

A Contribution to the Pollen Morphology of Korean *Salix* L. (Salicaceae)^{1*}

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韓國 버드나무屬 花粉의 形態學的 研究^{1*}

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ABSTRACT

The pollen morphology of nine species and one variety of Korean *Salix* was investigated by means of light and scanning electron microscopy. Pollen grains are tricolpate or tricolporate varying from subprolate or prolate. Based on aperture and sculpture patterns, the pollen morphology of the investigated Korean *Salix* appeared to exhibit three different types.

Key words : *Salix* (Willows) ; Salicaceae ; Pollen morphology.

要 約

韓國產 버드나무屬 9種 1變種의 花粉形態를 光學顯微鏡과 走査型 電子 顯微鏡으로 觀察하였는바 花粉粒은 長球型 또는 亞長球型으로서 三溝型이거나 三孔溝型이었다. 또한 調査된 韓國產 버드나무屬의 花粉은 發芽溝와 表面무늬에 依하여 3가지 型으로 區分할 수 있었다.

INTRODUCTION

Genus *Salix* (Willow) contains more than 400 species distributed from tropical to arctic areas. Recently, willows have received attention as stock for biomass plantations (Siren, 1974). The classification of species within this genus is somewhat controversial (Svortsov, 1968 ; Argus 1973, 1986 ;

Dorn, 1976). Many willows show strong within-species variation in morphology making the species identification difficult. Consequently, different names are at times given to the same species. Also, the classification of this genus into sections is still obscure (Dorn, 1975). Pollen morphology has received a lot of attention as a criterion for taxonomy (Medus and Flores, 1984, Samson and Enderss, 1984). The pollen morpho-

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logy of several *Salix* species was described and illustrated by Staraka (1952), Fægri (1953), Praglowski (1962), Kuprijanova (1965), Rowley and Erdtman (1969), Barth *et al.* (1975), Hesse (1979), Krizo (1980), Kim (1984). Most of these studies discussed European *Salix* species. The present study describes the pollen morphology of Korean *Salix* species.

MATERIALS AND METHODS

Pollen was collected from the field specimens (Appendix 1). A total of 9 species and 1 variety of Korean *Salix* were investigated. Pollen collected in the field was stored dry, or preserved in glacial acetic acid. The whole anthers were acetolysed (Erdtman, 1969) for optical studies and pollen measurement, and the pollen was subsequently mounted in glycerin jelly. The polar axis, equatorial diameter, sculpture pattern and exine thickness measurement (20 pollen grains for each species/variety) were made at 1,000× magnification with a light microscope. The exine thickness was measured in equatorial view in the centre of the mesocolpia. For scanning electron microscopy, acetolysed pollen grains were suspended in a drop of absolute alcohol, transferred to brass stubs. Gold-palladium coated for 7 minutes using a fine coat ION sputter JEC-1,100. Scanning electron micrographs were taken with a Jeol JSM 25S 11 microscope on 11 ford FP 4 film. The terminol-

ogy of pollen morphology follows mainly that of Erdtman (1969) and Praglowski and Punt (1973).

RESULTS

Pollen morphological data resulting from this study are presented in Table 1.

Pollen description of species

Salix dependens Nakai

Pollen grains in monads, isopolar, radially symmetrical, 3-colpate. Polar axis $22.5 \pm 1.1 \mu\text{m}$, equatorial diameter $14.2 \pm 0.5 \mu\text{m}$, P/E 158. Shape in polar view round to elliptic. Exine reticulate, thickness $1.1 \pm 0.1 \mu\text{m}$, sexine thicker than nexine, usually lumen diameter larger than muri; muri surface even, similar to rugulose. Colpi length $17.7 \pm 0.8 \mu\text{m}$, colpi width $1.8 \pm 0.1 \mu\text{m}$, colpus membrane studded with densely spaced spinules.

Salix gilgiana Seemen

Pollen grains monads, isopolar, radially symmetrical, 3-colpate. Polar axis $25.7 \pm 1.5 \mu\text{m}$, equatorial diameter $19.7 \pm 1.2 \mu\text{m}$, P/E 130. Shape in polar view round to rounded triangular. Exine reticulate, thickness $1.7 \pm 0.2 \mu\text{m}$, sexine thicker than nexine, usually muri diameter larger than lumen; muri surface uneven, similar to psilate or rarely scabrate. Colpi length $22.4 \pm 1.2 \mu\text{m}$, colpi width $2.0 \pm 0.1 \mu\text{m}$, colpus membrane studded with densely spaced granules or spinules.

