

Leaf epidermal patterns of Korean sedge taxa characterized by SEM and LM (IV. *Fimbristylis*)

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한국산 하늘직이속(*Fimbristylis*) 식물의 잎표피형 연구

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Abstract

Leaf epidermal patterns of seven Korean *Fimbristylis* taxa were examined using SEM and LM. Epidermal patterns of the leaf blades, including shape and arrangement of intercostal long cells, subsidiary cells in stomata and interstomatal, wall, cuticle, papillae, prickles and silica body, appear to be very useful for identification and classification of these taxa. In addition, leaf epidermal data from this study support the present classification scheme of Korean *Fimbristylis* taxa.

Introduction

I have previously reported epidermal patterns of the leaf blades in several Korean sedge taxa, including fourteen species of Korean *Fimbristylis*, and found them to be very useful in identification and classification of this group (1969, 1971-1974a,b, 1980a,b, 1985a,b, 1987a,b, 1988, 1991). The genus *Fimbristylis* includes 200-300 species (Cronquist, 1981, Dahlgren *et al.*, 1985), and characterized by tufted annuals or perennials; culms usually leafless,

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often more or less bifacially compressed; leaves radical, fascicled, rarely bladeless; inflorescence usually umbelliform, sometimes capitate or consisting of a solitary spikelet, usually subtended by a leafy bract or bracts at base; spikelets few- to many-flowered; flowers bisexual; scales spirally arranged or 2-ranked; perianth none; stamens 1-3; style-base somewhat thickened, articulate with the ovary and deciduous when mature; stigmas 2-3; achenes aborate, biconvex or 3-angled, smooth to tuberculate, rarely verrucoses. Plants of *Fimbristylis* are found in tropical, warm-temperate regions and mainly subtropical parts of Malaysia and Australia, and 15 species, 3 varieties and 2 forma (Lee, 1985) are found in Korea.

Anatomical features of leaves, stems, peduncles, and roots in 12 species of the American *Fimbristylis* taxa were studied by Holm (1899). Ward (1968), in his Flora of Florida, divided the genus into three sections, and provided the key on the basis of the spikelet, style, and achene shape. In addition, Koyama (1974, 1978, 1979) studied the geographical distribution of the *Fimbristylis* taxa in Ceylon and Thailand. The chromosome number of *Fimbristylis umbellaris* was reported as $n=3$ by Rath and Patnaik (1977). However, no detailed studies regarding the leaf epidermal patterns of the genus were conducted so far.

Therefore in this study, the leaf epidermal patterns of seven taxa in the genus *Fimbristylis* (Cyperaceae) were studied using both light and scanning electron microscopes.

Table 1. List of voucher specimens for the leaf epidermal study on the genus *Fimbristylis* in Korea.

Taxa	Localities	Date and collectors
<i>Fimbristylis aestivalis</i> (Retz.) Vahl. subsp. <i>squarrosa</i> (Vahl.) T. Koyama	Oryudong, Seoul	Oct. 9, 1971 Y.C. Oh & Y. N. Lee
<i>F. autumnalis</i> (L.) Roem. et Schultes	Illyong, Kyonggido	Sept. 20, 1969 Y. C. Oh
<i>F. complanata</i> (Retz.) Link. for. <i>exalata</i> T. Koyama	Panchuckgoall, Kyonggido	Oct. 9, 1972 Y.C. Oh & Y.N. Lee
<i>F. dichotoma</i> (L.) Vahl.	Suwon, Kyonggido	Aug. 24, 1969 Y.C. Oh & Y.N. Lee
<i>F. dichotoma</i> Vahl. subsp. <i>longispica</i> (Steudel) T. Koyama	Isl. Choojado, Chejudo	Aug. 2. 1969 Y.C. Oh & Y.N. Lee
<i>F. ferruginea</i> (L.) Vahl. var. <i>sieboldii</i> (Miq.) Ohwi	Isl. Choojado, Chejudo	Aug. 2. 1969 Y.C. Oh & Y.N. Lee
<i>F. littoralis</i> Gaudich	Amsadong, Seoul	Sept. 24. 1977 Y. C. Oh

Materials and Methods

Herbarium specimens of three species, two subspecies, one variety, and one forma of the genus *Fimbristylis* stored in the Department of Biology, Sungshin Women's University (SWU) were used in this study (Table 1). For each taxon, the widest portion of the leaf blade of basal leaves was taken, softened by boiling in water for 30 min. to 1 hr., and fixed in FAA. The epidermis of each taxon was peeled off and observed under an Olympus BH light microscope (LM). The stomatal size was measured along the lateral subsidiary cells, and an average of 10 measurements was calculated for each taxon.

