



## *Symplocarpus koreanus* (Araceae; Orontioideae), a new species based on morphological and molecular data

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**ABSTRACT:** *Symplocarpus koreanus* (Araceae; Orontioideae) from Korea is described as new. *Symplocarpus koreanus* has long been considered to be conspecific with *S. renifolius* in Japan, but phylogenetic, morphological, and cytological data indicate its taxonomic distinction. Compared to *S. renifolius*, *S. koreanus* has a much smaller spathe and more spherical spadix with fewer, smaller flowers. Previous phylogenetic studies also suggested that *S. koreanus* is more closely related to nonthermogenic *S. nipponicus* than to *S. renifolius* in Japan. Like its nonthermogenic sister species, *S. nipponicus*, in Korea and Japan, *S. koreanus* is diploid ( $2n = 2x = 30$ ), while *S. renifolius* in Japan is tetraploid ( $2n = 4x = 60$ ). A detailed species description, geographical distribution, major morphological differences between the species and a dichotomous key to the species in eastern Asia are provided.

**Keywords:** Araceae, Orontioideae, *Symplocarpus koreanus*, Korean endemic, Korean skunk cabbage

*Symplocarpus* Salisb. ex W. P. C. Barton (Araceae, Orontioideae), a genus with disjunct distribution, represents one of a number of eastern Asian-eastern North American examples (Mayo et al., 1997). *Symplocarpus* includes five species, all but one occurring in eastern Asia. *Symplocarpus foetidus* (L.) Salisb. ex W. P. C. Barton is the only species in eastern North America, occurring from Nova Scotia, southern Quebec, and Minnesota to North Carolina and Tennessee. In eastern Asia, two species, *S. renifolius* Schott ex Tzvelev and *S. nipponicus* Makino, occur broadly throughout Japan, Korea, northeast China and the Russian Far East (Ohwi, 1984; Tsvelev, 1996; Ko, 2007; Li et al., 2010; Murata, 2016), while two recently described species, *S. nabekuraensis* Otsuka & K. Inoue and *S. egorovii* N. S.

Pavlova & V. A. Nechaev, occur narrowly in northern Nagano Prefecture in central Japan and the Primorye region in Russia, respectively (Otsuka et al., 2002; Pavlova and Nechaev, 2005). Two intercontinental disjunct sister species, *S. foetidus* in eastern North America and *S. renifolius* in eastern Asia, share several characteristics, such as flowering in early spring before the emergence of leaves, fruit ripening in the fall of the same year and exothermic spadices (Wada and Uemura, 2000; Ito et al., 2004). *Symplocarpus egorovii* is similar to *S. renifolius* and *S. foetidus*, but differs in its yellowish white spathe and distinct habitat in coniferous forests (Pavlova and Nechaev, 2005). *Symplocarpus nabekuraensis* can be distinguished from its congeneric species in Japan based on leaf shape and peduncle length

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(Otsuka et al., 2002). While *S. nipponicus* and *S. egorovii* are diploid ( $2n = 2x = 30$ ), *S. renifolius*, *S. foetidus*, and *S. nabekuraensis* are tetraploid ( $2n = 4x = 60$ ) (Sokolovskaya and Probatova, 1985; Iwatsubo and Otsuka, 2005; Marhold, 2008; Probatova et al., 2012). The three tetraploid species are known to have an exothermic spadix, whereas the diploid *S. nipponicus* has a non-exothermic spadix (Knutson, 1974; Wada and Uemura, 1994; Ito et al., 2004; Otsuka et al., 2011).

In a phylogeny of the subfamily Orontioideae based on extensive sampling in eastern Asia and eastern North America, we recognized several novel features (Nie et al., 2006; Lee et al., 2019). Two major lineages of *Symplocarpus* were revealed: one lineage included *S. foetidus*, *S. nabekuraensis* and *S. renifolius* (Japan); the other included *S. nipponicus*, *S. egorovii* and *S. renifolius* (Korea). We further confirmed that *S. renifolius* in Korea was diploid ( $2n = 30$ ), while *S. renifolius* in Japan and *S. foetidus* were tetraploid (Lee et al., 2019). The large scale phylogeny of *Symplocarpus* and chromosome numbers suggested that *S. renifolius* in Korea represented a distinct taxon. In this study, we compared several morphological characteristics between populations of *S. renifolius* in Japan and Korea. Based on the molecular, morphological, and cytological evidence, we here describe the populations of *S. renifolius* in Korea as a distinct taxon, *S. koreanus*.

