



A comparative morphological study of *Viburnum* (Adoxaceae) in Korea

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ABSTRACT: *Viburnum* in Korea includes ten species. The phylogenetic relationships and morphology of the genus *Viburnum* in general have been studied substantially for the past three decades. A clear understanding of the systematic relationships and an assessment of the level of morphological variation of these plants distributed in Korea are lacking. This study investigated the morphology of these species using herbarium specimens and fresh materials obtained during fieldwork to examine the morphological variation level for a better understanding of each species in the genus. A comparative analysis showed that the species of *Viburnum* in Korea are easily distinguishable based on various characters of the bud, leaf, extrafloral nectary, inflorescence, corolla, fruit, and stone.

Keywords: morphology, *Viburnum*, Adoxaceae, Viburnaceae

The genus *Viburnum* L. (Adoxaceae) consists of 175–200 species of small trees and shrubs widely distributed in temperate and subtropical regions of Europe, North Africa, Asia, and the Americas (Rehder, 1908; Donoghue, 1983; Hara, 1983; Donoghue et al., 2004). Most of the species are distributed in eastern Asia, eastern North America, and in the mountains of Mexico and South America. Species of *Viburnum* are easily distinguished from other species in angiosperms by having the growth forms of small trees and shrubs; simple, opposite (rarely whorled) and petiolate leaves; paniculate or umbellate inflorescences, sometimes with marginal sterile flowers; and red to purple black drupes with a single stone (Donoghue et al., 2003). Plants of *Viburnum* have often been cultivated as ornamentals due to their showy flowers and fragrant, such as *V. opulus* L., and *V. carlesii* Hemsl., and as a medicine source, such as *V. tinus* L. and *V. erosum* Thunb. (Mabberley, 1997; Ahn, 1998; Kwon et al., 2003).

Established by Linnaeus (1753), *Viburnum* was initially classified in Caprifoliaceae (Jussieu, 1789) and later separated into its own family, Viburnaceae (Rafinesque, 1820). The Angiosperm Phylogeny Group (APG) system recognizes that *Viburnum* is a member of Adoxaceae together with *Sambucus* L. (Angiosperm Phylogeny Group, 2016) based on phylogenetic analyses of Dipsacales, in which *Viburnum* forms a strongly supported clade with *Adoxa*, *Sinoadoxa*, *Tetradoxa*

(the three traditional members of Adoxaceae), and *Sambucus* (e.g., Bell et al., 2001).

The correct family name for *Viburnum* is complex. Reveal (2008) simultaneously made three proposals for the family name of *Viburnum*. The first of his proposals (proposal number 1800) recommended the conserving of Viburnaceae owing to Tinaceae, based on the genus *Tinus*, a synonym of *Viburnum*. The publication date of Tinaceae is August of 1820 (Reveal, 2008), one month earlier than the publication date of Viburnaceae. This proposal was recommended at the Nomenclature Committee for Vascular Plants (Applequist, 2013). Due to the conservation of Viburnaceae, it is difficult to apply the family name for the clade, which consists of *Viburnum*, *Sambucus* and Adoxaceae. When *Viburnum* and *Sambucus* are united with Adoxaceae, Viburnaceae has priority over Adoxaceae, an existing conserved name published in 1839, which would result in the merging of Adoxaceae into Viburnaceae. His second proposal is a “superconservation” of Adoxaceae when Viburnaceae is united with Adoxaceae and *Sambucus*. This proposal was neither recommended nor rejected by the Specialist Committee, unfortunately (Turland et al., 2018). His third simultaneous proposal is to use the alternative family name Sambucaceae when Adoxaceae, *Viburnum*, and *Sambucus* are united. This proposal was neither recommended nor rejected by the Specialist Committee

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(Turland et al., 2018). Thus, the correct name would be Viburnaceae when a single family is recognized. We believe that this is unfavorable. No botanical study has ever recognized Viburnaceae as including Adoxaceae and *Sambucus*. We use Adoxaceae in this paper, following the APG system (Angiosperm Phylogeny Group, 2016).

Various sectional classification systems within *Viburnum* have been suggested by different authors. The most widely accepted is by Oersted (1861) and Hara (1983), with ten sections recognized (*Solenotinus*, *Viburnum*, *Pseudotinus*, *Tomentosa*, *Tinus*, *Megalotinus*, *Lentago*, *Oreiotinus*, *Odontotinus*, *Opulus*) based on morphological characters such as bud scales, leaf margins, and the types of inflorescence.

Viburnum received much attention in morphological and evolutionary studies. Egolf (1962) and Zhang et al. (2016) examined chromosome numbers and conducted cytological analyses. Jacobs et al. (2008) investigated seed anatomy and more recently Spriggs et al. (2018) examined leaf form evolutionary processes among species. Hara (1983) in his revision of Caprifoliaceae and Adoxaceae included morphological studies of *Viburnum* providing taxonomic treatment of the genus for the Japanese species.

Phylogenetic relationships of the sections within *Viburnum* have been extensively studied based on morphology and molecular data (Donoghue, 1983; Donoghue et al., 2004; Winkworth and Donoghue 2004, 2005; Clement and Donoghue 2011, 2012; Clement et al., 2014). These studies have shown that most sections within *Viburnum* (Hara, 1963) were supported as monophyletic (Donoghue et al., 2004; Winkworth and Donoghue 2004, 2005; Clement and Donoghue 2011, 2012; Clement et al., 2014). In addition to the traditional classification system, Clement et al. (2014) proposed a phylogenetic classification (Cantino et al., 2007) providing names for strongly supported clades within *Viburnum*.

