A new distribution of *Dalbergia hupeana* Hance (Fabaceae) in Korea and its taxonomic characteristics

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우리나라 황단나무의 신분포 및 분류학적 특징

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ABSTRACT: A new distribution of *Dalbergia hupeana* has been reported at Mt. Yudal in Mokpo-si, Korea. It was previously thought to be restricted to China, but is now recognized as a new addition to Korean flora. Species identification was confirmed according to morphological characteristics and DNA sequences. The genus *Dalbergia* is clearly distinguished from other leguminous tree species in Korea due to its diadelphous (5+5) stamens. Here, we describe the characteristics of the genus and species and speculate about whether its origins are native or introduced in Korea.

Keywords: *Dalbergia hupeana*, Fabaceae, New distribution, Korea

적 요: 목포시 유달산에서 발견된 황단나무(*Dalbergia hupeana*)의 신분포를 보고한다. 본 종은 중국에만 분포하는 것으로 알려져 있었으나 이번 연구를 통해서 한반도에도 자라는 것이 확인되었다. 종의 동정은 형태형질과 DNA 염기서열을 통해 확인하였다. 황단나무속(Genus *Dalbergia*) 또한 한국산으로 처음 보고되는데, 다른 한국산 콩과 수종들과는 양체웅예(5+5)를 가지는 것으로 뚜렷이 구분된다. 본 속과 종의 형태형질에 대해 기재하였으며, 이들의 국내 분포기원이 자생 또는 도입에 의한 것인지 논의하였다.

주요어: 황단나무, 콩과, 신분포, 한국

Dalbergia L. f. (Fabaceae; Papilionoideae; Dalbergieae) is a pantropical tree genus with over 200 species that is distributed primarily in Central and South America, Africa, Madagascar, and Asia (Klitgaard and Lavin, 2005). Generally known as a rosewood (Klitgaard and Lavin, 2005; Patel, 2007; Vatanparast et al., 2013), its highly valuable timber products were historically imported into Korea as an important building material for furniture and statues in Buddhist temples during the Koryo Dynasty (Kim, 2013). However, we have recently found a

population of *Dalbergia hupeana* Hance on the mountainous slopes of Mt. Yudal, Mokpo-si, Jeollanam-do, Korea (Figs. 1, 2).

Materials and Methods

The distribution of *Dalbergia hupeana* in Korea was investigated through field, literature, and oral surveys. Dried voucher specimens collected by the authors are being stored in the herbaria of Inha University (IUI) and the Chinese Academy of Sciences (PE), Beijing. Materials for morphological observations included dried specimens prepared from our own field samples at Mt. Yudal as well as those from the PE herbarium (Appendix). The molecular analysis involved DNA sequences of the nuclear internal transcribed

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Fig. 1. *Dalbergia hupeana* Hance. A. flowering tree; B. inflorescence; C. bark; D. bud; E. seed; F. fruit; G. leaf.

Fig. 2. Flower of *Dalbergia hupeana*. A. flower; B. standard; C. wing; D. keel-petal; E. calyx (interior); F. stamens (5+5); and G. gynoecium.

spacer (nrITS) region plus plastid *matK* and *rbcL* (Table 1). Methods for analysis largely followed those described by Choi et al. (2013). Primer pairs were used for ITS (White et al., 1990), *matK* (Wojciechowski et al., 2004), and *rbcL* (Olmstead et al., 1992).

Results and Discussion

Surveys of habitat status and distribution

Plants of *Dalbergia hupeana* found at Mt. Yudal are located

near the Buddhist temples. The population is restricted to lower elevations (approximately 120 m) where it dominates in more humid areas on slopes. This habitat contains more than 100 adult trees and numerous young seedlings of this species, with a maximum height of ca. 15 m and a diameter at breast height (DBH) of ca. 55 cm. Therefore, the *D. hupeana* population appears to be autochthonous and has a high rate of reproduction. The understory in this habitat also includes three evergreen species: *Ligustrum japonicum* Thunb., *Trachelospermum asiaticum* (Siebold & Zucc.) Nakai, and *Hedera rhombea* (Miq.) Siebold & Zucc. ex Bean. Further investigations revealed no other natural populations in Korea. However, trees of this species have been planted at three locations in Jeolla-do: Chonnam National University, Namwon National Gugak Center, and Manchui Garden. Among these, Manchui Garden is the oldest, having been built in 1913 at the end of the Chosun Dynasty. That site also features the oldest *D. hupeana* individual, a tree with a DBH of ca. 55 cm.