## Taxonomic Treatment

***Symplocarpus koreanus*** J. S. Lee, S. H. Kim & S. C. Kim, sp. nov. (Fig. 1)—TYPE: Korea. Gangwon-do: Chuncheon-si, Sabuk-myeon, Goseong-ri, Sayeogol-gil, Yonghwasan Mountain, N 38 00.918, E 127 45.286, elev. 333 m, 21 Mar 2020, *S. C. Kim 200321500* (holotype: SKK; isotype: KB).

Herbs, perennial, seasonally dormant. Roots contractile, string-like, 1.6–5.3 mm in diam. Rhizome hypogenous, erect, 10–27 mm in diameter. Leaves in a rosette, appearing after flowers, 2–5; petiole basally sheathing, sulcate, purplish striped, 5.8–17 cm × 1.9–10.2 mm; leaf blade subcordate or cordate-ovate, 7–24 × 4.6–19 cm, yellowish green or green, base cordate or reniform, slightly uneven, margin entire, apex acute, acuminate, or obtuse; venation reticulate, midvein prominent, primary lateral veins 5–7 on each side of midvein, arching and branching apically, merging with inconspicuous marginal veins, lowermost veins running into basal lobes. Inflorescences 1–3, in a sympodium, appearing before leaves,

29–62 flowered; peduncle erect, partly below ground, shortly exerted above ground, terete, 3.5–21 cm × 0.3–2.1 mm, yellowish green or purplish tinged. Spathe hood-like, convolute at base, fleshy, 6–11 × 2.8–5.8 cm, yellowish brown or yellowish green, usually dark purple spotted or striped, apex 2-keeled, acute or acuminate, twisted or incurved, not persisting in fruit. Spadix subglobose or ellipsoid, 9.3–17 × 7.4–15 mm, stipitate; stipe cylindrical, 2–9.3 × 2–4.4 mm. Flowers bisexual, 2.7–5.5 × 2.3–5 mm; tepals 4, imbricate, yellow; stamens 4, free; filaments flattened, connective slender; anthers 2-locular, basifixed, yellow, dehiscing longitudinally; ovary 1-locular; ovule 1; style cylindrical, truncate or capitate. Infructescence globose or broadly ellipsoid, spadix 2.7–3.3 × 2.4–3 cm, stipe 10.8–19 × 4.5–6.3 mm. Fruit a berry, embedded in enlarged spongy spadix, initially greenish or dark purple, becoming blackish brown at maturity, ripening below ground in summer of same year. Seed brown, somewhat irregular in shape, 4.6–11.5 × 4.8–13.7 mm, smooth. Chromosome number:  $2n = 30$ .

