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A Palynotaxonomic Study of Korean *Adonis* (Ranunculaceae)

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The pollen morphology of Korean *Adonis* was examined to clarify its specific recognition. Pollen grains were divided into two major types, according to the size and number of their echinae; those with many small echinae were further subdivided into two subtypes: 2 to 3 aligned foveolae vs. unaligned foveolae. The three types of pollen morphology determined here agree well with recent taxonomic treatments of Korean *Adonis*. Those analyses, based on morphological and molecular properties, previously recognized *Adonis amurensis, Adonis multiflora,* and *Adonis pseudoamurensis.*

Keywords: *Adonis amurensis, A. multiflora, A. pseudoamurensis*, pollen morphology, Ranunculaceae

The *Adonis* genus (Ranunculeae; Ranunculaceae) has conventionally included both perennial and annual herbs. Approximately 30 species are widely distributed in the temperate zones of Asia and Europe, and less frequently in southwestern Asia, northern Africa, and the Mediterranean region (Wang, 1980, 1994a, b; Mabberley, 1990; Tamura, 1991). Recently, Holub (1998) has transferred its perennial members to *Chrysocyathus* Falcon, in combination with *Adonanthe*, so that *Adonis* now contains solely annual species. However, in the study presented here, the generic name of *Adonis* is applied *sensu lato* to Korean taxa because the removal of those perennial members by Holub (1998) requires further confirmation.

In addition to taxonomic disagreements at the generic level, considerably different ideas have been suggested for Korean *Adonis* at the specific level. Nakai (1952) reported three varieties of *A. amurensis* Regel et Radde from Korea -- *parviflora* Nakai, *ramosa* Makino, and *uniflora* Makino. However, Chung (1965) recognized only two of these in his study of Korean flora. Those included *A. amurensis* var. *parviflora*, from all over the Korean peninsula and Cheju Island, plus *A. amurensis* var. *ramosa*, from Daenanji Island (Chungcheongnam-do) and Gwangneung (Kyunggi-do). Later authors accepted no varieties for that original species (Park, 1974; Lee, 1980).

Lee (1996) claimed that Korean *Adonis* constituted four taxa by adding three new infraspecific taxa of *A. amurensis*, namely ssp. *nanus* Y. Lee, for. *argentatus* Y. Lee, and for. *viridiscensicalyx* Y. Lee. *A. amurensis* var. *ramosa* Makino was also recognized for the Korean genus. In contrast, Lee (1998) newly described *A. longicalyx* S. Park et S. Lee (nom. nud.) and *A. ramosa* var. *pulchra* S. Park et S. Lee (nom. nud.). Recently, Suh et al. (2002) have used the results of RAPD molecular analysis and ITS sequencing to assert that Korean *Adonis* comprises *A. amurensis, A. pseudoamurensis* Wang, and *A. multiflora* Nishikawa et Ito. Examination of the *Adonis* morphology as well as scanning electron-microscopic features of its fruit have also strongly supported the molecular data (Lee et al., 2003).

Nishikawa (1988, 1989a, b) recognized three species of *Adonis* in Japan based on chromosome number and morphological characteristics: *A. amurensis, A. ramosa*, and *A. multiflora*. However, Suda and Herai (1991) stated that the latter two were conspecific with the former, despite their different numbers of chromosomes. Wang (1980) had described *A. pseudoamurensis,* a new species from Liaoning and Kirin (China), which lacks cauline leaves and has ovoid to rhomboid sepals. Later, both *A. pseudoamurensis* and *A. multiflora* were synonymized to *A. ramosa* (Wang and Liu, 1988; Wang, 1994a, b).

The pollen morphology of Ranunculaceae is a useful tool for estimating the relationships among taxa (Lee and Blackmore, 1992); that of the *A. amurensis* populations in Japan has already been examined (Sohma and Suda, 1992). Li and Zhang (1989) divided the pollens of Chinese *Adonis* taxa into two major

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types -- *Adonis* and *Consiligo* and also designated four subtypes. Park (1995) then classified 30 taxa of *Adonis* into two subgenera, *Adonis* and *Adonanthe*, with the latter containing two sections, i.e., *Veranales* and *Chrysocyathus*, based on their pollen morphology. In that same study, Korean *Adonis* was placed in section *Chrysocyathus* (of subgenus *Adonanthe*), but that decision was later criticized for its mis-identification of Korean *Adonis* as well as for neglecting the foveolae (Lee et al., 2003).