There are ten species known in Korea (Hong and Im, 2003; Kim, 2007). *Viburnum erosum*, *V. dilatatum* Thunb., *V. wrightii* Miq., *V. opulus*, and *V. carlesii* var. *calvescens* are common in the thickets of forests. *Viburnum koreanum* is rare in Korea, found at high elevations on Seoraksan Mt., and *V. furcatum* is distributed on Jeju Island and Ulleungdo Islands. The occurrence of *V. furcatum* on Jabyeongsan Mt. in Gangwon-do was reported (Son et al., 2008). The evergreen species *V. japonicum* (Thunb. in Murray) Sprengel and *V. odoratissimum* var. *awabuki* (K. Koch) Zabel ex Rümpler are restricted to Gageodo Island and Jeju Island, respectively. *Viburnum burejaeticum* Regel & Herder is mainly distributed in northern Korea and is designated as an endangered species of Korea by the Ministry of the Environment.

This study aims to examine the morphological characters across the Korean species of *Viburnum* and determine the level of variation for a better understanding of the phylogenetic relationships and to clarify the taxonomic identity of each species.

Materials and Methods

In this study, we included ten taxa of *Viburnum* distributed in Korea. Specimens were collected from the wild in Korea, China, and Japan during the study in 2017 and 2018 and others borrowed from the Herbarium of Vascular Plants at the National Institute of Biological Resources (KB) were used. Specimens collected during this study are deposited at the Daejeon University herbarium (TUT). Approximately 250 specimens were investigated (Appendix 1). Morphological characters such as the habit, bud scale, trichome on branchlets, leaf shape and distribution of the trichome, inflorescence type, corolla shape, fruit color, and stone were examined from the materials. A stereoscopic microscope was used to examine the internal structures of the flowers and trichomes and the characteristics of the stones.

Results

The species of *Viburnum* in Korea can be distinguished by several morphological characters, such as the habit, buds, vestiture, leaf size and shape, stipules, extrafloral nectaries, inflorescences, corolla, fruit color, and stone shape.

Habit

All of the Korean *Viburnum* species are shrubs. The distinctive feature of two species, *V. japonicum* and *V. odoratissimum* var. *awabuki*, is that they are evergreen woody plants. All other Korean species are deciduous.

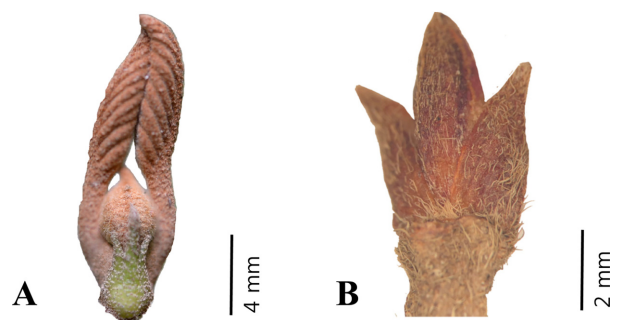


Fig. 1. Buds found in *Viburnum* in Korea. **A.** Naked bud without scales. A pair of young leaves which would extend in the next spring is exposed. **B.** Scaled bud with two pairs of scales.

Bud

The buds are located at the apex or the axils of the branchlets and form in summer, lasting until the next spring. There are two types of buds associated with scales: naked buds and scaled buds (Fig. 1). Naked buds do not have scales and expand their outer organs into the leaves (Fig. 1A). Naked buds are found in *V. burejaeticum*, *V. carlesii*, and *V. furcatum*. In most of the species in Korea, buds are enclosed by two or three pairs of scales that fall off as the shoot expands in spring (Fig. 1B). *Viburnum burejaeticum* and *V. carlesii* are closely related, forming a clade according to a phylogenetic analysis (Clement et al., 2014; Choi et al., 2018) and placed in sect. *Viburnum* (Hara, 1983). In *V. furcatum*, a pair of minute caducous scales can be seen in summer, but the bud scales are absent in late fall and winter. The phylogenetic relationships associated with *V. furcatum* are unclear, with classification into sect. *Pseudotinus*. Clement et al. (2014) suggested that the naked bud may be an ancestral trait in *Viburnum* and that evolution of the scaled bud from the naked bud may have occurred three times independently within the genus.

Vestiture

There are two types of non-glandular trichomes in the Korean *Viburnum*: simple and stellate trichomes. Types of trichomes are useful to distinguish the species in Korea (Table 1). Stellate trichomes densely cover branchlets, petioles, and the adaxial and abaxial surfaces of leaves in *V. burejaeticum*, *V. carlesii*, and *V. furcatum*, all of which have naked buds, as stated previously. In some species, two types of trichomes occur together. Stellate trichomes and simple hairs are found in

branchlets, bud scales, petioles, and both surfaces of the leaves in *V. erosum* at a high density. In *V. dilatatum*, both stellate and simple hairs are densely distributed in branchlets and petioles, and only simple hairs are found in bud scales and on both surfaces of the leaves. Bud scales, petioles, and leaves in some plants in *V. wrightii* are sparsely pubescent with simple hairs, and those in other plants are glabrous. Petioles and both surfaces of the leaves in *V. koreanum* and *V. opulus* var. *calvescens* are glabrous or are sparsely pubescent with simple hairs. Plants of *V. japonicum* are glabrous, and those of *V. odoratissimum* var. *awabuki* are nearly so, except that the bud scales of the latter are sparsely pubescent with stellate trichomes.

Leaves

Like other members of *Viburnum*, the Korean species has simple, opposite leaves. The distribution of stipules varies across the species (Table 2). A pair of stipules 3–7 mm long can be found in *V. erosum*, *V. koreanum*, and *V. opulus* var. *calvescens*. All other species in Korea are estipulate. Leaves of *V. koreanum* and *V. opulus* var. *calvescens* are shallowly three-lobed, and those of other species in Korea are unlobed. *Viburnum erosum* var. *taquetii* is recognized by having deeply incised leaves with two short lobes (Hara, 1983). Plants with this type of leaf are usually small and also bear unlobed leaves.