Table 1. Pollen morphological data of Korean *Salix*

Taxa	E. V.	Pollen grain size (μm)		P/E (%)	Exine thickness (μm)	Aperture (μm)			Pollen type
		P	E			Type	Length	Width	
<i>S. dependens</i>	prolate	22.5 ± 1.1	14.2 ± 0.5	158	1.1 ± 0.1	3-colpate	17.7 ± 0.8	1.8 ± 0.1	3
<i>S. gilgiana</i>	subpro.	25.7 ± 1.5	19.7 ± 1.2	130	1.7 ± 0.2	3-colpate	22.4 ± 1.2	2.0 ± 0.1	2
<i>S. graciliglans</i>	prolate	21.6 ± 2.3	15.5 ± 2.2	139	1.0 ± 0.1	3-colpate	18.1 ± 1.9	1.9 ± 0.3	1
<i>S. glandulosa</i>	prolate	22.4 ± 1.3	16.7 ± 1.9	134	1.3 ± 0.1	3-colpate	17.7 ± 1.2	1.7 ± 0.3	3
<i>S. gracilistyla</i>	subpro.	18.2 ± 1.1	15.2 ± 0.6	119	0.9 ± 0.2	3-colpate	14.4 ± 0.8	1.9 ± 0.2	2
<i>S. hallaisanensis</i>	prolate	25.5 ± 2.0	18.2 ± 1.7	140	1.5 ± 0.1	3-colpate	19.2 ± 1.5	1.5 ± 0.1	3
<i>S. koreensis</i>	subpro.	25.1 ± 2.5	20.2 ± 0.8	124	1.8 ± 0.1	3-colpate	22.1 ± 1.4	2.0 ± 0.1	2
<i>S. pseudolasiogyne</i>	subpro.	22.4 ± 1.2	17.2 ± 0.6	130	1.2 ± 0.1	3-colpate	14.7 ± 1.5	1.9 ± 0.2	3
<i>S. purpurea</i> var. <i>japonica</i>	prolate	21.9 ± 4.8	15.7 ± 1.5	139	1.3 ± 0.2	3-colpate	18.1 ± 1.6	2.0 ± 0.3	2
<i>S. stipularis</i>	subpro.	21.6 ± 0.8	16.3 ± 0.9	132	0.9 ± 0.1	3-colpate	17.2 ± 1.4	1.9 ± 0.1	2

Pollen type: 1=*graciliglans* type, 2=*koreensis* type, 3=*glandulosa* type

***Salix graciliglans* Nakai**

Pollen grains in monads, isopolar, radially symmetrical, 3-colpate. Polar axis $21.6 \pm 2.3 \mu\text{m}$, equatorial diameter $15.2 \pm 2.2 \mu\text{m}$, P/E 139. Shape in polar view round to elliptic. Exine reticulate, thickness $1.9 \pm 0.3 \mu\text{m}$, sexine thicker than nexine, usually muri diameter smaller than lumen. Colpi length $18.1 \pm 1.9 \mu\text{m}$, colpi width $1.9 \pm 0.3 \mu\text{m}$, colpus membrane studded with densely spaced spinules; ora elongate, circular to elliptic, approximately $2 \mu\text{m}$ long (Figs. 1-2).

***Salix glandulosa* Seemen**

Pollen grains in monads, isopolar, radially symmetrical, 3-colpate. Polar axis $22.4 \pm 1.3 \mu\text{m}$, equatorial diameter $16.7 \pm 1.9 \mu\text{m}$, P/E 134. Shape in polar view round to elliptic. Exine reticulate, thickness $1.3 \pm 0.1 \mu\text{m}$, sexine thicker than nexine, usually muri diameter smaller than lumen; muri surface even, similar to psilate or rarely scabrate. Colpi length $17.8 \pm 1.2 \mu\text{m}$, colpi width $1.7 \pm 1.2 \mu\text{m}$, colpus membrane studded with densely spaced spinules (Figs. 5-6).

***Salix gracilistyla* Seemen**

Pollen grains in monads, isopolar, radially symmetrical, 3-colpate. Polar axis $18.2 \pm 1.1 \mu\text{m}$, equatorial diameter $15.2 \pm 0.6 \mu\text{m}$, P/E 119. Shape in polar view round to elliptic. Exine reticulate, thickness $0.9 \pm 0.2 \mu\text{m}$, sexine thicker than nexine, usually muri diameter larger than lumen; muri surface uneven, similar to rugulose. Colpi length $14.4 \pm 0.8 \mu\text{m}$, colpi width $1.9 \pm 0.2 \mu\text{m}$, colpus membrane studded with densely spaced spinules or process.