In this study, the morphological characteristics of pollen from Korean *Adonis* were examined in order to clarify its taxonomic entity as it compared with recent specific recognitions, based on morphology and molecular data. The pollen morphology of some *Adonis* taxa from China, Russia and Japan were also investigated for purposes of comparison.

MATERIALS AND METHODS

Pollen grains of *Adonis* species were collected from 13 localities in Korea. As a reference source, grains from *A. pseudoamurensis*, *A. multiflora*, and *A. ramosa* were also sampled from 5 sites in Japan, as well as from herbarium specimens of *A. pseudoamurensis* and *A. amurensis* at the Peking Botanical Garden and the Gray Herbarium, respectively (Table 1).

These pollen grains were acetolyzed according to the method of Erdtman (1972), as modified by Kim and Lee (1978). The acetolyzed grains (at least 20 per sample) were sealed in glycerin jelly and measured under a light microscope (Leiborlux 12; Leitz). They were air-dried on the stub, ion-coated with Au by an ion sputter (JFC-1100, JEOL), and examined at 20KV under a scanning electron microscope (EM-ASID-4D, JEOL) for measurements and photographs. All terminology and abbreviations followed those defined by Erdtman (1972).

RESULTS

General Description

The pollen grains of the *Adonis* species are monad. Their dimensions range from 24.39 to 36.54 μm in polar axis length and 22.02 to 33.23 μm in equatorial diameter, with the smallest being found at Mt. Jeoksang (25.86 × 22.31 μm average) and the largest located at Mt. Jeombong (36.54 × 30.99 μm). Polar shapes are circular; equatorial shapes, oblate-spheroidal to subprolate (P/E = 0.95 to 1.30) (Table 2). The aperture is tricolpate, or rarely 6-pantocolpate. Surfaces are echinate on the foveolate surface, with the foveolae being round to elongate, and a few, straightly aligned (Fig. 1). Their exine thicknesses range from 1.54 to 2.65 μm, with the polar exine being slightly thicker than the equatorial one (Table 2).

Based on these foveolae and echinae features, we can separate the pollen grains of Korean *Adonis* and *A. ramosa* from Japan into three major types and

Table 1. Taxa of *Adonis* included in this study. Asterisks represent reference pollen from the vicinity of Korea.

Taxa and localities		Collector and no. (Voucher)	
A. amurensis	Mt. Cheonma, Gyeonggi-do	Lee, S et al. s.n.	(SKK)
	Mt. Chukryong, Gyeonggi-do	Lee, S et al. s.n.	(SKK)
	Mt. Jeombong, Gangwon-do	Lee, CH et al. s.n.	(SKK)
	Mt. Jeoksang, Jeollapuk-do	Lee, S et al. s.n.	(SKK)
	Primorskij (Mandshuria), Russia*	Legit N Palezewsky	(GH)
	Deokjeok Isl., Gyeonggi-do	Lee, S et al. s.n.	(SKK)
A. pseudoamurensis	Jangbong Isl. 1, Gyeonggi-do	Lee, S et al. s.n.	(SKK)
	Jangbong Isl. 2, Gyeonggi-do	Lee, S et al. s.n.	(SKK)
	Mt. Gyeryong, Chungcheongnam-do	Lee, S et al. s.n.	(SKK)
	Palgong Mt., Gyeongsangbuk-do	Lee, CH et al. s.n.	(SKK)
	Uiryeong, Gyeongsangbuk-do	Lee, NS et al. s.n.	(SKK)
	Naesosa, Byunsan, Jeollabuk-do	Lee, NS et al. s.n.	(SKK)
	Nishiyoshino-mura, Yoshino-gun, Nara Pref., Japan*	Lee, NS & S Yeau s.n.	(SKK)
	Kirin, Hweinan, China*	Chen, C 1204	(PE)
A. multiflora	Gwaneumsa, Mt. Halla, Jeju-do	Lee, S et al. s.n.	(SKK)
	Eorimok, Mt. Halla, Jeju-do	Lee, S et al. s.n.	(SKK)
	Ryonuma, Nishine-mashi, Iwate Pref., Japan*	Lee, N.S. & Suda TS4973	(SKK)
A. ramosa	Tamayama-mura, Nishigori, Iwate Pref., Japan*	Lee, NS & Suda NG4886	(SKK)