Morphological identification and characteristics

Based on descriptions of Korean floras, this species is most similar to the little known Korean *Cladrastis platycarpa* (Maxim.) Makino, which is considered indigenous to the Mt. Yudal region (Lee, 2003; Chang et al., 2011; Chang et al., 2012). However, the trees we found at Mt. Yudal clearly differ morphologically from *C. platycarpa*. The former is characterized by leaflets with obtuse or slightly emarginated apex, whitish corolla with purple stripes, and diadelphous (5+5) stamens, whereas the latter has leaflets with acuminate apex, whitish corolla with yellow spot in throat, and 10 free stamens. Alternatively, they show minor contrasts in characteristics when compared with descriptions of *D. hupeana* from China

Table 1. Site of variation among aligned sequences for ITS 2, partial *matK*, and partial *rbcL* from *Dalbergia hupeana* and related species.

ITS 2										matK					rbcL	
Taxon										Taxon					Taxon	
	0	0	0	0	1	1	1	1	2		3	3	3	5	0	
	2	2	6	8	3	5	8	9	1		0	1	2	1	1	
	0	9	3	0	5	4	4	5	6		0	0	1	4	6	
<i>D. hupeana</i> (GU217673)	C	G	T	T	C	A	T	G	T	<i>D. hupeana</i> (HQ427296)	C	C	G	G	<i>D. hupeana</i> (HQ427142)	A
<i>D. hupeana</i> (Mt. Yudal)	•	•	•	•	T	•	•	•	•	<i>D. hupeana</i> (Mt. Yudal)	•	•	•	•	<i>D. hupeana</i> (Mt. Yudal)	•
<i>D. assamica</i> (AB828610)	•	•	•	•	•	•	A	A	C	<i>D. assamica</i> (HG326215)	T	•	A	T	<i>D. nigrescens</i> (AB925438)	C
<i>D. balansae</i> (AB828612)	A	A	C	C	•	G	A	A	C	<i>D. nigrescens</i> (AB924826)	T	T	A	T	<i>D. stipulacea</i> (KF181521)	C

(Chen, 1994; Chen et al., 2010). In fact, our observations are in accord with the type specimen and protologue reported by Hance (1882). The Flora of China (Chen et al., 2010) states that both surfaces of *D. hupeana* leaflets are glabrous and have a sub-leathery texture. Moreover, their flowers are 6 to 7 mm long. However, leaves from plants collected at Mt. Yudal are pubescent on both sides, a papery or sub-leathery surface texture, and floral size of 8 to 10 mm. Although there is distinction between the description of the Flora of China and Mt. Yudal specimens, all the specimens we observed from the PE herbarium presented variable traits on the leaflet pubescence and texture. Hair and texture characteristics vary by season, with leaflets being pubescent on both sides and having a papery texture during the flowering season but being glabrescent on the adaxial surface and having a coriaceous texture during the fruiting period. We attribute those variations in flower sizes to different criteria being used for measurements. Therefore, we have devised an amended description for Korean *D. hupeana*.

Molecular characters from nrITS and cpDNA

The sequenced ITS region is 614 bp long and contains ITS 1 (231 bp), 5.8S (167 bp), and ITS 2 (216 bp). The ITS sequence shows low similarity (72.6% pairwise identity) to *Cladrastis platycarpa* (GenBank No. JQ676974). Blast results indicate high similarity to *Dalbergia* species. Both of those findings support our identification. Because complete, available sequences are not sufficient for *D. hupeana* and related species, we compared the partial ITS, *matK*, and *rbcL* regions and were able to distinguish *D. hupeana* from other congeneric species (Table 1). Only a single substitution occurred in the ITS 2 region while the *matK* and *rbcL* sequences were identical between Chinese and Korean *D. hupeana*.