***Salix hallaisanensis* Leveille**

Pollen grains in monads, isopolar, radially symmetrical, 3-colpate. Polar axis $25.5 \pm 2.0 \mu\text{m}$, equatorial diameter $18.2 \pm 1.7 \mu\text{m}$, P/E 140. Shape in polar view round to elliptic. Exine reticulate, thickness $1.5 \pm 0.1 \mu\text{m}$, sexine thicker than nexine, usually muri diameter smaller than lumen; muri surface even, similar to psilate or rarely

scabrate. Colpi length $19.2 \pm 1.5 \mu\text{m}$, colpi width $1.5 \pm 0.1 \mu\text{m}$, colpus membrane studded with densely spaced granules or spinules.

***Salix koreensis* Andersson**

Pollen grains in monads, isopolar, radially symmetrical, 3-colpate. Polar axis $25.1 \pm 2.5 \mu\text{m}$, equatorial diameter $20.2 \pm 0.8 \mu\text{m}$, P/E 124. Shape in polar view round to rounded triangular. Exine reticulate, thickness $1.8 \pm 0.1 \mu\text{m}$, sexine thicker than nexine, usually muri diameter larger than lumen; muri surface even, similar to psilate or rarely scabrate. Colpi length $22.1 \pm 1.4 \mu\text{m}$, colpi width $2.0 \pm 0.1 \mu\text{m}$, colpus membrane studded with densely spaced spinules.

***Salix pseudo-lasiogyne* Leveille**

Pollen grains in monads, isopolar, radially symmetrical, 3-colpate. Polar axis $22.4 \pm 1.2 \mu\text{m}$, equatorial diameter $17.2 \pm 0.6 \mu\text{m}$, P/E 130. Shape in polar view round to elliptic. Exine reticulate, thickness $1.3 \pm 0.2 \mu\text{m}$, sexine thicker than nexine, usually muri diameter larger than lumen; muri surface even, similar to psilate. Colpi length $14.7 \pm 1.5 \mu\text{m}$, colpi width $1.9 \pm 0.2 \mu\text{m}$, colpus membrane studded with coarse granules.

***Salix purpurea* var. *japonica* Naka**

Pollen grains in monads, isopolar, radially symmetrical, 3-colpate. Polar axis $21.9 \pm 4.8 \mu\text{m}$, equatorial diameter $15.7 \pm 1.5 \mu\text{m}$, P/E 139. Shape in polar view round to elliptic. Exine reticulate, thickness $1.3 \pm 0.2 \mu\text{m}$, sexine thicker than nexine, usually lumen diameter larger than muri; muri surface uneven, similar to rugulose. Colpi length $18.1 \pm 1.6 \mu\text{m}$, colpi width $2.0 \pm 0.3 \mu\text{m}$, colpus membrane studded with densely spaced spinules (Figs. 3-4).

***Salix stipularis* Smith**

Pollen grains in monads, isopolar, radially symmetrical, 3-colpate. Polar axis $22.4 \pm 1.2 \mu\text{m}$, equatorial diameter $17.2 \pm 0.6 \mu\text{m}$, P/E 130. Shape in polar view round to elliptic. Exine reticulate,

thickness $1.3 \pm 0.1 \mu\text{m}$, sexine thicker than nexine, muri diameter larger than lumen; muri surface uneven, similar to rugulose. Colpi length $17.2 \pm 1.4 \mu\text{m}$, colpi width $1.9 \pm 0.1 \mu\text{m}$, colpus membrane studded with coarse granules or process.

Key of pollen types

1. Colpus tricolporate
 -*glaciliglans* type (Pollen type 1)
1. Colpus tricolpate
 2. Muri surface uneven, similar to rugulose
 -*koreensis* type (Pollen type 2)
 2. Muri surface even, similar to psilate or rarely scabrate.
 -*glandulosa* type (Pollen type 3)

The pollen type of investigated Korean *Salix* species analyzed according to this key is indicated in Table 1.