Table 2. Pollen measurements from *Adonis* taxa.

Taxa and localities	Polar length	Equatorial diameter	P/E	Exine thickness[1]		Foveola no.[2]	Echina			
				pole	equator		no.[2]	Ht	Wh	H/W
Pollen Type I (*A. amurensis*)										
Mt. Cheonma	30.85 ± 2.89[3]	28.00 ± 2.35[3]	1.10	2.60 ± 0.52[3]	2.09 ± 0.08[3]	40	4	1.04	0.70	1.49
Mt. Chukryong.	27.36 ± 1.00	28.50 ± 1.46	0.96	2.35 ± 0.22	2.05 ± 0.24	36	2	1.03	0.69	1.49
Mt. Jeoksang	25.86 ± 2.86	22.31 ± 1.94	1.16	2.49 ± 0.29	2.11 ± 0.22	27	2	0.90	0.63	1.43
Mt. Jeombong	36.54 ± 2.45	30.99 ± 1.65	1.18	2.14 ± 0.27	1.59 ± 0.27	30	3	1.24	0.85	1.46
Prov. Primorskij Russia*	-[4]	-	-	-	-	25	3	0.94	0.74	1.27
Pollen Type II (Japanese *Adonis ramosa*)										
Tamayama-mura, Japan	32.25 ± 1.34	33.23 ± 1.49	0.97	1.86 ± 0.36	1.73 ± 0.35	20	4	0.80	0.63	1.27
Pollen Type III-1 (*A. multiflora*)										
Gwaneumsa	31.50 ± 1.58	24.36 ± 0.78	1.29	2.52 ± 1.58	2.06 ± 0.32	40	7	0.59	0.81	0.73
Eorimok	31.06 ± 1.51	26.98 ± 1.34	1.15	2.12 ± 0.22	1.89 ± 0.37	35	8	0.47	0.60	0.78
Ryonuma, Japan	29.51 ± 1.10	25.04 ± 1.42	1.18	2.35 ± 0.27	1.96 ± 0.28	27	6	0.35	0.44	0.80
Pollen Type III-2 (*A. pseudoamurensis*)										
Deokjeok Is.	26.43 ± 1.06	26.32 ± 1.37	1.00	2.29 ± 0.25	2.12 ± 0.32	44	11	0.67	0.63	1.06
Uiryoung	30.04 ± 1.09	31.16 ± 0.93	0.96	2.75 ± 0.35	2.65 ± 0.38	47	8	0.42	0.42	0.84
Jangbong Isl. 1	24.39 ± 1.07	25.73 ± 1.04	0.95	2.24 ± 0.26	2.42 ± 0.29	32	6	0.51	0.51	1.28
Jangbong Isl. 2	28.68 ± 1.42	22.02 ± 0.92	1.30	1.61 ± 0.18	1.15 ± 0.20	55	17	0.31	0.31	1.29
Mt. Gyeryong	30.04 ± 1.28	28.00 ± 2.35	1.10	2.63 ± 0.32	2.09 ± 0.44	43	10	0.49	0.49	1.11
Gwanchon	33.93 ± 3.42	31.16 ± 1.71	1.09	2.66 ± 0.36	2.41 ± 0.48	23	6	0.51	0.51	0.74
Naesosa	29.76 ± 3.05	24.02 ± 1.30	1.15	1.98 ± 0.32	1.47 ± 0.30	35	7	0.67	0.67	1.24
Mt. Palgong	34.49 ± 2.60	28.78 ± 2.40	1.20	2.20 ± 0.22	2.00 ± 0.27	23	7	0.74	0.74	0.94
Kirin, China	27.93 ± 2.00	26.32 ± 2.14	1.07	1.61 ± 0.36	1.54 ± 0.40	46	6	0.65	0.65	1.02

[1]unit in μm; [2]number per 49 μm; [3]mean ± standard deviation; [4]Not measured due to bad condition, *This is assigned to Type I based only on echinae number, height, and geographical distribution.

two subtypes.

