (Guangxi)	24.49ºN, 110.47ºE	W	CFH	http://www.cfh.ac.cn/album/ShowPhoto.aspx?photoid=ee67a17f-d4df-4f37-9a5b-5ba2134f9acd
K. delagoensis	Garden of the Institute of Traditional Chinese Medicine of Gemaling,	22.84ºN, 108.32ºE	C	CVH	GXMI 006547 and 006548 [Herbarium specimen]; http://www.cvh.ac.cn/spm/GXMI/GXMI00

	Nanning (Guangxi)				6547; http://www.cvh.ac.cn/spm/GXMI/GXMI006548
K. delagoensis	Guangxi Medical Botanical Garden, Nanning (Guangxi)	22.85ºN, 108.37ºE	C	CFH	http://www.cfh.ac.cn/album/ShowPhoto.aspx?photoid=20027a5f-06de-4c97-bbd0-1950a0f84c83
K. delagoensis	**Haikou Old Quarter (Hainan)**	**20.04ºN, 110.34ºE**	**W**	**This work**	**HUTB-K1 [Herbarium specimen]**
K. delagoensis	Xinlong Tropical Botanical Garden, Wanning (Hainan)	18.73ºN, 110.20ºE	C	CVH/PPBC	IBSC 0143076 [Herbarium specimen]; http://www.cvh.ac.cn/spm/IBSC/0143076; http://www.plantphoto.cn/tu/83951
K. delagoensis	Yuen Long District, New Territories (Hong Kong SAR)	22.44ºN, 114.01ºE	W	iNaturalist	https://www.inaturalist.org/observations/1192734
K. delagoensis	Nanjing Botanical Garden, Nanjing (Jiangsu)	32.05ºN, 118.83ºE	C	CFH	http://www.cfh.ac.cn/album/ShowPhoto.aspx?photoid=6b7287ed-4cf2-45f2-a84f-53360a40bd58
K. delagoensis	Gengzhuang, Heze (Shandong)	35.40ºN, 115.43ºE	C	PPBC	http://www.plantphoto.cn/tu/2182628
K. delagoensis	Jinjiang District, Chengdu (Sichuan)	30.58ºN, 104.14ºE	C	PPBC	http://www.plantphoto.cn/tu/1785333
K. delagoensis	Cycad Garden, Panzhihua (Sichuan)	26.57ºN, 101.72ºE	C	CFH	http://www.cfh.ac.cn/album/ShowPhoto.aspx?photoid=3bafb3bc-faf5-426d-a416-fc78365d0395
K. delagoensis	Dashu, Kaohsiung (Taiwan)	22.71ºN, 120.43ºE	W	TAIBIF	http://taibif.tw/zh/occurrence/id/2477630
K. delagoensis	Dashu, Kaohsiung (Taiwan)	22.71ºN, 120.41ºE	W	TAIBIF	http://taibif.tw/zh/occurrence/id/2477629
K. delagoensis	Jiaxian, Kaohsiung (Taiwan)	23.08ºN, 120.67ºE	W	TAIBIF	http://taibif.tw/zh/occurrence/id/2469176
K. delagoensis	Nanzhuang, Miaoli County (Taiwan)	24.64ºN, 121.02ºE	W	TAIBIF	http://taibif.tw/zh/occurrence/id/2490656
K. delagoensis	W Tai'an, Miaoli	24.39ºN, 120.92ºE	W	TAIBIF	http://taibif.tw/zh/occurrence/id/956754