For SEM observation, the leaf segments fixed in FAA were dehydrated in the gradient acetone series, affixed on stubs, and then coated with gold/palladium by an ion sputter JFC-1,100. Epidermal patterns were observed using an JEOL, JSMT 300 SEM at 15KV. The photographs were taken with Kodak Vp 20. The terminology used here mainly follows Metcalfe (1960, 1964), Ellis (1979), Hilu (1984), and Oh (1991).

Results

The shape and the size of stomata in Korean taxa of the genus *Fimbristylis* are summarized in Table 2. As seen in Table 2, the smallest stomata were observed in *F. complanata* forma *exalata* (33-37-42 μ m long; 21-21-21 μ m wide), and the largest in *F. dichotoma* subsp. *longispica* (52-58-67 μ m long; 25-33-46 μ m wide).

The shape of subsidiary cells shows significant variation in these taxa; triangular shape was observed in *F. aestivalis* subsp. *squarrosa* and *F. autumnalis*, sub-triangular shape in *F. complanata* forma *exalata*, high-dome shape in *F. ferruginea* var. *sieboldii*, and dome shape in *F. dichotoma*, *F. dichotoma* subsp. *longispica* and *F. littoralis*. The intercostal cells were also variable in shape and size. The shape of intercostal cells wall was deeply undulated wavy in *F. complanata* forma *exalata*; sinuously wavy in *F. autumnalis*, *F. dichotoma* subsp. *longispica*, and *F. littoralis*; shallowly wavy in *F. dichotoma*; slightly sinuously wavy in *F. aestivalis* subsp. *squarrosa* and *F. ferruginea* var. *sieboldii*.

The A₁-shaped (Metcalf and Gregory, 1964) silica bodies were present in *F. dichotoma* subsp. *longispica*, whereas A₂-shape was found in *F. aestivalis* subsp. *squarrosa*, *F. autumnalis*, and *F. ferruginea* var. *sieboldii*. In *F. dichotoma* and *F. littoralis*, the silica bodies were B₁-shaped, and they were B₂-shaped in *F. complanata* forma *exalata*.

The epidermal patterns in these taxa observed using SEM were shown in Figs.1-12. The shape of intercostal long cells was long, narrow, and uniform in *F. aestivalis* subsp. *squarrosa*, *F. complanata* forma *exalata*, *F. dichotoma*, *F. ferruginea* var. *sieboldii* and *F. littoralis*. In *F. autumnalis*, it was long, narrow, and non-uniform, whereas in *F. dichotoma* subsp. *longispica* it was rectangular and non-uniform. Walls of the intercostal long cells was sinuously

wavy in *F. autumnalis*, *F. complanata* forma *exalata*; straightly sinuous wavy in *F. aestivalis* subsp. *squarrosa*; sinuously wavy and raised in *F. dichotoma* subsp. *longispica*, *F. ferruginea* var. *sieboldii* and *F. littoralis*; straightly sinuous wavy, and raised in *F. dichotoma*. The shape of stomata were high-dome, non-inflated, and V-shaped in *F. littoralis*; low-dome, inflated, and U-shaped in *F. autumnalis*, *F. complanata* forma *exalata*, *F. dichotoma*, and *F. dichotoma* subsp. *longispica*; low-dome, inflated and V-shaped in *F. aestivalis* subsp. *squarrosa*; low-dome, non-inflated and V-shaped in *F. ferruginea* var. *sieboldii*.

The well-developed cuticle layer was present on both leaf surfaces of *F. aestivalis* subsp. *squarrosa*, *F. autumnalis*, *F. complanata* forma *exalata*, *F. dichotoma*, *F. dichotoma* subsp. *longispica* and *F. ferruginea* var. *sieboldii*. In *F. littoralis*, it was present only on the abaxial surface of the leaf. Especially, prickles were present on both leaf surfaces of *F. dichotoma*, and papillae were present on the abaxial surface of *F. autumnalis* and *F. complanata* forma *exalata*.