Various leaf shapes are found in the Korean *Viburnum*, such as rounded, ovate, elliptic, obovate, and oblanceolate (Fig. 2, Table 2). Ovate and elliptic leaves are most commonly found in all species in Korea. There is a wide range of variation within the species, and even within a single plant. It is difficult to distinguish the species clearly based on the leaf shape. The

Table 1. Distribution of trichomes in *Viburnum*.

Species	Branchlet	Bud scale	Petiole	Leaves	
				Adaxial surface	Abaxial surface
<i>V. burejaeticum</i>	Stellate, ++	-	Stellate, ++	Stellate, ++	Stellate, ++
<i>V. carlesii</i>	Stellate, ++	-	Stellate, ++	Stellate, ++	Stellate, ++
<i>V. dilatatum</i>	Stellate & simple, ++	Simple, ++	Stellate & simple, ++	Simple, +	Simple, +
<i>V. erosum</i>	Stellate & simple, ++	Stellate & simple, ++	Stellate & simple, ++	Stellate & simple, ++	Stellate & simple, ++
<i>V. wrightii</i>	Glabrous	Simple, +; glabrous	Simple, +; glabrous	Simple, +; glabrous	Simple, +; glabrous
<i>V. japonicum</i>	Glabrous	Glabrous	Glabrous	Glabrous	Glabrous
<i>V. koreanum</i>	Glabrous	Glabrous	Simple, +; glabrous	Simple, +; glabrous	Simple, +; glabrous
<i>V. opulus</i> var. <i>calvescens</i>	Glabrous	Glabrous	Simple, +; glabrous	Simple, +; glabrous	Simple, +; glabrous
<i>V. furcatum</i>	Stellate, ++	-	Stellate, +	Stellate, +	Stellate, +
<i>V. odoratissimum</i> var. <i>awabuki</i>	Glabrous	Stellate, +	Glabrous	Glabrous	Glabrous

+, sparsely pubescent; ++, densely pubescent.

Table 2. Comparison of key morphological character of *Viburnum* in Korea.

Species	Bud scale	Stipule	Leaves						
			Petiole length (cm)	Shape	Length (cm)	Width (cm)	Apex	Base	Margin
<i>V. burejaeticum</i>	Naked	Absent	0.5–1.5	Ovate, elliptic	3.6–8.9	2.1–4.8	Acute, obtuse	Obtuse, rounded	Serrulate
<i>V. carlesii</i>	Naked	Absent	0.3–0.7	Ovate, elliptic, rounded	2.5–10.0	2.0–7.0	Acute, rounded	Obtuse, cordate, rounded	Serrate
<i>V. dilatatum</i>	Scaled	Absent	0.3–1.6	Ovate, elliptic, obovate	4.5–15.0	2.1–9.2	Acute, obtuse	Cuneate, rounded	Serrate
<i>V. erosum</i>	Scaled	Present	0.2–0.6	Ovate, elliptic, obovate	4.6–9.2	1.8–5.0	Acute, obtuse	Cuneate, rounded	Serrate
<i>V. wrightii</i>	Scaled	Absent	0.8–1.3	Ovate, elliptic, obovate	5.4–11.0	4.2–8.7	Acute, obtuse	Cuneate, rounded	Serrate
<i>V. japonicum</i>	Scaled	Absent	1.6–3.1	Ovate, elliptic, rhombic	5.6–13.6	3.6–10.0	Acute, obtuse	Cuneate, rounded	Serrate
<i>V. koreanum</i>	Scaled	Present	0.4–2.0	Ovate, elliptic, suborbicular with 3-lobes	5.0–8.1	4.2–7.8	Acute, acuminate	Cordate, rounded	Irregularly serrate
<i>V. opulus</i> <i>var. calvescens</i>	Scaled	Present	1.4–3.7	Ovate, elliptic, suborbicular with 3-lobes	3.5–11.2	3.4–12.9	Acute, acuminate	Cordate, rounded	Irregularly serrate
<i>V. furcatum</i>	Scaled/ naked	Absent	1.7–3.3	Ovate, rounded	7.5–11.1	5.9–9.7	Acuminate, rounded	Cordate, rounded	Irregularly serrate
<i>V. odoratissimum</i> <i>var. awabuki</i>	Scaled	Absent	1.5–3.3	Elliptic, broadly elliptic, oblanceolate	6.0–16.2	2.8–8.0	Acute, obtuse	Cuneate	Entire

Table 2. (Continued.)

Species	Extrafloral nectary	Inflorescence	Marginal sterile flower	Corolla			Fruit color in maturity	Stone	
				Shape	Tube length (mm)	Anther color		Shape	No. of groove (dorsal, ventral side)
<i>V. burejaeticum</i>	Absent	Umbel	Absent	Rotate	<1	Yellow	Black	Ellipsoid	2, 3
<i>V. carlesii</i>	Absent	Umbel	Absent	Tubular	8-13	Yellow	Black	Ellipsoid	2, 3
<i>V. dilatatum</i>	Laminar	Umbel	Absent	Rotate	<1	Yellow	Red	Ovoid	2, 3
<i>V. erosum</i>	Laminar	Umbel	Absent	Rotate	<1	Yellow	Red	Ovoid	2, 3
<i>V. wrightii</i>	Laminar	Umbel	Absent	Rotate	<1	Yellow	Red	Ovoid	2, 3
<i>V. japonicum</i>	Laminar	Umbel	Absent	Rotate	<1	Yellow	Red	Ovoid	2, 3
<i>V. koreanum</i>	Petiolar	Umbel	Absent	Rotate	<1	Yellow	Red	Ovoid-ellipsoid	2, 1
<i>V. opulus</i> <i>var. calvescens</i>	Petiolar	Umbel	Present	Rotate	<1	Dark purple	Red	Ovoid-ellipsoid, cordate	0, 0
<i>V. furcatum</i>	Absent	Umbel	Present	Rotate	<1	Yellow to red, becoming dark purple	Black	Ovoid-ellipsoid	1, 1
<i>V. odoratissimum</i> <i>var. awabuki</i>	Absent	Panicle	Absent	Tubular	3-4.2	Yellow	Black	Ellipsoid, rhombic	0, 1