**Etymology:** The specific epithet, *koreanus*, is based on the name of the country of origin, Korea.

**Vernacular name:** Han-guk-an-jeun-bu-chaе (한국안은부채).

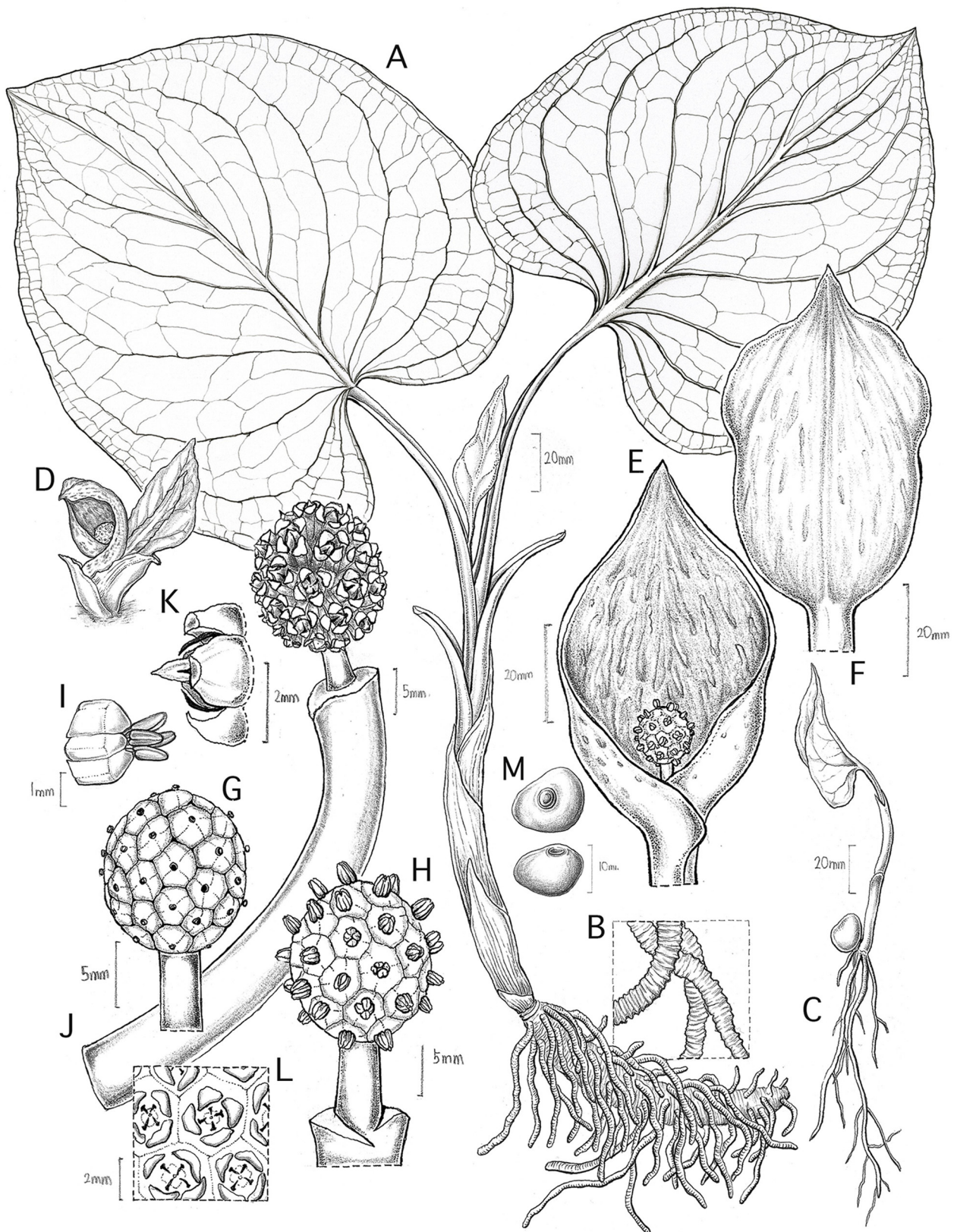
**English colloquial name:** Korean skunk cabbage.

**Phenology:** Flowering late February to April.

**Chromosome number:**  $2n = 2x = 30$ . 2C value range = 2.72–6.25 pg. (Fig. 2)

**Distribution and ecology:** *Symplocarpus koreanus* is restricted to the Korean Peninsula (North Korea, including Hamgyeongnam-do and South Korea, including Gyeonggi-do, Gangwon-do, Chungcheongbuk-do, Jeollabuk-do, Gyeongsangbuk-do, and Gyeongsangnam-do). It typically occurs in shaded, wet places, along streams and on moist rocky hillsides in mixed deciduous forests from ca. 100 to 750 m elevation.

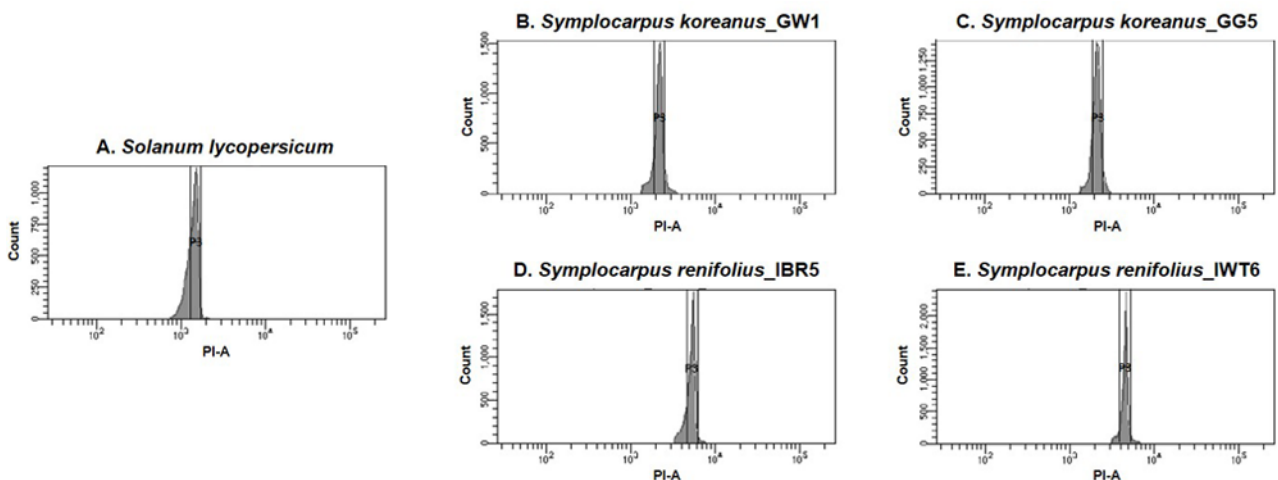
**Additional specimens examined:** KOREA. Gyeonggi-do: Gapyeong-gun, Buk-myeon, Baekdun-ri, Yeoninsan Mt., 3 May 2013, *W. B. Lee, NIBRVP0000517078* (KB); Gapyeong-gun, Oeseo-myeon, Hwayasan Mt., 26 Jun 2007, *W. K. Paik, VP-KB-377062-0173* (KB); Gapyeong-gun, Sang-myeon, Haenghyeon-ri, Chungnyeongsan Mt., 29 Mar 2016, *G. H. Nam et al., NIBRVP0000550794* (KB); 31 Mar 2012, *J. H. Kim et al., NIBRVP0000355001* (KB); Gapyeong-gun, Seorak-myeon, Yumyeongsan Mt., 4 Apr 2008, *B. G. Kwon, NIBRVP0000532404* (KB), *G. Y. Chung, NIBRVP0000197125* (KB); Gwacheon-si, Makgye-dong, Cheonggyesan Mt., 5 Apr 2012, *Y. S. Kim, 021215* (SKK); Gwangju-si, Taehwasan Mt.,