DISCUSSION

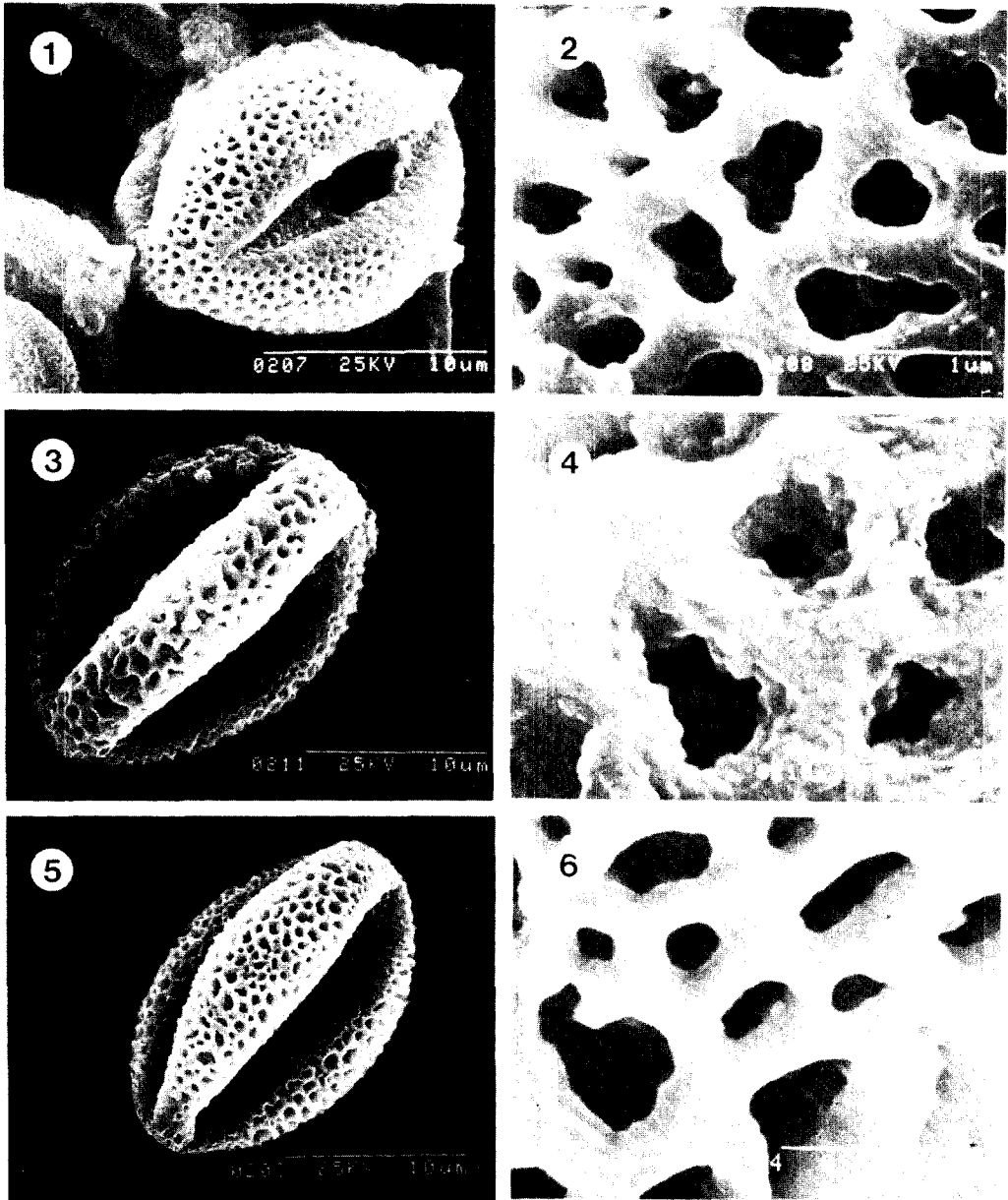
Pollen grains of Korean *Salix* are isopolar, 3-colporate or 3-colpate, and subprolate to prolate $17-28 \times 14-21 \mu\text{m}$. Colpi are distinct, slightly sunken, and varying in length. Exine consists of sexine and nexine, sexine is reticulate, muri is simply or less frequently duplibaculate with more or less straight segments in most species. Lumina varies in size, the largest lumina are found in the central part of the mesocolpia, decreasing progressively towards the colpi margins and poles. In some species the lumina are lacking in the area of the colpus margins. The reticulate is almost homobrochate. What must be considered in every case where *Salix* is investigated is a large overlap of characteristics between the species and therefore, it is often impossible to distinguish each species by considering pollen characteristic only.