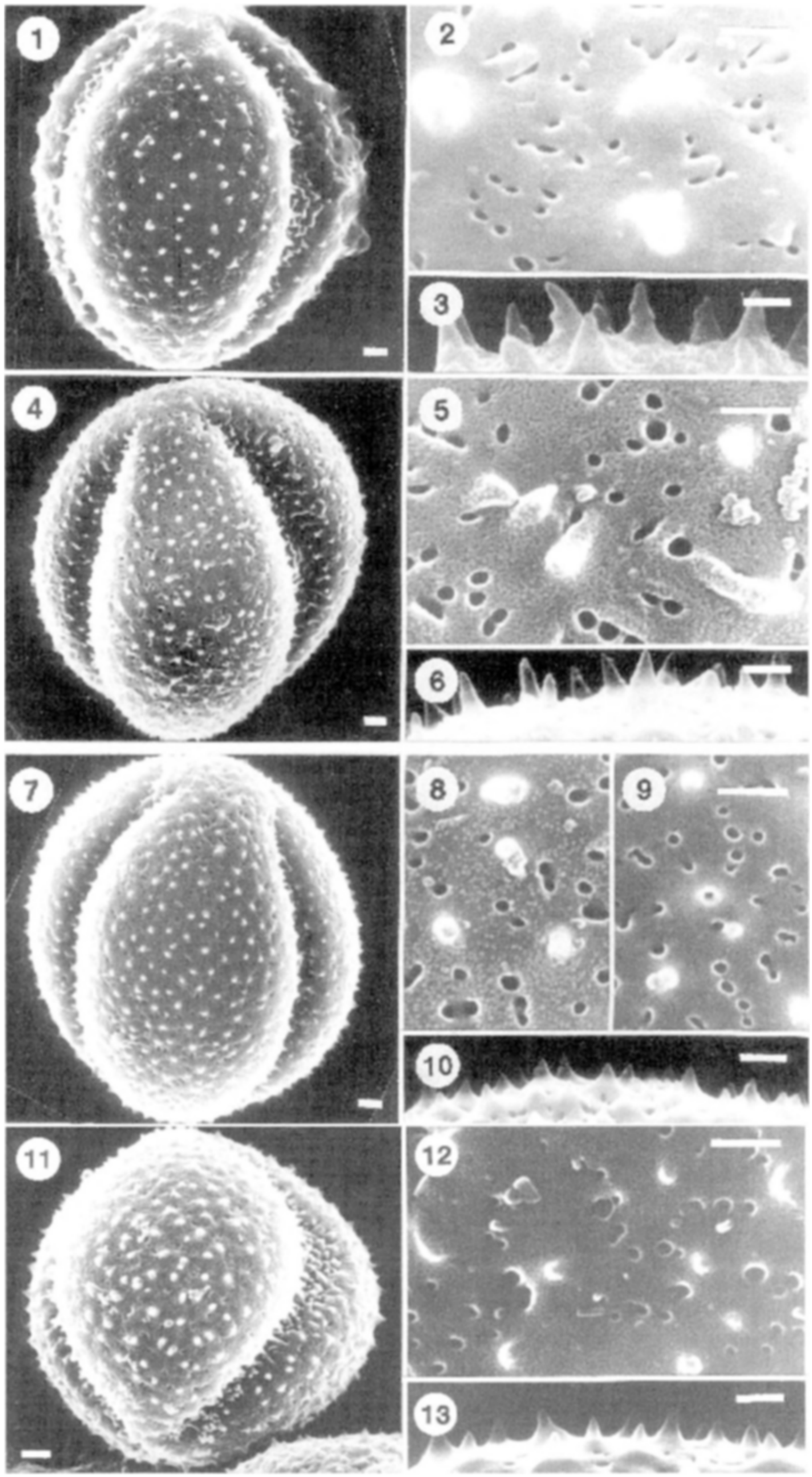
Key to Pollen Types

1. Echinae few (2 to 4 per 49 μm^2) and large (0.9 to 1.2 μm); foveolae elongate, 2 to 3 (5) foveolae straightly aligned··················Type I (*A. amurensis*)
1. Echinae many (4 to 17 per 49 μm^2) and small (0.3 to 0.8 μm); foveolae round or elongate, 2 to 3 (4) foveolae aligned or not.
   2. Fovaolae somewhat evenly large (0.2 to 0.4 μm), ca. 20 per 49 μm^2······Type II (*A. ramosa*)
   2. Foveolae small (ca. 0.1 to 0.2 μm) or variably large (0.2 to 0.5 μm), 20 to 55 per 49 μm^2.
      3. Mostly 2 to 3 foveolae aligned; L/W of echina 0.73 to 0.80 ·······························Type III-1 (*A. multiflora*)
      3. Foveolae not aligned; L/W of echina 0.84 to 1.29············Type III-2 (*A. pseudoamurensis*)

Description of Pollen Types