Leaf Epidermal Patterns

Fimbristylis aestivalis (Retz.) Vahl. subsp. *squarrosa* (Vahl.) T. Koyama

LM: Subsidiary cells triangular. Stomata 33-36-38 μ m long and 21-24-25 μ m wide. Two rows of stomata present in intercostal zone. Long cells 63-80-102 μ m long and 21-27-33 μ m wide, cell walls slightly sinuously wavy. Prickles present on both leaf surfaces. Silica body A₂-shaped.

SEM: Intercostal zones; many rows of long cells, square-long, narrow, and uniform, walls straightly sinuous wavy. Stomata; two rows in each zone, subsidiaries low-dome shape, inflated, interstomatal long and narrow, ends straightly long and V-shaped. Cuticle well-developed and rough on leaf surfaces (Figs. 1, 2).

F. autumnalis (L.) Roem. et Schul.

LM: Subsidiary cells triangular. Stomata 29-42-46 μ m long and 17-22-25 μ m wide. Three rows of stomata present in intercostal zone. Long cells 73-82-108 μ m long and 19-22-27 μ m wide, cell walls very sinuously wavy. Eight rows of long cells present in intercostal zone. Silica body A₂-shaped.

SEM: Intercostal zones; many rows of long cells, square-long, narrow, and non-uniform, walls sinuously wavy, papillae present near the walls. Stomata; three rows in each zone, subsidiaries low-dome shape, inflated, interstomatal long and swollen, ends short and broadly, U-shaped. The surface of the epidermal cells rough and covered by cuticle.

F. complanata (Retz.) Link. forma *exalata* T. Koyama

LM: Subsidiary cells sub-triangular. Stomata 33-37-42 μ m long and 21-21-21 μ m wide. Two or three rows of stomata present in intercostal zone. Long cells 63-69-81 μ m long and 15-19-25 μ m wide, cell walls deeply undulated wavy. Four or seven rows of long cell pre-

sent in intercostal zone. Silica body B₂-shaped.

SEM: Intercostal zones; many rows of long cells, square-long, narrow, and uniform, walls sinuously wavy, papillae present near the walls and distinct. Stomata; two or three rows in each zone, subsidiaries low-dome shape, inflated, interstomata long and swollen, end short and broadly, U-shaped. The surfaces of the epidermal cell rough (Figs. 3, 4).

F. dichotoma (L.) Vahl.

LM: Subsidiary cells dome-shaped. Stomata 44-47-50 μ m long and 27-31-33 μ m wide. Two rows of stomata present in intercostal zone. Long cells 73-89-121 μ m long and 25-27-33 μ m wide, cell walls shallowly wavy. Four or six rows of long cells present in intercostal zone. Silica body B₁-shaped.

SEM: Intercostal zones; four or six rows of long cells, square-long, narrow, and uniform, walls straightly sinuous wavy and raised. Stomata; two rows in each zone, subsidiaries low-dome shape, inflated, interstomata long, ends shortly and U-shaped. Prickles present on both surfaces of leaves, pointed and acicular type (Hilu, 1984). Cuticle well-developed on both surfaces (Figs. 5, 6).

F. dichotoma Vahl. subsp. *longispica* (Steudel) T. Koyama

Table 2. Some important epidermal characters of Korean *Fimbristylis* observed using LM.

Characters Taxa	Subsidiary cell shape	Stomata size	Cell wall shape	Silica body shape
<i>Fimbristylis</i> <i>aestivalis</i> subsp. <i>squarrosa</i>	triangular	33-36-38x 21-24-25*	slightly sinuously wavy	A ₂
<i>F. autumnalis</i>	triangular	29-42-46x 17-22-25	sinuously wavy	A ₂
<i>F. complanata</i> for. <i>exalata</i>	sub- triangular	33-37-42x 21-21-21	deeply undulat- ed wavy	B ₂
<i>F. dichotoma</i>	dome	44-47-50x 27-31-33	shallowly wavy	B ₁
<i>F. dichotoma</i> subsp. <i>longispica</i>	dome	52-58-67x 25-33-46	sinuously wavy	A ₁
<i>F. ferruginea</i> var. <i>sieboldii</i>	high-dome	42-47-52x 25-30-40	slightly sinuously wavy	A ₂
<i>F. littoralis</i>	dome	48-53-58x 27-28-29	sinuously wavy	B ₁

*length \times width (minimum-average-maximum) μ m

LM: Subsidal cells dome-shaped. Stomata 52-58-67 μ m long and 25-33-46 μ m wide. Usually one row of stomata present in intercostal zone. Long cells 79-93-113 μ m long and 19-25-29 μ m wide, cell walls sinuously wavy. Four rows of long cells present in intercostal zone. Silica body A₁-shaped.