	(Taiwan)				
K. delagoensis	Ren'ai, Nantou (Taiwan)	24.02ºN, 121.19ºE	W	TAIBIF	http://taibif.tw/zh/occurrence/id/665465
K. delagoensis	Changzhi, Pingtung (Taiwan)	22.74ºN, 120.58ºE	W	TAIBIF	http://taibif.tw/zh/occurrence/id/625738
K. delagoensis	Changzhi, Pingtung (Taiwan)	22.73ºN, 120.57ºE	W	TAIBIF	http://taibif.tw/zh/occurrence/id/625739
K. delagoensis	Donggang, Pingtung (Taiwan)	22.43ºN, 120.48ºE	W	TAIBIF	http://taibif.tw/zh/occurrence/id/778883
K. delagoensis	Gaoshu, Pingtung (Taiwan)	22.77ºN, 120.63ºE	W	TAIBIF	http://taibif.tw/zh/occurrence/id/620729
K. delagoensis	Jiadong, Pingtung (Taiwan)	22.45ºN, 120.57ºE	W	TAIBIF	http://taibif.tw/zh/occurrence/id/630902
K. delagoensis	Linbian, Pingtung (Taiwan)	22.43ºN, 120.51ºE	W	TAIBIF	http://taibif.tw/zh/occurrence/id/630904
K. delagoensis	Neipu, Pingtung (Taiwan)	22.64ºN, 120.57ºE	W	TAIBIF	http://taibif.tw/zh/occurrence/id/779849; http://taibif.tw/zh/occurrence/id/779848
K. delagoensis	Xinyuan, Pingtung (Taiwan)	22.52ºN, 120.47ºE	W	TAIBIF	http://taibif.tw/zh/occurrence/id/778884
K. delagoensis	Xinyuan, Pingtung (Taiwan)	22.49ºN, 120.45ºE	W	TAIBIF	http://taibif.tw/zh/occurrence/id/778886
K. delagoensis	Rende, Tainan (Taiwan)	22.91ºN, 120.24ºE	W	TAIBIF	http://taibif.tw/zh/occurrence/id/535661
K. delagoensis	National Taiwan University Campus, Taipei (Taiwan Island)	25.02ºN, 121.54ºE	C	TAIBIF	TAI 168840 [Herbarium specimen]; http://taibif.tw/zh/occurrence/id/53283
K. delagoensis	Yamingshan National Park, Taipei/New Taipei (Taiwan)	25.19ºN, 121.56ºE	W	Hua (2004)	Book
K. delagoensis	Tamsui River Mangrove Conservation Area, Tamsui (Taiwan)	25.16ºN, 121.46ºE	W	----	https://95b6d4dc83299ba2419c3ab9236f20c1aee2cc11.googledrive.com/host/0ByHgwY2tmBQJZGJqTkI4Ym91OTA/Travels5/t141.htm
K. delagoensis	Taida Redai Botanical Garden, Binhai (Tianjin	39.03ºN, 117.71ºE	C	PPBC	http://www.plantphoto.cn/tu/1531452

	Municipality)				
K. delagoensis	Xiqing District, Tianjin (Tianjin Municipality)	39.14ºN, 117.01ºE	C	PPBC	http://www.plantphoto.cn/tu/1831698
K. delagoensis	Kunming Botanical Garden, Kunming (Yunnan)	25.14ºN, 102.74ºE	C	PPBC	http://www.plantphoto.cn/tu/1046878

[1]The herbarium specimen has no leaves, and it has been labeled as "*K. gremontianum*". Since *K. delagoensis* is also present in the same locality (Gulangyu Island, Xiamen, Fujian), this specimen might actually be *K. delagoensis*.
[2]The herbarium specimen has no leaves, and it has been labeled as "*K. gremontianum*".
[3]Although the herbarium specimen has both flowers and leaves, it is not well preserved. Although it is labelled as "*Bryophyllum* sp.", we believe that it may correspond to either *K. daigremontiana* or *K.* × *houghtonii*.
[4]Although the herbarium specimen is not well preserved (and it has no flowers), we do not believe that it corresponds to *Bryophyllum pinnatum* (as labeled). Instead, this specimen might actually be either *K. daigremontiana* or *K.* × *houghtonii*.
[5]There is no information in the label about the exact location of the collected individual (just "Forestry Bureau" and "Xinjiang").

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