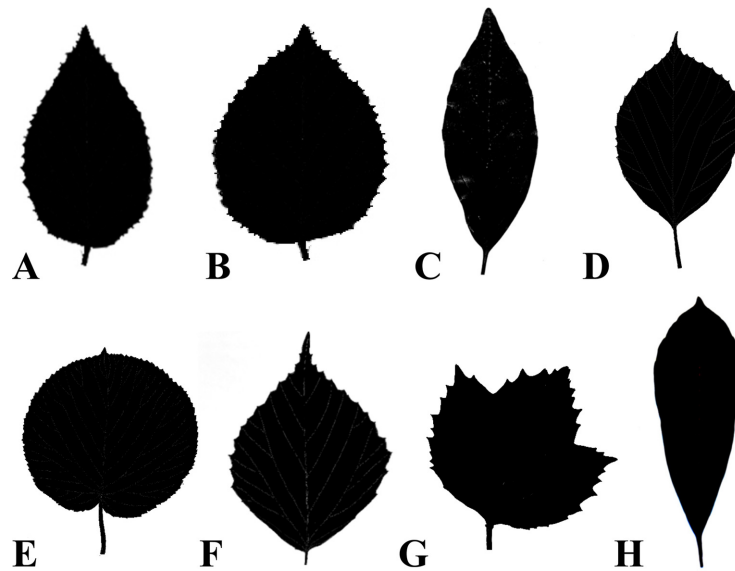


Fig. 2. Leaf shapes of *Viburnum* in Korea. **A.** Ovate. **B.** Broadly ovate. **C.** Elliptic. **D.** Obovate. **E.** Rounded. **F.** Rhombic. **G.** Suborbicular with three lobes. **H.** Oblanceolate. Distribution of the types can be found in Table 2.

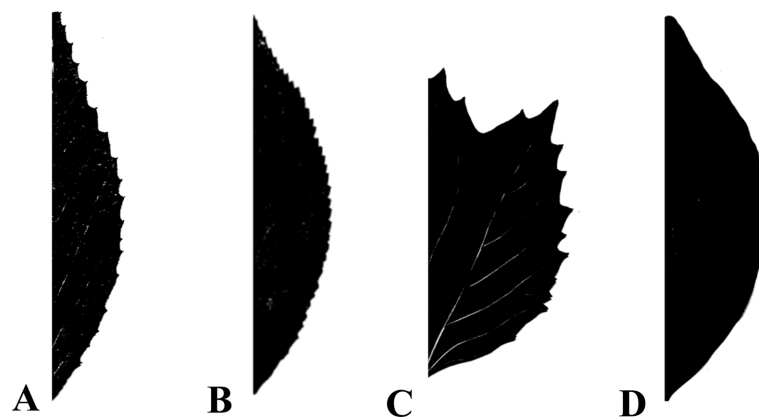


Fig. 3. Leaf margins of *Viburnum* in Korea. **A.** Serrate. **B.** Serrulate. **C.** Irregularly serrate. **D.** Entire. Distribution of the types can be found in Table 2.

apices of the species in Korea are acute, acuminate, obtuse, and rounded. Leaves with acute or obtuse apices are common and occur in *V. burejaeticum*, *V. erosum*, *V. dilatatum*, *V. wrightii*, *V. japonicum*, and *V. odoratissimum* var. *awabuki*. Leaves with acute to acuminate apices are found in *V. koreanum* and *V. opulus* var. *calvescens*. Leaves with acute or rounded apices are found in *V. carlesii*. Leaves of *V. furcatum* have rounded or acuminate apices. Members of the Korean *Viburnum* have cordate, rounded, obtuse, or cuneate leaf bases (Table 2). A cuneate or rounded leaf base is found in *V. dilatatum*, *V. erosum* var. *erosum*, *V. japonicum*, and *V. wrightii* and a cordate or rounded leaf base can be found in *V. carlesii*, *V. opulus* var. *calvescens*, *V. koreanum*, and *V. furcatum*.

Cuneate leaf base can be found in *V. odoratissimum* var. *awabuki*. Leaves of *V. burejaeticum* have obtuse or rounded bases and those of *V. carlesii* have obtuse, rounded, or cordate bases. Leaf margins of the Korean *Viburnum* species are serrate or serrulate, except for *V. odoratissimum* var. *awabuki*, which has an entire margin (Fig. 3, Table 2).

Extrafloral nectary

The presence of an extrafloral nectary is an important character within *Viburnum*. Extrafloral nectaries are found on the upper petiole and on the base of the abaxial surfaces of the leaves in the Korean species (Fig. 4A, B). An extrafloral nectary is absent in *V. burejaeticum*, *V. carlesii*, *V. furcatum*,



Fig. 4. Extrafloral nectary (A, B) and inflorescence (C, D) found in the species of *Viburnum* in Korea. A. Laminar nectary. B. Petiolar nectary. The arrow indicates an extrafloral nectary. C. Paniculate inflorescence. D. Umbellate inflorescence. Distribution of the types can be found in Table 2.

and *V. odoratissimum* var. *awabuki*. A petiolar extrafloral nectary is found in *V. koreanum* and *V. opulus* var. *calvescens*, and a laminar extrafloral nectary exists in *V. dilatatum*, *V. erosum* var. *erosum*, *V. japonicum*, and *V. wrightii*. Clement et al. (2014) showed that each type of extrafloral nectary evolved once within *Viburnum*. It is hypothesized that an extrafloral nectary is associated with mite-containing domatia, which are mutually beneficial to plants and mites (Romero and Benson, 2005).