Type I (Fig. 1; 1-3) (Korea: Mt. Chukryeong, Mt. Cheonma, Mt. Jeoksang, and Mt. Jeombong; Russia: Primorskij): Pollen grains 25.86 to 36.54 × 22.31 to 30.99 μm (P × E), oblate- spheroidal to subprolate (P/E = 0.96 to 1.18), exine thickness 2.14 to 2.60 μm at poles and 1.59 to 2.11 μm at equator. Aperture tricolpate. Size, equatorial shape, and exine thickness differ among populations. Echinae 2 to 4 per 49 μm^2, 0.9 to 1.2 μm in length, 0.63 to 0.85 μm in width, and L/W = 1.43 to 1.49. Foveolae elongate, small and abundant (27 to 40 per 49 μm^2), 2 to 3 (5) aligned somewhat straightly.

Pollen Type I is separated from Type II by having elongated and straightly aligned foveolae, and few and large echinae (Fig. 1; 1-3). This alignment of foveolae is also found in Ryonuma *Adonis* of Type III-1 (Fig. 1; 9), but the number of foveolae per echina is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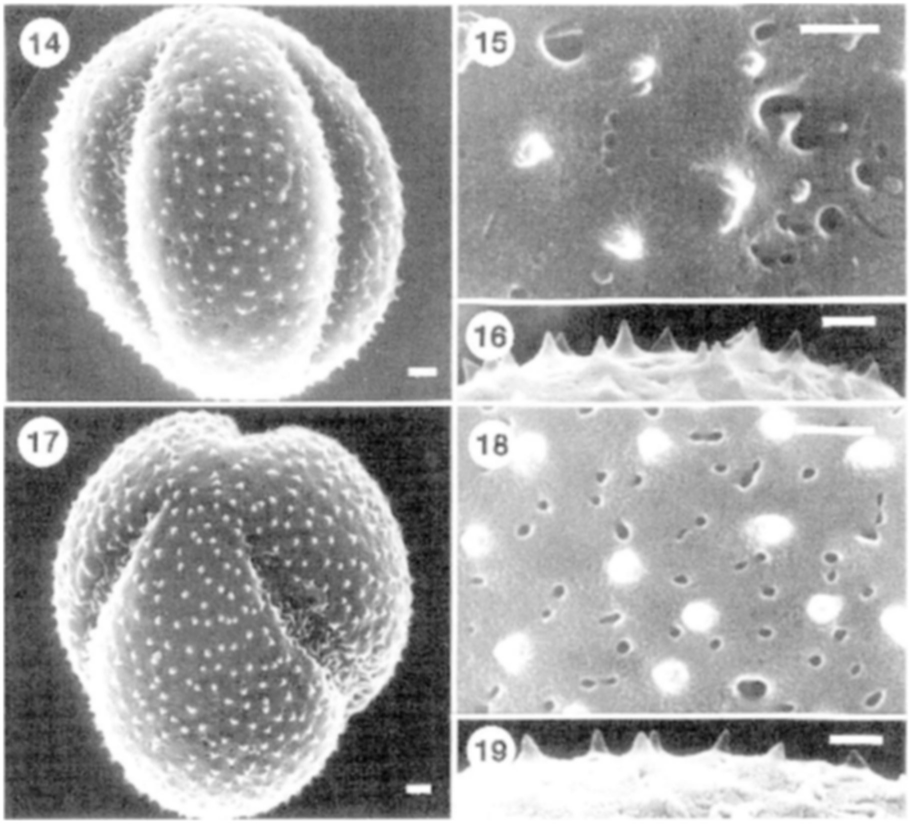