**Fig. 1.** *Symplocarpus koreanus*. A. Habit. B. Details of roots. C. Young plant. D. Flowering habit. E, F. Spathe and spadix. G. Pistillate phase spadix with stipe. H. Staminate phase spadix with stipe. I. Flower with four stamens. J–L. Inflorescence. M. Seeds.

19 Apr 2013, *K. I. Heo et al.*, 021210 (SKK); Hanam-si, Baealmi-dong, Geomdansan Mt., 3 Aug 2007, *J. O. Hyun et al.*, NIBRVP0000111433 (KB); 11 Sep 2015, *M. S. Cho et al.*, 035869 (SKK); Namyangju-si, Hwado-eup, Cheonmasan Mt., 15 Apr 2007, *W. K. Paik*, VP-KB-377061-0133 (KB); 22 Mar 2013, *Song et al.*, NIBRVP0000464822 (KB); Namyangju-si, Jinjeop-eup, Gwangreung, 24 May 1954, *T. G. Joo*, 021191 (SKK); Jun 1965, *T. H. Chung*, 021193 (SKK); Namyangju-si, Onam-eup, Onam-ri, Cheonmasan Mt., 6 Apr 2009, *G. H. Nam et al.*, NIBRVP0000206699, NIBRVP0000206700 (KB); Namyangju-si, Sudong-myeon, Chukryeongsan Mt., 28 Mar 1999, *S. P. Hong and K. W. Park*, NIBRVP0000102296 (KB); Paldalsan Mt., 31 May 1967, *T. B. Lee*, 00072835 (SNUA); Sudong-myeon, Namyangju-si, Chukryeongsan Mt., 5 Apr 2005, *J. Kim et al.*, 021204, 021224 (SKK); *M. H. Lim et al.*, 021232, 21203 (SKK); *N. I. Gong et al.*, 21202 (SKK); *S. R. Lee et al.*, 021199 (SKK), *T. E. Park et al.*, 021200 (SKK); 6 Feb 2007, *S. T. Lee et al.*, 021201 (SKK); 8 May 1993, *K. R. Lim et al.*, 021192 (SKK); 9 Apr 2010, *S. C. Kim et al.*, 021229 (SKK); 27 Apr 2007, *K. I. Heo et al.*, 021225, 021226, 021227, 021228, 021234 (SKK); 27 Mar 1992, *S. T. Lee et al.*, 021195, 021196 (SKK); 30 Mar 2002, *S. T. Lee et al.*, 021233 (SKK). Gangwon-do: Cheongnyeongpo, 13 Aug 2004, *J. M. Chung et al.*, 04080073 (KH); Cheorwon-gun, Geunnam-myeon, Gwangdeoksan Mt., 12 May 1997, *S. P. Hong and H. S. Choi*, NIBRVP0000102297 (KB); Chuncheon-si, Sabuk-myeon, Jipdarigol Recreation Forest, 30 May 2013, *S. C. Kim et al.*, 021208, 021209 (SKK); Chuncheon-si, Sabuk-myeon, Yonghwasan Mt., 5 Apr 2012, *K. I. Heo et al.*, 021211 (SKK); 30 May 1998, *D. M. Choi et al.*, 0003644 (HUH); 21 Mar