The origin of *Dalbergia hupeana* in Korea: Native vs. Introduced

Researchers can speculate about whether *D. hupeana* is native or was introduced into Korea. However, the large, wide trunks of some trees suggest a persistent presence in Korea that might span at least one century. Plants of this species are naturally distributed throughout the Chinese provinces of Anhui, Fujian, Guangdong, Guangxi, Henan, Hubei, Hunan, Jiangsu, Jiangxi, Shandong, Shaanxi, Sichuan, Yunnan, and Zhejiang (Chen, 1994; Chen et al., 2010). Its northern boundary of range is thought to be approximately 34° 40' N (Fig. 3). Therefore, a location at Mt. Yudal (34° 47' N) would appear to be suitable as a natural habitat. The area near Mt. Yudal is also the only place in Korea that can sustain the growth of another Fabaceae family member, i.e., the warm-temperate tree

Fig. 3. Distribution of *Dalbergia hupeana*, modified from the PE herbarium website (<http://pe.ibcas.ac.cn/>).

Albizia kalkora Prain (Choi, 2007). From a biogeographic perspective, moreover, the pantropical distribution and mismatch between geographical and phylogenetic groupings of *Dalbergia* species may have resulted from long-distance dispersal via wind and water (Vatanparast et al., 2013). However, when we take into account its preferred environment, the distribution of this species in Korea appears to be more the outcome of a historically anthropogenic introduction. Our theory is also supported by the discovery of *Dalbergia* timber that dates from A.D. 1323 near the seabed at Mt. Yudal (Kim, 2013). Furthermore, neither morphological nor molecular data indicate that it is significantly different from Chinese plants, which implies that this disjunctive distribution is relatively recent. Whether native or introduced, it is true that these trees are now autochthonous and actively reproductive. Thus, populations of this warm-temperate species could potentially expand to more northerly locations in Korea due to global warming. Finally, the timing and manner of establishment for Korean populations could be further elucidated through the use of molecular phylogeographic analyses and extensive field surveys in the southwestern parts of Korea.

Dalbergia Linnaeus f., Suppl. Pl. 52, 316. 1782.

Korean name: 황단나무속 Hwang-dan-na-mu-sok (신칭)

Shrubs, trees and climbing lianas. Leaves alternate, imparipinnate; leaflets alternate, rarely opposite, estipellate. Inflorescences terminal or axillary, racemes or panicles, usually numerous flowered. Flowers small; calyx campanulate, 5-toothed; teeth unequal, rarely subequal, lowest tooth usually largest, upper pair usually wider than others and partially connate; petals white, pale green, or rarely purple; standard

ovate, oblong, or orbicular; wings with base cuneate, truncate, or sagittate; keel often boat-shaped, $\pm$ united above; stamens 9 or 10, monadelphous, usually united in an open sheath, or diadelphous and then in 2 bundles of 5 each (5+5), or 9 united and 1 free (9+1); anthers erect, small, dehiscent by short apical slits; ovary stipitate, few ovuled. Fruits oblong to oblong-elliptical, samaroid, crescent or kidney-shaped, or orbicular to suborbicular, membranaceous, subcoriaceous or coriaceous, thickened over the seed cavity or thickened throughout. Seeds reniform, compressed; radicle inflexed.

Species: ca. 250

Distribution: pantropical; Africa (including Madagascar), Asia, Australia, South and Central America.

Dalbergia hupeana Hance, J. Bot. 20: 5. 1882; Chen, Fl. Reip. Popul. Sin. 40: 119. 1994; Chen et al., Fl. China. 10: 129. 2010. **Type:** Yichang, Hubei, China, *T. Watters s.n.* (herb. propr. n. 21189) (Holotype, BM, seen as a photo!)