Figure 1. Scanning electron microphotographs of pollen grains of *Adonis* from Korea and vicinity (all scale bars = 1 μm). Pictures on left are pollen grains; on right, upper pictures in each set show surface of mesocolpus, lower ones show side view of echinae (1-3) **Type I** (Chukryong Mt.: *A. amurensis*); (4-6) **Type II** (Tamayama-mura: *A. ramosa*); (7-10) **Type III-1** (7, 8, 10, Gwaneumsa; 9, Ryonuma: *A. multiflora*); (11-19) **Type III-2** (11-13, Kirin; 14-16, Nishiyoshino-mura; 17-19, Gwanchon: *A. pseudoamurensis*).

higher than for Ryonuma *Adonis* of Type III-1. Foveolae are much more elongate and slender, and echina is much larger than for those of Type II.

Type II (Fig. 1; 4-7) (Japan: Tamayama-mura): Pollen grain 32.25 × 33.23 μm (P × E), oblate-spheroidal (P/E = 0.97), exine thickness 1.86 μm at poles and 1.73 μm at equator. Aperture tricolpate. Echinae ca. 4 per 49 μm^2, 0.80 μm in length, 0.63 μm in width, and L/W = 1.27. Foveolae round, large and less abundant (ca. 20 per 49 μm^2) than those of Type I, foveolae individually scattered, or rarely two foveolae joining together. Pollen morphology of Type II is separated from other Types by having uniformly large and segregated foveolae (Fig. 1; 5).

Type III. Aperture is tricolpate plus rarely 6-pantocolpate, or with tips of two to three colpi joining at pole. Echinae short (0.3 to 0.7 μm) and numerous (6 to 17 per 49 μm^2). Foveolae round to elongate, small to large, size variable in same locality, and rarely to somewhat two or three foveolae aligned, number of foveolae per echina is intermediate (23 to 55 per 49 μm^2) between Types I and II.

Subtype III-1. (Fig. 1; 7-10) (Korea: Gwaneumsa, Eorimok; Japan: Ryonuma): Pollen grain 29.51 to 31.50 × 24.36 to 26.98 μm (P × E), prolate-spheroidal to subprolate (P/E = 1.15 to 1.29), exine thickness 2.12 to 2.52 μm at poles and 1.96 to 2.06 μm at equator. Aperture tricolpate, rarely 6-pantocolpate, or two colpi tips of tricolpate joined at pole. Echinae 6 to 8 per 49 μm^2, 0.35 to 0.59 μm in length, 0.44 to 0.81 μm in width, and L/W = 0.73 to 0.80. Foveolae 27 to 40 per 49 μm^2, two foveolae often join together.

Pollen size, and number of echinae and foveolae in *A. multiflora* taxon from Ryonuma, Japan (Fig. 1; 9) are smaller and fewer than that from Jeju Isl. (Fig. 1; 8) of Korea (Table 2). Echinae are smaller (Fig. 1; 10 vs. Fig. 1; 13, 16, 19) and foveolae are rather uniformly sized and rather aligned (Fig. 1; 8-9 vs. Fig. 1; 12, 15, 18) in Type III-1 than in Type III-2. The presence of odd-shaped apertures, such as 6-pantocolpate or tricolpate apertures with the tips of two colpi joining at the pole, also supports the close affinity of these two subtypes.