Inflorescence

Two different types of inflorescence can be found in the Korean species of *Viburnum* (Fig. 4C, D, Table 2). Paniculate inflorescences are found in *V. odoratissimum* var. *awabuki*. Umbellate inflorescences are found in the remaining species

of *Viburnum*. The umbellate inflorescence in *Viburnum* exists in a compound form in which the cymes branch from a single point, resembling a compound umbel. Umbellate inflorescences are most common in *Viburnum*, as a paniculate inflorescence is only found in the *Solenotinus* clade (Clement et al., 2014). *Viburnum clemensiae*, a sister to the remaining species of *Viburnum* has paniculate inflorescences. Paniculate inflorescences in these lineages were independently derived from umbellate inflorescences (Clement and Donoghue, 2011). Paniculate inflorescences consist of lateral branches of cymes along the main axis, being panicles of cymes. Hara (1983) postulated that the umbellate inflorescence was derived from the paniculate inflorescence by means of the evolutionary condensation of internodes of the main axis. A phylogenetic analysis of *Viburnum* (Clement and Donoghue,

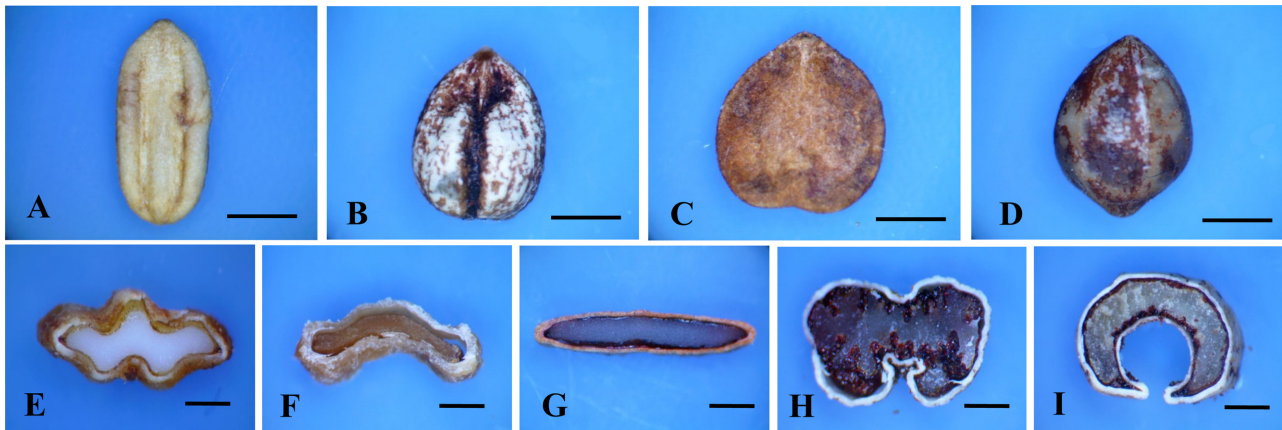


Fig. 5. Microscopic photographs of stones found in the species of *Viburnum* Korea. **A–D.** Overall shape of the stones. **E–I.** Cross-section of the stones. **A.** Ellipsoid. **B.** Ovoid. **C.** Cordate. **D.** Rhombic. **E.** Two dorsal (upper side in the photograph) and three ventral grooves. **F.** Two dorsal grooves and one ventral groove. **G.** Flat, without grooves on both sides. **H.** One dorsal and one ventral groove. **I.** One groove only on the ventral side. Scale bars: A–D = 2.5 mm, E–I = 1 mm.

2011), however, suggested that paniculate inflorescences evolved from an umbellate form by elongation of the primary axis.

Marginal sterile flowers occur in *V. opulus* var. *calvescens* and *V. furcatum*. The corolla lobes of the marginal flowers are three to five times longer than the corolla lobes of fertile regular flowers in the same inflorescence. All other species have only fertile flowers in an inflorescence.

Flower

Regular flowers of *Viburnum* are bisexual and actinomorphic. The corolla is rotate or tubular (Table 2). A tubular corolla is found in *V. carlesii* and *V. odoratissimum* var. *awabuki* and rotate corollas can be found in all other remaining species in Korea. Members of the Korean *Viburnum* have five stamens alternate to corolla lobes. Stamens are exerted in all species in Korea, except for *V. carlesii*, in which the stamens are included in the corolla tube. The length of the filaments in *V. carlesii* is the longest among the Korean members, in a range of 7–10 mm, whereas the filaments in the other species are 3–4 mm long. The anther color varies across the species in Korea (Table 2). Yellow anthers are common in the Korean members of *Viburnum*. Purple anthers are found in *V. opulus* var. *calvescens*. Anthers of *V. furcatum* are initially yellow to red but become dark purple.

Fruit

The fruits in all species of *Viburnum* are drupes containing a one-seeded stone. Fruits are red or black in maturity depending on the species (Table 2). Initially, the fruits in all species of the Korean *Viburnum* are red in color, but those in

V. burejaeticum, *V. carlesii*, *V. furcatum*, and *V. odoratissimum* var. *awabuki* turn black when mature.

The stone shape and the number of grooves have been used to distinguish the species within *Viburnum* (Hara, 1983). Among the Korean members of *Viburnum*, ellipsoid and ovoid shapes and their derivatives or intermediate forms can be found (Fig. 5, Table 2). The number of grooves on the stone is a clear phylogenetic signal and can be examined by the cross-section of the stone (Fig. 5). The cross-section of the stone in *V. opulus* var. *calvescens* is flat and with no groove on either side. Stones of *V. odoratissimum* var. *awabuki* have one groove on the ventral side only, and those of *V. furcatum* have one groove each on the dorsal and ventral sides. Two dorsal and one ventral grooves are found in the stones of *V. koreanum*. The type with two dorsal and three ventral grooves is most common in the Korean *Viburnum*, occurring in six species (*V. burejaeticum*, *V. carlesii*, *V. dilatatum*, *V. erosum* var. *erosum*, *V. japonicum*, and *V. wrightii*). The shapes of the cross-section of the stones can vary (Fig. 5).