2020, *S. C. Kim et al.*, 200321001, 200321002, 200321003, 200321004, 200321005, 200321006, 200321007, 200321008, 200321009, 200321010, 200321011, 200321012, 200321013, 200321014, 200321015, 200321016, 200321017, 200321018, 200321019, 200321020, 200321021, 200321022, 200321501, 200321502, 200321503, 200321504 (SKK); 13 Jun 2020, *S. C. Kim et al.*, 200613001, 200613002, 200613003, 200613004, 200613005, 200613006, 200613007, 200613008, 200613009, 200613010, 200613011, 200613012, 200613013 (SKK); Chuncheon-si, Seo-myeon, Deokduwon-ri, Samaksan Mt., 1 Jul 2012, *K. I. Heo et al.*, 021216, 021217, 021231 (SKK); 30 Mar 2013, *S. C. Kim et al.*, 021206 (SKK); Chuncheon-si, Sindong-myeon, Jeongjok-ri, Geumbyeongsan Mt., 19 Jun 2007, *G. E. Yu*, 063114 (KWNNU); 1 Jul 2012, *K. I. Heo et al.*, 021221 (SKK); 30 Mar 2013, *S. C. Kim et al.*, 021207 (SKK); Deungseon Falls, 27 May 1995, *H. G. Lee et al.*, 0003645 (HUH); Donghaesi, Bugok-dong, Mita Temple, 26 Apr 2011, *G. H. Nam and W. J. Jeong*, NIBRVP0000284290 (KB); Gangneung-si, Wangsan-myeon, Gangneung-si, Hwaranbong Peak, 30 Apr 2009, *J. H. Kim and H. J. Kim*, NIBRVP0000318582 (KB); Garisan Mt., 15 Jun 2011, *K. O. Yoo et al.*, koyoo0118 (KH); Hugog Mineral Spring, 4 Jun 1999, *C. S. Chang*, 00070596 (SNUA); Hwacheon-gun, Baekjeoksan Mt., 24 May 2000, *K. C. Yang and J. D. Jung*, NIBRVP0000102304, NIBRVP0000102305 (KB); Hwacheon-gun, Sanae-myeon, Gwangdeok-ri, Gwangdeoksan Mt., 7 Apr 2007, *S. T. Lee et al.*, 021198, 021222 (SKK); Apr 2009, *G. H. Nam et al.*, NIBRVP0000206708 (KB); 7 Aug 2013, *S. T. Lee et al.*, 021205 (SKK); 7 May 2010, *K. I. Heo*, 021230 (SKK); 15 Apr 2006, *J. H. Lee et al.*, 021223 (SKK); 18 May 2012,



**Fig. 2.** Flow cytometry histograms of *Symplocarpus koreanus* and *S. renifolius*. **A.** *Solanum lycopersicum*, internal standard (2C = 1.96 pg.). **B.** *Symplocarpus koreanus* (GW1; Gangwon-do population, Korea). **C.** *S. koreanus* (GG5; Gyeonggi-do population, Korea). **D.** *S. renifolius* (IBR5; Ibaragi population, Japan). **E.** *S. renifolius* (IWT6; Iwate population, Japan).

*K. I. Heo et al.*, 021212, 021213, 021214, 021218, 021219, 021220 (SKK); 7 Apr 2009, *G. H. Nam et al.*, NIBRVP0000206709 (KB); Hwacheon-gun, Sangseo-myeon, Baekjeoksan Mt., 3 Aug 2000, *J. H. Kim and D. K. Kim*, NIBRVP0000102307 (KB) Chungcheongbuk-do: Danyang-gun, Gagok-myeon, Sobaecksan Mt., 17 May 1999, *C. W. Park et al.*, EN99SNU315 (KB); 20 Apr 2007, *G. Y. Chung*, NIBRVP0000121631 (KB); Dutasan Mt., 25 May 2002, *B. U. Oh et al.*, 04206 (CBU); Gaseopsan Mt., 30 Apr 2000, *S. H. Paeng et al.*, 04204 (CBU); Geumdangsan Mt., 22 May 1999, *C. S. Chung et al.*, 04202 (CBU); Guryongsan Mt., 17 May 1997, *B. U. Oh et al.*, 07317 (CBU); Ingyeongsan Mt., 21 May 2011, *B. U. Oh et al.*, 22620 (CBU); Seondosan Mt., 31 May 1997, *B.*