Subtype III-2 (Fig. 1; 17-19) (Korea: Deokjeok Isl., Jangbong Isl., Mt. Gyeryong, Mt. Palgong, Uiryeong, Gwanchon, and Naesosa; China: Kirin; Japan: Nishi-yoshino-mura): Pollen grain 24.39 to 34.49 $\times$ 22.02 to 31.16 μm (P $\times$ E), oblate-spheroidal to subprolate (P/E = 0.95 to 1.30), exine thickness 1.61 to 2.75 μm at poles and 1.15 to 2.65 μm at equator. Aperture tricolpate, rarely 6-pantocolpate, or three colpi tips of tricolpate joined at pole. Echinae 6 to 17 per 49 μm^2, 0.31 to 0.74 μm in length, 0.24 to 0.79 μm in width, L/W = 0.84 to 1.29. Foveolae 23 to 55 per 49 μm^2, size variable, aligning tendency of foveolae is the least among pollen types. Pollen size, equatorial shape, exine thickness, and ultra-structural surface pattern are quite variable among localities.

Among the Type III-2 grains, those from Gwanchon and Deokjeok Isl., having smaller and more uniformly sized foveolae, differ from the rest, which are small to large-sized. The pollens of Uiryoung, Mt. Palgong, and Gwanchon are distinguished from the rest by their broadly footed echinae (L/W = 0.84 to 1.29).

DISCUSSION

Based on our palynological results, we have divided Korean *Adonis* into two pollen types, with two subtypes. The most widely distributed throughout the Korean peninsula is Type III-2, which also includes grains from Kirin (China) and Nishi-yoshino-mura (Japan). The next most widely distributed is Type I, found in the mountains above 800 m in elevation on the Korean peninsula. Type III-1 is restricted to Jeju Island of Korea, but also found in Ryonuma, Iwate Prefecture of Japan.

The morphological (Lee et al., 2003) and molecular data recognizing three species for Korean *Adonis* (Suh et al., 2002) are also consistent with their pollen morphology, which separates the grains of Korean *Adonis* into Types I, III-1, and III-2. These correspond to *A. amurensis, A. multiflora,* and *A. pseudoamurensis*, respectively.

As with the results from morphological and ITS sequence analyses, both the plant samples from Jeombong, which were recognized as *A. amurensis* ssp. *nanus* by Lee (1996), and those from Chukryeong, reported as *A. longicalyx* S. Park et S. Lee (nom. nud.) (Lee, 1998) possess the same pollen Type, I, listed for *A. amurensis* from Primorskij, Russia. In addition, plants from Gyeryong, Palgong, and Uiryeong, which have been identified as *A. ramosa* (Lee, 1998) or *A. amurensis* var. *ramosa* (Nakai, 1952; Chung, 1965; Lee, 1996, 1998), have the same pollen Type, III-2, as that of *A. pseudoamurensis* from Kirin, China. Previously, Wang (1980) described *A. pseudoamurensis,* from Liaoning and Kirin (China) and from the Korean peninsula, as having 5 to 7 sepals (ovate to rhomboid) that were shorter than the petals, and cauline leaves that lacked petioles. However, *Adonis pseudoamurensis* and *A. multiflora* were later synonymized to *A. ramosa* Franchet (Wang and L, 1988; Wang, 1994 a, b). Nevertheless, our present study does not support these treatments because pollen Type II of the Japanese *A. ramosa*, with its uniformly large and segregated foveolae, is distinct from that of Type III-2, which corresponds to *A. pseudoamurensis*. Moreover, pollen Type III-2, representing *A. pseudoamurensis*, can be distinguished from Type III-1, i.e., *A. multiflora*, in having variable vs. evenly sized foveolae. These morphological characters and ITS sequences also clearly separate *A. pseudoamurensis* from *A. multiflora* by exhibiting acuminate vs. acute pinnae tips as well as 8 vs. 5 sepals, respectively. Therefore, their pollen morphology supports our claim that *A. pseudoamurensis* should be recognized as a species distinct from *A. amurensis* and *A. multiflora*.