SEM: Intercostal zones; four rows of long cells, square-rectangular, and non-uniform, walls sinuously wavy and raised. Stomata; one row in each zone, subsidiaries low-dome shape, inflated, interstomata long and narrow, ends shortly and U-shaped. Cuticle well-developed on both leaf surfaces and rough (Figs. 8, 9).

F. ferruginea (L.) Vahl. var. *sieboldii* (Miq.) Ohwi

LM: Subsidal cells high-dome shape. Stomata 42-47-52 μ m long and 25-30-40 μ m wide. One row of stomata present in intercostal zone. Long cells 58-84-125 μ m long and 21-25-36 μ m

Table 3. Some important epidermal characters of Korean *Fimbristylis* observed using SEM.

Taxa	Characters	Shape of long cells	Cell wall shape	Stomata shape	ab; ad; I II III
<i>Fimbristylis</i>		long and	straightly	low-dome	+ - -
<i>aestivalis</i>		narrow	sinuous	inflated	+ - -
subsp. <i>squarrosa</i>		uniform	wavy	V-shaped	
<i>F. autumnalis</i>		long and	sinuously	low-dome	+ + -
		narrow	wavy	inflated	+ - -
		non-uniform		U-shaped	
<i>F. complanata</i>		long and	sinuously	low-dome	+ + -
for. <i>exalata</i>		narrow	wavy	inflated	+ - -
		uniform		U-shaped	
<i>F. dichotoma</i>		long and	straightly	low-dome	+ - +
		narrow	sinuous	inflated	+ - +
		uniform	wavy, raised	U-shaped	
<i>F. dichotoma</i>		rectangular	sinuously	low-dome	+ - -
subsp. <i>longispica</i>		non-uniform	wavy, raised	inflated	+ - -
				U-shaped	
<i>F. ferruginea</i>		long and	sinuously	low-dome	+ - -
var. <i>sieboldii</i>		narrow	wavy	non-	+ - -
		uniform	raised	inflated	
				V-shaped	
<i>F. littoralis</i>		long and	sinuously	high-dome	+ - -
		narrow	wavy	non-	- - -
		uniform	raised	inflated	
				V-shaped	

I; cuticle, II; papillae, III; prickle, ab; abaxial surface, ad; adaxial surface, +; present, -; absent

wide, cell walls slightly sinuously wavy. Three or five rows of long cells present in intercostal zone. Silica body A₂-shaped.

SEM: Intercostal zones; three or five rows of long cells, square-long, narrow, and uniform, walls sinuously wavy and raised. Stomata; one row in each zone, subsidiaries low-dome shape, non-inflated, interstomatals long and narrow, ends straightly long and V-shaped. Cuticle well-developed and thickened (Figs. 10-12).

F. littoralis Gaudich

LM: Subsidal cells dome-shaped. Stomata 48-53-58 μ m long and 27-28-29 μ m wide. Two rows of stomata present in intercostal zone. Long cells 73-95-119 μ m long and 21-27-33 μ m wide, cell walls very sinuously wavy. Six or ten rows of long cells present in intercostal zone. Stomata present on both surfaces of the leaf blade. Silica body B₁-shaped.

SEM: Intercostal zones; six rows of long cells, square-long, narrow, and uniform, walls sinuously wavy and raised. Stomata; two rows in each zone, subsidiaries high-dome shape, non-inflated, interstomatals long and narrow, ends shortly and V-shaped. Cuticle well-developed on the abaxial surface of leaf (Fig. 7).