Discussion

This study reviews the morphological characteristics of *Viburnum* in Korea, including *V. japonicum*, which is reported as being from Gageodo Island (Hong and Im, 2003). Despite the misconception that species of *Viburnum* may lack morphological features, various characters in the bud, leaf, extrafloral nectary, inflorescence, corolla, fruit, and stone are useful to distinguish the species and infer relationships.

Viburnum odoratissimum var. *awabuki* is most distinctive species in Korea by having evergreen leaves with an entire

1. Plants evergreen.
 2. Inflorescence paniculate *V. odoratissimum* var. *awabuki*
 2. Inflorescence umbellate *V. japonicum*
1. Plants deciduous.
 3. Winter buds naked or enclosed by a pair of caducous scales; leaves without extrafloral nectaries; drupes initially red, black at maturity; stones not compressed, deeply grooved.
 4. Buds with a pair of caducous scales becoming naked in winter; inflorescences subsessile; large marginal sterile flowers present; stones with 1 dorsal and 1 ventral grooves *V. furcatum*
 4. Buds naked from beginning; inflorescences pedunculate; all flowers fertile; stones with 2 dorsal and 3 ventral grooves.
 5. Corolla rotate white; stamens exserted *V. burejaeticum*
 5. Corolla tubular, pale pink; stamens included *V. carlesii*
 3. Winter buds enclosed by 2 or 3 pairs of scales; leaves with extrafloral nectaries on petioles or on abaxial surface; drupes red at maturity; stones compressed, shallowly grooved.
 6. Leaves 3–5-lobed, palmately 3–5-veined, extrafloral nectaries present on petioles.
 7. Marginal flowers in inflorescences sterile *V. opulus* var. *calvescens*
 7. All flowers fertile *V. koreanum*
 6. Leaves serrate, pinnately veined, extrafloral nectaries present at base on abaxial surface.
 8. Stipules present *V. erosum*
 8. Stipules absent.
 9. Branchlets glabrous; petioles glabrous or sparsely pubescent with simple hairs *V. wrightii*
 9. Branchlets and petioles densely pubescent with simple and stellate hairs *V. dilatatum*

Fig. 6. A key to the species of *Viburnum* in Korea

margin and paniculate inflorescences (Table 2). It is classified in the sect. *Solenotinus* (Rehder, 1908; Hara, 1983). Members of the section have a basic chromosome number of $x = 8$, paniculate inflorescences, and one deep longitudinal groove on the ventral side. *Viburnum odoratissimum* var. *awabuki* is found on Jeju Island in Korea and in Japan, Taiwan, and the Philippines. Plants with thin, widely obovate leaves with four to six lateral veins, and green petiole and sub-rotate corollas with a tube less than 2 mm long are considered as *V. odoratissimum* var. *odoratissimum* (Hara, 1983), which is distributed in Assam, Myanmar, northeastern Thailand, and western and central China.

Viburnum furcatum is easily distinguished from other members of the Korean *Viburnum* by having a pair of caducous bud scales resulting in naked buds in winter, stellate trichomes, umbellate inflorescences with marginal sterile flowers, and one groove each on both sides of the stones (Tables 1, 2). The species belongs to sect. *Pseudotinus* (Hara, 1983). It is commonly distributed from South Sakhalin to Japan but extends to Korea and then to Taiwan (Hara, 1983; Kim, 2007). Plants of this species are locally common at high elevations on Hallasan Mt. and are rare on Ulleungdo Island. An occurrence of the species at Jabyeongsan Mt. in Gangwon province in Korea was reported (Son et al., 2008), but we did not locate the population.

Viburnum carlesii was originally described from Korea (Incheon and west Korea) (Forbes and Hemsley, 1888) and can be easily distinguished from other members of Korean *Viburnum* by having tubular corollas in which stamens are included (Table 2). It is closely related to *V. burejaeticum* by having densely pubescent with stellate trichomes on the branchlets, petioles, and leaves; naked buds; and stones with two dorsal and three ventral grooves (Tables 1, 2). The two species are classified in sect. *Viburnum* (Hara, 1983) and placed in the *Lantana* clade (Clement et al., 2014). While *V. carlesii* is common in Korea, it is rare in Japan and China. *Viburnum burejaeticum* is distributed at high latitudes in Korea, the Russian Far East, and northeastern China, but is rare in Korea. Hara (1983) recognized *V. carlesii* var. *bitchiuense* (Makino) Nakai by having ovate or elliptic leaves with an acute apex and a roundish base, loose cymes, a pink corolla tube, and stamens inserted below the middle of the corolla tube with longer free filaments. The characteristics are variable within a population and the two varieties are thus considered as indistinct.

Viburnum koreanum and *V. opulus* are distinctive by having a petiolar extrafloral nectary (Fig. 4) and shallowly three-lobed leaves. *Viburnum opulus* is rather common and often planted in gardens and along streets. It is easily distinguished by having

marginal sterile flowers and an irregularly loose serrate leaf margin. Plants of the two species are usually glabrous, and leaves can be sparsely pubescent with simple hairs. *Viburnum koreanum* is rare in Korea and is distributed on Seoraksan Mt.