The morphology of *Salix* pollen has been studied by Lüdi (1950), Straka (1952), Rowley and Erdtman (1952 and 1969), Fægri and Iverson (1974), Nilsson *et al.* (1977), Hesse (1979), and Kim (1984). The following pollen grain sizes are

indicated in the literature for genus *Salix*: $15-35 \mu\text{m}$ (Lüdi 1950); $20-36 \mu\text{m}$ (Erdtman, 1952); $20-38 \mu\text{m}$ (Straka, 1952); $15-36 \mu\text{m}$ (Kuprijanova, 1965). These results, as well ours, indicate variability in the size of pollen grains. Several literature references state that similar problems can be expected also in other taxa (Krizo, 1980). Thus the size of pollen grains does not appear useful as taxonomic criterion in separating species. Erdtman (1952) reported that *Salix* pollen grain is only tricolporoidate. To the contrary, Fægri and Iverson (1974) also observed tricolpate and found that colpate and colpate types of pollen were not easily distinguishable. Korean *Salix* pollen grains can be observed tricolporate or tricolpate. Korean *Salix* species exhibit three completely different types, and pollen morphological stability of each type is high and is characteristic of the species.

The first type, *glaciliglans*, is tricolporate and prolate on the equatorial view, and it comprises *Salix glaciliglans* (Figs. 1-2). The second type, *koreensis*, is tricolpate in aperture, subprolate or prolate in the equatorial view; the muri surface is uneven, similar to rugulose, and this group comprises 4 species and 1 variety; *Salix koreensis*, *S. gilgiana*, *S. gracilistyla*, *S. stipularis* and *S. purpurea* var. *japonica* (Figs. 3-4). The third type, *glandulosa*, is tricolpate in the aperture, prolate or subprolate on the equatorial view; the muri surface is even, similar to psilate or rarely scabrate, and this group comprises 4 species; *S. dependens*, *S. glandulosa*, *S. hallaisanensis* and *S. pseudo-lasiogyne* (Figs. 5-6).

A considerable difference in size could distinctly be noticed in almost every pollen grain. However, instabilities in other pollen characters were not significant (Table 1). There may be relationship between higher chromosome numbers and increasing pollen size. This phenomenon has been studied earlier (Erdtman, 1962). The volume of Graminae pollen was directly proportional to the chromosome number. For Korean *Salix* this relationship is not clear, but distinct in species with the largest pollen.



LEGEND FOR FIGURES

Figs. 1-2. *Salix glasiliglans*. 1. Pollen grain in equatorial view, showing the pore of colpus membrane studded with densely spaced spinules. SEM×2,600. 2. Part of exine showing reticulate. SEM×40,000.

Figs. 3-4. *Salix koreensis*. 3. Pollen grain in equatorial view. SEM×2,400. 4. Part of

exine, showing muri surface uneven. SEM×40,000.

Figs. 5-6. *Salix glandulosa*. 5. Pollen grain in equatorial view. SEM×2,900. 6. Part of exine, showing muri surface even. SEM×40,000.

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Appendix 1. Specimens investigated

- Salix dependens* Nakai (개수양버들). Korea, Onyang, Chungnam, April 3, 1985, K.H. Kim s.n.
- S. gilgiana* Seemen (넷버들). Korea, Cheulwon, Kangwon, April 7, 1985, K.H. Kim s.n.
- S. glandulosa* Seemen (왕버들). Korea, Jeonbug Nat. Univ. Jeonbug, March 19, 1979, K.H. Kim s.n.
- S. glacialiglans* Nakai (눈갯버들). Korea, Jeonnam Nat. Univ. March 21, 1985, J.S. Lee s.n.
- S. gracilistyla* Miquel (갯버들). Korea, Byunsan, Jeonbug, March 19, 1980, K.H. Kim s.n.
- S. hallaisanensis* Leveille (떡버들). Korea, Jeju island, April 7, 1986, J. S. Lee s.n.
- S. koreensis* Anderson (버드나무). Korea, Jeonju, Jeonbug, March 18, 1980, K. H. Kim s.n.
- S. pseudo-lasiogyne* Leveille (능수버들). Korea, Jeonju, Jeonbug, Mach 1982, K.H. Kim s.n.
- S. purpurea* var. *japonica* Nakai (키버들). Korea, cheulwon, Kangwon, April 3, 1982, K.H. Kim s.n.
- S. stipularis* Smith (꽃버들). Korea, Chuncheon, Kangwon, March 27, 1985, H. Kim s.n.

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