*U. Oh et al.*, 08908 (CBU); Sosokisan Mt., 13 May 2005, *B. H. Oh et al.*, *Eumseonggun (Sosogisan)-0505* (KH). Jellabuk-do: Jangsu-gun, Geunnam-myeon, Jangan-ri, 21 Sep 1997, *B. Y. Sun and C. H. Kim*, EN98JNU 464 (KB); Jangsu-gun, Gyeonam-myeon, Jangansan Mt., 19 Jun 2009, *J. K. Ahn et al.*, NIBRVP0000266477, NIBRVP0000266707 (KB); 19 May 2007, *B. Y. Sun*, NIBRVP0000128343 (KB); Jinan-gun, Jucheon-myeon, Daebul-ri, Unjangsan Mt., *C. H. Kim and S. H. Lee*, NIBRVP0000537859 (KB); Sunchang-gun, Gurim-myeon, Ansim-gil, Hoemunsan National Recreation Forest, 14 Mar 2014, *S. H. Kim et al.*, 2014314500 (SKK). Gyeongsangbuk-do: Bibongsan Mt., 6 Aug 2000, *S. W. Lee et al.*, 218 (KNU); Gallasan Mt., 6 Jun 2008, *M. S. Park*, ANH-

**Table 1.** Comparison of key diagnostic features between *Symplocarpus koreanus* and *S. renifolius*.

Character		<i>S. koreanus</i> (mean ± SD)	No. of plants	<i>S. renifolius</i> (mean ± SD)	No. of plants
Root	Root thickness (mm)	1.56–5.26 (3.22 ± 0.73)	6	-	-
	Rhizome thickness (mm)	9.90–26.99 (18.88 ± 6.82)			
Leaves	Petiole length (cm)	5.77–16.95 (11.15 ± 3.68)	29	-	-
	Petiole width (mm)	1.88–10.20 (5.03 ± 1.87)			
	Blade length (cm)	6.93–23.47 (12.00 ± 4.03)	29	-	-
	Blade width (cm)	4.56–18.79 (9.30 ± 3.63)			
	Number of primary lateral veins	5–7 (5.92 ± 0.64)	13	-	-
Inflorescence and flowers	Peduncle length (cm)	3.46–20.79 (12.76 ± 5.34)	18	-	-
	Peduncle width (mm)	0.33–2.04 (0.92 ± 0.33)			
	Spathe length (cm)	5.59–10.90 (7.50 ± 1.27)	22	6.10–12.51 (8.85 ± 1.65)	26
	Spathe width (cm)	2.79–5.82 (4.22 ± 0.74)		3.83–7.59 (5.51 ± 1.06)	
	Spadix length (mm)	9.27–16.88 (12.21 ± 2.01)	22	13.42–32.60 (21.59 ± 4.24)	26
	Spadix width (mm)	7.44–15.04 (10.42 ± 1.76)		9.52–23.07 (15.14 ± 2.86)	
	Spadix ratio (length/width)	1.02–1.44 (1.18 ± 0.09)		1.14–1.70 (1.43 ± 0.14)	
	Stipe length (mm)	2.01–9.27 (5.66 ± 2.03)	22	-	-
	Stipe width (mm)	2.04–4.36 (3.14 ± 0.58)			
	Flower number/Spadix	29–62 (40.04 ± 8.70)	22	37–113 (79.34 ± 17.16)	26
	Flower size widest (mm)	2.65–5.51 (3.84 ± 0.51)		3.15–7.56 (4.72 ± 0.85)	
	Flower size narrowest (mm)	2.26–5.00 (3.37 ± 0.43)		2.98–6.29 (4.22 ± 0.65)	
Chromosomes	Chromosome number (2n)	30	60		
	Ploidy level	2x, diploid	4x, tetraploid		
	2C value (pg.)	Gangwon population: 2.92–6.25 (4.63 ± 0.85)	13	Ibaragi population: 6.11–7.63 (7.08 ± 0.39)	12
	Gyeonggi population: 2.72–6.02 (3.99 ± 0.68)	16	Iwate population: 5.69–7.93 (6.96 ± 0.71)	7	

Measurements were made from fresh samples of two representative populations of *S. koreanus* (Gangwon-do, Yonghwasan Mt. and Gyeonggi-do, Chungryungsan Mt.) and *S. renifolius* (Iwate and Ibaragi Prefectures) as well as from herbarium specimens (Appendix 1). Representative voucher specimens of measured populations from Korea and Japan were deposited at SKK and TUS, respectively (see additional specimens examined). “-” Measurements were not taken due to lack of fresh materials.