The *V. dilatatum* complex, which consists of four closely related species (*V. dilatatum*, *V. erosum*, *V. wrightii*, and *V. japonicum*), is characterized by free bud scales and serrate leaves with pinnate veins and extrafloral nectaries at proximal regions on the abaxial surface (Tables 1, 2). *Viburnum japonicum* can be easily distinguished from the other members of the complex by having evergreen leaves. It is distributed in the warm temperate forests of southern Japan and the Ryukyu archipelago, and disjunctively on Gageodo Island in Korea. Deciduous members of the complex *V. erosum*, found in southern China, Taiwan, southern Japan, and Korea, can easily be distinguished by having stipulate leaves and stellate trichomes together with simple hairs on bud scales and branchlets. Leaf shapes vary greatly, being obovate with a cuneate base, ovate with a rounded base, and deeply incised with two short lateral lobes at the base. Different types of leaves can be found on the same branch. *Viburnum dilatatum* is widely distributed in Korea, Japan, and China. Bud scales are usually densely pubescent with simple hairs, and branchlets are covered with both stellate and simple hairs. In contrast, plants of *V. wrightii* are glabrous except that the apex of bud scales, petioles, and leaves may have simple hairs. The leaves of *V. wrightii* tend to be wide compared to those of *V. dilatatum*. There are some plants showing intermediate or aberrant forms in the *V. dilatatum* complex. More detailed studies of the taxonomic nature and origin of these forms are underway.

Based on our morphological study, we here provided a key to the species of *Viburnum* in Korea (Fig. 6).

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Conflict of Interest

The authors declare that there are no conflicts of interest.

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Appendix 1. List of specimens examined in this study.

- V. burejaeticum*:** KOREA. Gangwon-do: Pyeongchang-gun, 4 Sep 2016, *Suh H. J.* 7129 (TUT); 5 May 2017, *Lee D. H.* 7194 (TUT); 8 May 2012, *Kim J. H. et al.* KIMJH12048 (KB 356575). CHINA. Jilin, Antu, 4 Jun 2011, *Kim J. S.* BDS72 (KB 289365).
- V. Carlesii*:** KOREA. Gangwon-do: Hongcheon-gun, 6 May 2004, *Yoo K. O. et al.* 1306 (KB 277454); Jeongseon-gun, 19 Apr 2016, *Nam G. H.* Baeki160223 (KB 568269); Pyeongchang-gun, 23 Apr 2016, *Kim S. H. & Oh Y. S.* PC02A3034 (KB 577861); Yanggu-gun, 1 May 2008, *Yoo K. O.* VP KB 387162 0143 (KB 154489); Yeongwol-gun, 2 Jun 2010, *Hyun J. O. & Kang S. I.* NAPI 20101309 (KB 300036). Gyeonggi-do: Incheon-si, Ongjin-gun, 14 Apr 2007, *Hyun J. O.* 2007018 (KB 110788); 16 Jun 2009, *Hyun J. O. et al.* NAPI 20100259 (KB 292426); 17 Jun 2009, *Hyun J. O. et al.* NAPI 20100398 (KB 292954); 22 May 2012, *Lee B. C. & Seo W. B. s.n.* (KB 428884). Gyeongsangbuk-do: Andong-si, 24 Apr 2007, *Jung K. Y.* ANH en 070424 003 (KB 121542); Ulleung-gun, Ulleungdo Island, 29 May 2017, *Ahn J. G.* 7274 (TUT).
- V. dilatatum*:** KOREA. Gyeongsangbuk-do: Sangju-si, 7 Jun 2008, *Chung G. Y. & Park M. S. s.n.* (KB 156815); Seongju-gun,

26 May 2012, *Kang S. H.* 358021 (KB 445136). Gyeongsangnam-do: Hapchun-gun, 28 May 2007, *Ko S. C. & Kim J. H.* s.n. (KB 277245). Jeollabuk-do: Wanju-gun, 14 May 2017, *Yun N. R.* 7214 (TUT). Jeollanam-do: Yeongam-gun, 19 Oct 2013, *Kim M. H.* seed3482 (KB 448592). Jeju-do: Aewol-eup, 4 Oct 2013, *Moon M. O. & Kim J. E.* 4926 (KB 478461); Jeju-si, Gujwa-eup, 2 Sep 2014, *Moon M. O.* 5806 (KB 512282); Odeung-dong, 2 Oct 2013, *Moon M. O. & Kim J. E.* 4895 (KB 478430).

***V. erosum* var. *erosum*:** KOREA. Gyeonggi-do: Incheon-si, Ganghwa-gun, 12 May 2015, *Na H. R.* N EX11 (KB 534161). Chungcheongnam-do: Taean-gun, 21 May 2015, *Lee H. S.* sulee20151 (KB 545752). Gyeongsangbuk-do: Gunsan-si, 20 May 2017, *Hwang S. H.* 7219 (TUT); Namwon-si, 2006, *Baek W. K.* s.n. (KB 278061); Pohang-si, 27 Jul 2005, *Kim Y. D. et al.* 05171 (KB 277686). Gyeongsangnam-do: Miryang-si, 17 Jun 2013, *Hong Y. H.* HNHM KB 131654 (KB 531012); Ulsan-si, 7 May 2007, *Lee S. M. & Bak S. S.* s.n. (KB). Jeollabuk-do: Imsil-gun, 5 May 2007, *Sun B. Y.* 1029 (KB 127413); Namwon-si, 2006, *Paik W. K. et al.* s.n. (KB 278061). Jeollanam-do: Sinan-gun, Hongdo Island, 20 May 2017, *Oh S. H. et al.* 7224 (TUT). Jeju-do, Jeju-si, Gujwa-eup, 29 Jul 2011, *Kim H. J.* 110729 JJ253 (KB 577555); Seogwipo-si, Namwon-eup, 15 Jun 2009, *Kang C. M. et al.* 27315 (KB 257106).