Adonis ramosa Franchet (1894) from the Aomori region (Japan) was first treated as *A. amurensis* var. *ramosa* (Franchet) Makino (1901), then later synonymized to *A. amurensis* Regel & Redde (Makino, 1940). Again, our present study results cannot support either of those treatments because pollen Type I, representing *A. amurensis*, is well separated from Type II, i.e., *A. ramosa*, with respect to the number of foveolae and the exine thickness at the pole. Therefore, we endorse the treatment of Nishikawa (1988, 1989a) that *A. ramosa* should be separated from *A. amurensis*.

Nishikawa (1989a) also speculated that *A. ramosa* is of allotetraploid origin, arising between *A. amurensis* and *A. multiflora*, and having morphological intermediacy between *A. amurensis/A. multiflora* or *A. pseudoamurensis*, based on the number and size of its echinae. This implies, therefore, that other possibilities, such as an autotetraploid origin, cannot be excluded, although the Nishkawa hypothesis for the origin of *A. ramosa* could be plausible. If the foregoing claims are true, *A. ramosa* could feasibly also appear in sympatric habitat on the Korean peninsula. However, a preliminary study of the chromosome numbers for Korean *Adonis* (Yeau et al., personal communication) has revealed that *A. amurensis, A. multiflora,* and *A. pseudoamurensis* are diploid (2n = 16), and that the tetraploid species

A. ramosa has never been found in Korea.

The pollen morphology results of *A. amurensis* research by Shoma and Suda (1992) were not confirmed in our study. In that earlier work, Japanese *Adonis* was assigned one species, *A. amurensis*, but their report of triploid pollen seems comparable to the pollen of *A. multiflora* and *A. pseudoamurensis* described here. Likewise, the tetraploid pollen reported by Shoma and Suda (1992) was never observed in the current study, in which the aligning tendency of foveolae was much more similar to that of *A. amurensis*. However, the arrangements of the aligned foveolae differ, i.e., they are positioned somewhat radially from each echina in *A. amurensis*.

We have separated *A. multiflora* (Kyushu and Honshu in Japan, and Jeju Island, Korea) from *A. amurensis* and have newly described the former as having more flowers per stem, and petals that are twice as long as the sepals. The present study has also demonstrated that its Type III-1 pollen differs from those of both Type I and Type III-2. These observations further support our belief that *A. multiflora* should be treated as a distinct species from *A. amurensis* (Nishikawa, 1988, 1989a), rather than being considered synonymous with *A. amurensis* (Suda and Adachi, 1991; Suda and Herai, 1991; Sohma and Suda, 1992; Suda, 1995, 1998).

In their palynological investigation of 17 mainly Chinese *Adonis* species, Li and Zhang (1989) recognized four subtypes within the *Consiligo* pollen type. Among these, Subtype 2 included *A. pseudoamurensis*, which is characterized by large and irregularly distributed foveolae. In contrast, Subtype 4, containing *A. amurensis* and *A. ramosa*, shows smaller and aligned foveolae, descriptions that are somewhat congruent with our current study. However, the hierarchy encompassing these subtypes is not same.

To conclude, we believe that, based on palynological results, Korean *Adonis* can be grouped into two pollen types, with two subtypes. Types I, III-1, and III-2, then, would include *A. amurensis*, *A. multiflora*, and *A. pseudoamurensis*, respectively. Moreover, *A. amurensis* (pollen Type I) is found throughout the Korean peninsula, excluding Jeju Island, but is restricted to mountainous regions above 800 m in elevation. The second species, *A. multiflora* (Type III-1 pollen), is restiricted on Jeju Island in Korea and also in Ryonuma, Iwate Prefecture of Japan. The third species, *A. pseudoamurensis* (Type III-2) is distributed in the mountains below 800m and adjacent islands west to the Taebaeksanmaek mountain ranges in the Korean peninsula and Liaoning and Kirin, China.

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