000014010 (ANH); Jachosan Mt., 13 May 2010, G. Y. Chung et al., ANH-100513125 (ANH); Joosan Mt., 20 May 1999, D. R. Choi and S. G. Kwon, 00072844 (SNUA); Maengdongsan Mt., 28 Aug 2006, G. Y. Jeong, Jeong210 (KH); Muposan Mt., 2 Oct 2010, G. Y. Chung et al., ANH-000012103 (ANH); Podosan Mt., 7 Jul 2007, G. Y. Chung et al., ANH-0001504 (ANH). Gyeongsangnam-do: Geochang-gun, Buksang-myeon, Deokyusan Mt., 31 May 2006, B. Y. Sun, NIBRVP0000119643 (KB).

**Note:** *Symplocarpus koreanus* has long been considered to be conspecific with *S. renifolius* in Japan (Appendix 1). A recent phylogenetic study based on extensive sampling revealed that *S. renifolius* in Korea, now described as *S. koreanus*, is more closely related to *S. nipponicus* in Korea and Japan than it is to *S. renifolius* in Japan and the Russian Far East (Lee et al., 2019).

Morphologically, *S. koreanus* is most similar to *S. renifolius* in Japan, including in life history traits, perhaps sharing their

**Table 2.** Comparison of major features of *Symplocarpus koreanus* and related species in eastern Asia.

Character	<i>S. koreanus</i>	<i>S. renifolius</i>	<i>S. egorovii</i>	<i>S. nipponicus</i>	<i>S. nabekuraensis</i>
Distribution	Korea	China (Heilongjiang), Japan, Russia (Far East)	Russia (South Primorian)	China (Heilongjiang), Korea, Japan	Japan (Nagano Pref., Honshu)
Leaves: number	2–4	Several	10–40	2–5	3–5
Petiole: length (cm)	5.8–17	Up to 40	30–50	Up to 30	20–50
Leaf blade shape	Subcordate or cordate-ovate	Orbicular-cordate	Widely ovate	Ovate to ovate-oblong	Reniform–cordate
Leaf base	Cordate or reniform	Deeply cordate	Deeply cordate	Obtuse to cordate-subcordate	Cordate
Blade length (cm)	6.9–23.5	30–40	17–24	10–20	10–25
Blade width (cm)	4.6–18.8	Up to 33	15–18	7–12	20–40
Primary lateral veins: number	5–7	5	3–5	6 or 7	–
Leaf emergence	After emergence of spathe	After emergence of spathe	Simultaneous with spathe emergence	Before emergence of spathe	Simultaneous with spathe emergence
Leaf senescence	Summer	Summer or Autumn	Summer (mid-August)	Summer	Autumn
Spathe: apex posture	Elongated and pointing horizontally	Elongated and pointing horizontally	Short and pointing upward	Short and pointing upward	Short and pointing upward
Spathe position	Basal part in ground	Basal part in ground	Basal part in ground	Basal part in ground	Above ground
Spathe length (cm)	6–11	15–20	5–8	4–7	4–7
Peduncle length (cm)	3.5–20.8	7–13 (–20)	Up to 10	–	4–8
Spadix shape	Subglobose or ellipsoid	Ellipsoid	Spherical	Ellipsoid	Ellipsoid
Spadix length (mm)	9.3–16.9	13.4–32.6	25	–	–
Spadix width (mm)	7.4–15	9.5–23.1	20	–	–
Flowering season	Late Feb–early Mar	Late Feb–early Mar	Late Mar–early Apr	Mid-Jul–late Aug	Late Jun–early Jul
Seed size: widest (mm)	4.6–11.5	–	10	–	2–10
Fruiting	Same year as flowering	Same year as flowering	Same year as flowering	Following year after flowering	Same year as flowering
Spadix exothermic	Yes	Yes	Unknown	No	Yes
Chromosome number (2n)	30 Lee et al. (2019)	60 Sokolovskaya and Probatova (1985), Iwatsubo and Otsuka (2005)	30 Marhold (2008)	(28), 30 Iwatsubo and Otsuka (2005), Jang and Weiss–Schneeweiss (2018)	60 Iwatsubo and Otsuka (2005)

most recent common ancestor. However, *S. koreanus* has a much smaller and more spherical spadix with fewer, smaller flowers than *S. renifolius* (Tables 1, 2). The average spadix length of *S. koreanus* is 12 mm, while that of *S. renifolius* is 22 mm. In addition, the average spadix width of *S. koreanus* is 10 mm, whereas that of *S. renifolius* is 15 mm. The ratio between spadix length (L) and width (W) is also different: 1.2 and 1.4 for *S. koreanus* and *S. renifolius*, respectively. Lastly, *S. koreanus* has many fewer flowers per spadix than *S. renifolius*: average of 40 versus 79. Thus, the spadix of *S. koreanus* in its size, shape and flower number is more similar to the spadix of *S. nipponicus* than to *S. renifolius*.