Korean name: 황단나무 Hwang-dan-na-mu (신칭)

Tree, up to 15 m tall; bark dull gray or brownish gray; branches glabrous. Leaves of flowering twig 7- to 9-foliolate, 15–25 cm long including peduncle, sprouting in June; terminal leaflet elliptic to oblong elliptic, sometimes ovate or obovate, $5.0\text{--}7.5 \times 2.5\text{--}3.5$ cm, papery to subleathery, upper surfaces shiny, persistent sparse, short whitish hair, or occasionally glabrescent in autumn, lower surfaces pubescent with yellowish hair, veinlets prominent, base rounded or broadly cuneate, apex obtuse or slightly emarginated; lateral ones similar to terminal but gradually smaller toward peduncle. Panicles terminal or extending into axils of uppermost leaves, $5\text{--}20 \times 5\text{--}20$ cm, sparsely rusty, puberulent. Flowers 8–10 mm long; pedicel ca. 5 mm long, sparsely rusty, puberulent as calyx; bracts and bracteoles caducous, ovate, pubescent. Calyx campanulate, 5-lobed, $4.5\text{--}5.5$ mm long including lowest lobe; two upper lobes rounded, subconnate, two lateral lobes smaller, ovate, lowest lobe lanceolate, ca. 2 times longer than others. Petals clawed; standard white with purple stripes inside, orbicular, emarginated at apex, $6.5\text{--}7.2$ mm long, $5.3\text{--}6.3$ mm wide; wings white, half-moon-shaped, $7.5\text{--}9.2$ mm long, $3.2\text{--}3.8$ mm wide; keel auriculate on upper side below, $6.0\text{--}6.7$ mm long, $2.6\text{--}3.2$ mm wide. Stamens 10, diadelphous (5+5). Ovary shortly stipitate, pubescent at base, 2- or 3-ovuled; style slender; stigma capitate, small. Fruit oblong or broadly ligulate, $4\text{--}7$ (~ 12) $\times 1.3\text{--}1.5$ (~ 1.8) cm, thinly leathery, reticulate opposite 1 or 2 (–4) seeds, base gradually tapering to stipe, apex acute. Seeds reniform, $7\text{--}14 \times 5\text{--}9$ mm. Fl. Jul-

Aug. Fr. Sep–Oct.

Distribution: China, Korea.

Korea: Jeollanam-do.

Taxonomic note: This report of *Dalbergia hupeana* in Korea extends the distribution of this species northeastward. Moreover, this genus is a new addition to Korean flora. Its leaflet morphology, especially texture, is highly plastic by season, and lengths vary between flowering (5.0–7.5 cm) and non-flowering (7–11 cm) material. In Korea, new leaves emerge in late June, with the last dates being recorded for trees growing at Mt. Yudal. Based on this, the species can be readily distinguished from others because trees of the former appear to be withered during the springtime.

From the same locality at Mokpo-si, Lee (2003), Chang et al. (2011), and Chang et al. (2012) described *Cladrastis platycarpa* without including pictures or whole illustrations. However, leaf diagram for trees labeled as Korean *C. platycarpa* (Chang et al., 2011; Chang et al., 2012) did not resemble *C. platycarpa* but, rather, *D. hupeana*. Furthermore, we found no specimens of *C. platycarpa* during our field survey at Mt. Yudal. Therefore, the recording of *C. platycarpa* in Korean flora (Lee, 2003; Chang et al., 2011; Chang et al., 2012) is referable Korean *D. hupeana*.