***V. furcatum*:** KOREA. Jeju-do: Jeju-si, Aewol-eup, 27 May 2010, *Moon M. O.* 339 (KB 291710); 16 Jun 2010, *Kim C. H. & Yoon N. R.* 50400 (KB 329347); 11 Sep 2010, *Ko S. C. & Son D. C.* HNHM 2010 1214 (KB 307714); 20 Jul 2011, *Ko S. C. et al.* HNHM 2001 0656 (KB 386202); Haean-dong, 26 Sep 2011, *Moon M. O. & Kim J. E.* 2509 (KB 368833); Jocheon-eup, 15 Apr 2014, *Moon M. O. & Im E. Y.* 5543 1 (KB 511949); Seogwipo-si, Hawon-dong, 22 Jun 2010, *Kang C. M. & Lim J. N.* 29854 (KB 317840); 15 May 2017, *Oh S. H. et al.* 7203 (TUT). JAPAN. Hokkaido: Sapporo Pref., 27 Aug 2017, *Oh S. H. et al.* 7464 (TUT).

***V. japonicum*:** KOREA. Jeollanam-do: Sinan-gun, Gageodo Island, 2 May 2009, *Hyun J. O. et al.* s.n. (KB 337387); 21 May 2011, *Nam K. H. et al.* Gageo118 (KB 289026); 22 May 2011, *Nam K. H. et al.* Gageo211 (KB 289119); Gageo234 (KB 289142); 13 Jul 2011, *Nam G. H. et al.* Gageo435 (KB 307885); 24 Oct 2013, *Choi H. G. et al.* 754 (KB 473764); 25 Oct 2013, *Choi H. K. et al.* 893 (KB 474443); 17 May 2017, *Lee D. H.* 7216 (TUT). JAPAN. Kyushu: Nagasaki Pref., 21 Aug 2018, *Hwang S. H. et al.* Kyushu-043 (TUT).

***V. koreanum*:** KOREA. Gangwon-do: Inge-gun, 3 Jun 2017, *Lee D. H.* 7294 (TUT). CHINA. Jilin, Fusong, 5 Aug 2018, *Suh H. J.* 7589, 7590 (TUT).

***V. odoratissimum* var. *awabuki*:** KOREA. Gyeongsangnam-do: Geoje-si, 19 Jun 2010, *Jeon E. S.* 348031(s0686) 0146 (KB 409268); Jeju-do: Jeju-si, Gujwa-eup, 5 May 2011, *Choi B. H. et al.* 336083 006 (KB 393880); Hangeyeong-myeon, 8 Oct 2009, *Kim D. S.* seed12 (KB 246520); Seogwipo-si, Andeok-myeon, 21 Mar 2012, *Kang S. H.* s.n. (KB 434902); Jungmun-dong, 4 Sep 2012, *Kang C. M. et al.* 36062 (KB 418140); 12 Jun 2017, *Choi Y. G.* 7317 (TUT); Namwon-eup, 5 Sep 2012, *Kang C. M. et al.* 36118 (KB 418149); Sanghyo-dong, 9 Jul 2010, *Kang C. M. & Hong S. C.* 29912 (KB 321129); Seongsan-eup, 13 Jun 2017, *Choi Y. G.* 7321 (TUT).

***V. opulus* var. *calvescens*:** KOREA. Gangwon-do: Cherwon-gun, 29 May 05 2017, *Hwang S. H.* 7275 (TUT); Hongcheon-gun, 9 Jun 2010, *Hyun J. O. & Kwon H. J.* NAPI 20101397 (KB 299993); Inge-gun, 30 Jun 2009, *Ko S. C.* HNHM 0339 (KB 252268); Jeongseon-gun, 12 Jun 2009, *Im H. T. et al.* Im0152 (KB 258540); 18 Sep 2009, *Im H. T. et al.* Im0515 (KB 258800); Pyeongchang-gun, 9 Jul 2009, *Jung J. D. & Kim C. K.* 0907282 1 (KB 255027); Wonju-si, 14 Jun 2003, *Kim K. J. et al.* 2003 0886 (KB 208170); Yanggu-gun, 23 Jun 2008, *Yoo K. O. et al.* s.n. (KB 154759); Yeongwol-gun, 26 May 2010, *Nam K. H. et al.* SHY291 (KB 235185). Gyeonggi-do: Incheon-si, 29 May 2017, *Oh S. H. et al.* 7273 (TUT); Yeoncheon-gun, 3 Jul 2008, *Lee J. H. et al.* 2008480768 (KB 161802); 23 Jul 2008, *Kim D. K. & Hwang S. H.* 387131 065 (KB 157769); 30 May 2017, *Hwang S. H.* 7276 (TUT). Chungcheongbuk-do: Danyang-gun, 4 Aug 2009, *Ko S. C. et al.* HNHM 1135 (KB 253062).

***V. wrightii*:** KOREA. Gangwon-do: Hoengseong-gun, 3 Jun 2008, *Ko S. C.* 2008 0009 (KB 198135); Inje-gun, 5 Sep 2009, *Kim H. W. & Yang S. Y.* 2008 0936 (KB 163578); 28 Aug 2009, *Moon M. O. et al.* CH41460 (KB 264939); 3 Jun 2010, *Yoo K. O. s.n.* (KB 492372); 16 Sep 2013, *Han B. W. et al.* NAPI S2013086 (KB 458890); Pyeongchang-gun, 30 Jun 2008, *Jung G. Y.* ANH en 080630 104 (KB 197686). Gyeongsangbuk-do: Ulleung-gun, Ulleungdo Island, 16 Sep 2005, *Hyun J. O. et al.* NAPI 20101239 (KB 293906). Jeollabuk-do: Jeongeup-si, 15 May 2011, *Kim C. H. et al.* J600415 (KB). Jeju-do: Jeju-si, Aewol-eup, 16 Jun 2010, *Kim C. H. et al.* J50374 (KB); Gujwa-eup, 4 May 2018, *Oh S. H. et al.* 7539 (TUT). JAPAN. Kyushu: Saga Pref., 20 Aug 2018, *Hwang S. H. et al.* Kyushu-003 (TUT).