We utilized flow cytometry to estimate ploidy level between *S. koreanus* and *S. renifolius* (see comprehensive review and references in Kron et al., 2007). Briefly, young, fresh leaf samples were analyzed on BD FACSAria Fusion Sorter System (BD Biosciences Ltd., Franklin Lakes, NJ, USA) in the Cooperative Center for Research Facilities in the School of Medicine at Sungkyunkwan University. We followed the general procedures described in Doležal et al. (2007); each analysis was repeated three times. It was previously determined that three previously sampled populations of *S. koreanus* (Geumbyeong, Samak, and Ungil mountains) were diploid (Lee et al., 2019). Flow cytometry in this study confirmed that the genome of *S. koreanus* was diploid when compared to the tetraploid genome of *S. renifolius* in Japan (Fig. 2). Two additional populations of *S. koreanus* (Gangwon-do, Yonghwasan Mt. and Gyeonggi-do, Chungryungsan Mt.) had 2C (pg.) average values of 4.63 and 3.99, respectively. In contrast, the 2C value of *S. renifolius* had an average value of 7.08 for a population in Ibaragi Prefecture and 6.96 for a population in Iwate Prefecture. The flow cytometry results showed twice the 2C value in *S. koreanus*, suggesting a different ploidy level, as previously determined using karyotyping (Iwatsubo and Otsuka, 2005; Lee et al., 2019).

### Key to the species of *Symplocarpus* in eastern Asia

1. Inflorescence emerging before leaves in early spring; apex of spathe oriented horizontally.
2. Leaf blade 30–40 cm long; spathe 15–20 cm long; spadix 1.3–3.3 cm long ..... *S. renifolius* 앓은부채
2. Leaf blade 6.9–23.5 cm long; spathe 6–11 cm long; spadix 0.9–1.7 cm long ... *S. koreanus* 한국앓은부채
1. Inflorescence emerging simultaneously with leaves in early spring or summer, or after leaves in summer; apex of spathe erect.
3. Inflorescence emerging after leaves in summer; leaf blade narrowly ovate to ovate-oblong; fruits ripening in spring of following year after flowering ..... *S. nipponicus* 앓기앓은부채
3. Inflorescence emerging simultaneously with leaves in early spring or summer; leaf blade cordate to widely ovate; fruits ripening in summer of same year as flowering.
4. Leaves 3–5, blade 20–40 cm wide; spadix ellipsoid; base of spathe above ground; flowering late June to early July; endemic to Japan ..... *S. nabekuraensis*
4. Leaves 10–40, blade 15–18 cm wide; spadix spherical; base of spathe partly below ground; flowering late March to early April; endemic to Russian Far East ..... *S. egorovii*

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### Conflict of Interest

The authors declare that there are no conflicts of interests.

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**Appendix 1.** Specimens of *S. renifolius* examined in this study.

JAPAN. Aomori Prefecture: Aomori City, Komagome, Michinokufukasawa Spa, 10 Jul 2004, *K. Yonekura*, TUS304706 (TU). Fukushima Prefecture: Omotego village, Kanayama, 3 May 1997, *K. Yonekura et al.*, TUS188229 (TU). Hokkaido Prefecture: Atsuma village, Haronai Mt., 21 May 1985, *H. Takahashi et al.*, TUS114928 (TU); Horokanai Town, Uryu Experimental Forest of Hokkaido University, 20 Jun 1996, *K. Yonekura and E. Hayasaka* TUS180566 (TU); Samani Town, Utoma, 13 May 1997, *H. Yamaji*, TUS390845 (TU). Hyogo Prefecture: Yoka Town, Myouken, 27 Apr 1986, *N. Kurosaki*, TUS125469 (TU). Ishikawa Prefecture: Komatsui City, Gohyaku Pass, 1 May 1994, *K. Yonekura*, TUS167165 (TU). Miyagi Prefecture: Marumori Town, Jiro-Taro Mt., 3 May 1984, *T. Yokoyama s.n.*, TUS245294 (TU); Marumori Town, Touge, 30 Mar 2012, *S. Y. Lee*, TUS419857 (TU). Tochigi Prefecture: Imaichi City, Fubasami, 828 May 1982, *H. Ohashi et al.*, TUS72187 (TU); Nakagawa Town, Umezo Park, 9 Apr 2012, *S. Y. Lee*, TUS419858 (TU).