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Appendix: Representative specimens examined for this study

Dalbergia hupeana Hance

KOREA, Jeollabuk-do: Namwon National Gugak Center, Eoheondong, Namwon-si, 7 Nov. 2014, *I.S. Choi 1411001-1411004* (IUI); **Jeollanam-do:** Manchui Garden, Dongho-dong, Gwangju-si, 7 Nov. 2014, *I.S. Choi 1411005-1411008* (IUI); Chonnam National University, Yongbong-dong, Gwangju-si, 21 Oct. 2014, *I.S. Choi 1410010-1410023* (IUI); Mt. Yudal, Jukgyo-dong, Mokpo-si, 21 Jul. 2014, *I.S. Choi & D.P. Jin 1407001-1407008, 1407010-1407011-1407018, 1407020* (IUI); Mt. Yudal, Jukgyo-dong, Mokpo-si, 21 Jul. 2014, *I.S. Choi & D.P. Jin 1407009* (PE); Mt. Yudal, Jukgyo-dong, Mokpo-si, 20 Oct. 2014, *B.H. Choi & I.S. Choi 1410001-1410004, 1410006, 1410007* (IUI); Mt. Yudal, Jukgyo-dong, Mokpo-si, 20 Oct. 2014, *B.H. Choi & I.S. Choi 1410005* (PE).