Key to the Korean *Fimbristylis* taxa based on the leaf epidermal characters using LM

- A. Subsidal cells triangular or sub-triangular.
 - B. Subsidal cells triangular.
 - C. Cell walls slightly sinuously wavy, prickles present on both leaf surfaces *F. asetivalis* subsp. *squarrosa*
 - C. Cell walls very sinuously wavy, prickles absent *F. autumnalis*
 - B. Subsidal cells sub-triangular *F. complanata* for. *exalata*
- A. Subsidal cells high-dome or dome shape.
 - B. Subsidal cells high-dome shape *F. ferruginea* var. *sieboldii*
 - B. Subsidal cells dome shape.
 - C. Cell walls sinuously or shallowly wavy.
 - D. Cell walls very sinuously wavy *F. littoralis*
 - D. Cell walls sinuously wavy *F. dichotoma* subsp. *longispica*
 - C. Cell walls shallowly wavy *F. dichotoma*

Key to the Korean *Fimbristylis* taxa based on the leaf epidermal characters using SEM

- A. Intercostal long cells long and narrow, uniform or non-uniform.
 - B. Intercostal long cells uniform, stomata low-dome or high-dome shape.
 - C. Stomata low-dome shape, inflated, V-shaped, U-shaped, or non-inflated, V-shaped.
 - D. Stomata inflated, V-shaped or U-shaped.
 - E. Stomata V-shaped *F. asetivalis* subsp. *squarrosa*

- E. Stomata U-shaped.
 - F. Cell walls sinuously wavy *F. complanata* for. *exalata*
 - F. Cell walls straightly sinuous wavy *F. dichotoma*
- D. Stomata non-inflated, V-shaped *F. ferruginea* var. *sieboldii*
- C. Stomata high-dome shape, non-inflated, V-shaped *F. littoralis*
- B. Intercostal long cells non-uniform, stomata low-dome shape, inflated, U-shaped *F. autumnalis*
- A. Intercostal long cells rectangular, non-uniform *F. dichotoma* subsp. *longispica*

Discussion

Results from this study show that many leaf epidermal characters, including the shape of subsidiary cells, intercostal cell walls, and the presence or absence and shape of silica bodies, were found to be important for the species classification and identification of Korean sedge.

Many systematists have studied gross morphology, including spikelet, achene and foliage characters (Holm, 1899; Ward, 1968; Koyama, 1974, 1978, 1979). Also some histological features of stem, leaves, and achenes of several sedge taxa were studied using scanning electron microscope (Schuyler, 1971; Walter, 1975; Toivonen and Timonen, 1976; Denton, 1983; Oh, 1980a, b, 1985a, b, 1987a, b, 1988, 1991). According to the present study, these characters can be used only in delimiting the taxa below the species level. In addition, several new important distinguishing characters were found from SEM observation. In LM observations, each taxa was distinguished mainly by the shape of subsidiary cells, intercostal cell wall, stomata, silica body, and the arrangement of papillae and prickles. However, in SEM observations, the most important distinguishing characters are the shape of intercostal long cells and the interstomatal shape. SEM observation also showed that the most useful distinguishing characters in these taxa are different from those.

In conclusion, the epidermal patterns of *Fimbristylis* seem to be very useful characteristics in classifying species.

摘 要

하늘직이속(*Fimbristylis*) 식물의 잎의 표피형에 대한 연구로서 3종, 2아종, 1변종, 1품종에 대하여 광학현미경과 주사전자현미경을 사용하여 표피형을 조사하였다. 표피형의 구성요소는 종류에 따라서 차이가 있어 하늘직이속 식물의 감별 및 분류에 사용할 수 있는 형질이 된다고 볼 수 있다. 조사된 특징은 기공의 크기, 부세포의 모양과 배열, 긴세포의 벽의 모양, 규소체, 가시털, 유두상돌기의 유무와 모양이었다. 관찰한 표피형에 대하여 사진기재와 검색표로 밝히는 바이다.

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Figs. 1, 2. *F. aestivalis* (Retz.) Vahl. subsp. *squarrosa*

Figs. 3, 4. *F. complanata* (Retz.) Link. for. *exalata*

Figs. 5, 6. *F. dichotoma*

Fig. 7. *F. littoralis*

Figs. 8, 9. *F. dichotoma* Vahl. subsp. *longispica*

Figs. 10-12. *F. ferruginea* (L.) Vahl. var. *sieboldii*

PLATE 1

PLATE 2