CHINA, Anhui: Mt. Langya, Chuzhou-shi, 4 Jun. 1953, *S.J. Yang et al. 540* (PE); Mt. Guniujiang, Penglongxiang, Qimen-xian, Huangshan-shi, 14 Aug. 2006, *M. Liu et al. A140118* (PE); Peak Taohua, Huangshan-shi, 3 Oct. 1955, *M.J. Wang 3628* (PE); Mt. Huang, She-xian, 18 Jul. 1975, *K.J. Guan 75367* (PE); **Fujian:** Mt. Wuyishan, Chongan-xian, 11 Jul. 1974, *236-6 team 723* (PE); Tongmu, Chongan-xian, 21 Jul. 2000, *G.S. He 9715* (PE); Chishuige, Dehua-xian, 5 Aug. 1931, *B.Q. Zhong 1015* (PE); Yangyuanbao, Jiangle-xian, 11 Jun. 1934, *L.G. Lin 630* (PE); Taining town to Diaocun, Taining-xian, 15 Jun. 1934, *L.G. Lin 676* (PE); Xiamen University, Xiamen-shi, 26 May 1977, *G.D. Ye 566* (PE); **Guangdong:** Mt. Wuzhi, Ruyuan-aozu-zizhixian, 30 May 1973, *Guangdong73 429* (PE); Shixing-xian, 9 Aug. 1958, *L. Deng 7115* (PE); Zhongshan university, 15 Jun. 1953, *S.Q. Chen 8318* (PE); **Guangxi:** Baise-shi, 13 Sep. 1953, *Guangxi investigation team 3675* (PE); **Guizhou:** Yang zhai nearby, Yaoshangping, Shiqian-xian, 28 Jul. 1988, *Wuling Mountain Expedition 3156* (PE); **Henan:** Mashankou, Neixiang-xian, 17 Jun. 1960, *Henan team 619* (PE); Jingangtai, Shangcheng-xian, 27 Jun. 1984, *Plant Resources Expedition D0622* (PE); Mt. Jigong, Xinyang-shi, 1 Jul. 1986, *Plant Resources Expedition D1695* (PE); Lijiazhai, Xinyang-shi, 12 Oct. 1966, *A.R. Li, P.Z. Zhang, R.S. Ni 151* (PE); Laomiao, Xin-xian, 9 Jul. 1984, *Plant Resources Expedition D0808* (PE); Taipingzhen to Erlangping street, Xixia-xian, 24 Jul. 1960, *D. Guan 1420* (PE); Puti temple, Zhenping-xian, 16 Jun. 1960, *D. Guan 448* (PE); **Hubei:** Baiyang nearby, 24 Jul. 1956, *H.J. Li 100* (PE); Mt. Luojia, 16 Jun. 1936, *H.K. Teng 200* (PE); Maodao, Lichuan-shi, 22 Sep. 1957, *G.X. Fu & Z.S. Zhang 1528* (PE); Yangjia River, Xingshan-xian, 12 Jul. 1957, *H.J. Li 1062* (PE); Xingshan-xian, 28 Jun. 1957, *G.X. Fu & Z.S. Zhang 378* (PE); Xuan'en-xian, 25 Jun. 1958, *H.J. Li 3169* (PE); **Hunan:** Mt. Shi, Guan-pu, Xinning-xian, 13 Jun. 1996, *Z.C. Luo 1406* (PE); Hengshan Nature Reserve, Hengshan-shi, 7 Jun. 2002, *Z.H. Hu 267* (PE); Hengshan Nature Reserve, Hengshan-shi, 13 Jun. 2002, *Z.H. Hu 293* (PE); Hengshan Nature Reserve, Hengshan-shi, 5 Jul. 2002, *Z.H. Hu 370* (PE); Hengshan Nature Reserve, Hengshan-shi, 20 Jul. 2002, *Z.H. Hu 411* (PE); Lingguanzhen Zaoyuan, Qidong-xian, 31 May 2004, *J.D. Li 625* (PE); Lingguanzhen Zaoyuan, Qidong-xian, 8 Jul. 2004, *J.D. Li 637* (PE); Mt. Shunhuang, Xinning-xian, 16 May 2004, *J.K. Liu 518* (PE); **Jiangsu:** Mt. Baoyan, Changshu-shi, 19 Aug. 1958, *W.X. Wu 4656* (PE); Peak Yangjia, Mt. Lao, Jiangpu-xian, 18 January 1933, *Y.Y. Ho 1924* (PE); Linggu temple, Nanjing-shi, 29 May 1952, *X.J. Yang & Z. Deng & J.S. Yue 445* (PE); Ming Tomb, Nanjing-shi, 11 Jun. 1929, *Y.L. Keng 2327* (PE); Mt. Qianyuntai, Suzhou-shi, 14 Aug. 1958, *F.X. Liu 10538* (PE); Mt. Caowu, Yaoshan, Wu-xian, 2 Aug. 1958, *W.X. Wu 3798* (PE); Geling to Zhangsudelu, Yixing-shi, 24 Aug. 1960, *W.Z. Fang et al. 270* (PE); **Jiangxi:** Taolao, Chongyi-xian, 2 Nov. 2002, *Expedition c141* (PE); Lushan-qu, 3 Sep. 1994, *M.X. Nie 94358* (PE); Mt. Tianhua, Guixi-shi, 23 Jul. 1958, *S.S. Lai 3710* (PE); Mt. Jinzhu, Jinggangshan-shi, 2 Oct. 1958, *J. Xiong 2866* (PE); Taihe-xian, 18 May 1959, *S.S. Lai 518* (PE); Tianbudagou-li, Wuning-xian, 21 Jul. 1999, *J.S. Xiong 99006* (PE); Mt. Wuyi, Yanshan-xian, 16 Aug. 1958, *M.X. Nie & S.S. Lai 4146* (PE); Gan river, Yongxin-xian, 18 Jun. 1959, *S.S. Lai 1009* (PE); **Sichuan:** Kwang-yun Hsien, Sep. 1930, *F.T. Wang 22556* (PE); Sichuan University Botanical Garden, Chengdu-shi, 1944, *Mao 19* (PE); Liang river, Dujiangyan-shi, 23 Jul. 1987, *International Exchange Team 870154* (PE); Guanghan-shi, 15 Sep. 1939, *S.E. Liu 682* (PE); Wanyuan-shi, 21 Jul. 2010, *Bashan collection team 2953* (PE); **Zhejiang:** Mt. Mogan, 10 Oct. 1961, *Z.P. Jie 61282* (PE); Yunqi, Hangzhou-shi, 10 Sep. 1963, *Y. Ping 130* (PE); Jiangnanwucun, Jiande-shi, 23 Jun. 1987, *Y.G. Chen L8515-066* (PE); Mt. Putuo, Ningbo-shi, 1958, *Hangzhou teacher college 1240* (PE).