

Microstructure of Perigynium and Achene Surfaces of *Carex* sect. *Siderostictae* in Korea

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Scanning electron microscope revealed several taxonomically useful characters in the perigynium and achene epidermis of sect. *Siderostictae* (*Carex siderosticta*, *C. ciliatomarginata* and *C. okamotoi*). Microscopic characters such as perigynium shape, hair presence or absence, beak shape, nodule situation in perigynium, achene shape, cell wall and silica cone in achene were useful in *Carex* at the species levels. A key was presented on the basis of features obtained from the examinations.

Keywords: microstructure, perigynium, achene, *Siderostictae*, SEM

The genus *Carex* (Cyperaceae) is very variable, and one of the largest and most widely distributed genera in the world (ca. 2,000 species, Dahlgren *et al.*, 1985).

Regarding the Korean species of sect. *Siderostictae*, Ohwi (1936) reported three species; *Carex ciliatomarginata* Nakai, *C. okamotoi* Ohwi, and *C. siderosticta* Hance. Park (1946) and Nakai (1952) also reported three species of sect. *Siderostictae*.

Oh (1983, 1984, 1986) published a series of revisions on the Korean Cyperaceae, including 13 genera and 184 species. She divided *Carex* in to two subgenera, *Vignea* and *Eucarex* (*Carex*), 56 sections following Ohwi (1936) system. Lee and Oh (1972) reported three species *C. ciliatomarginata*, *C. okamotoi*, and *C. siderosticta*, with detailed descriptions of gross morphology, leaf anatomy, ecological habitat, and distribution. Although, Koyama (1968, 1977) treated *C. ciliatomarginata* as a synonym of *C. siderosticta* Hance subsp. *pilosa* Lev. in sect. *Laxiflorae*, his treatment has not been accepted thus far by many taxonomists (Nakai, 1952; Lee, 1980; Oh, 1983; Ohwi, 1984 and Makino, 1988).

The epidermis of perigynia and achenes examined by the SEM have been recognized as insignificant characters for the genus *Carex* (Walter, 1975; Toivonen and Timonen, 1976; Kukkonen and Toivonen, 1988). Unfortunately, these characters of

Carex of Korea have never studied thus far. Although special attention should be paid to the gross morphology, such as inflorescence and flower structure, an identification of *Carex* of Korea are still confused due to the lack of this study.

Therefore, microstructure of the epidermis of perigynia and achenes of three Korean *Carex* species was examined using a scanning electron microscope to evaluate their usefulness for identification and classification.

MATERIALS AND METHODS

For observation of epidermal patterns of perigynia and achenes of three Korean species of sect. *Siderostictae*, herbarium specimens were used (see Appendix). All specimens used in this study were preserved in the Department of Biology, Ewha Womens University (EW) and Sungshin Women's University (SWU).

For the SEM, the author followed procedure of Toivonen and Timonen (1976). Since the epidermal cells on the basal and apical parts were variable those of on abaxial surfaces of the middle part of perigynia and achenes were chosen for comparison as suggested by Walter (1975), and Toivonen and Timonen (1976). Terminologies for discription of anatomical and morphological characteristics of perigynia and achenes mainly followed Metcalfe (1971) and Berggren (1969).

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RESULTS

Characteristics of perigynia and achenes of three Korean species of sect. *Siderostictae* are shown in Table 1 and 2. Outer cell walls of the perigynia of sect. *Siderostictae* were, in general, thickly cutinized. The cell surfaces were convex and whitish-punctate. In all three species examined, the outer cell walls, especially those of intercostal cells, were concave and coated with a layer of loose wax. In addition, the teeth on the margin were completely absent. The shape of perigynia was either trigonous in cross section and elliptic in outline or trigonous in cross section and ovate to oblong in outline. The beak and base of perigynia varied from short to long (Plate 1). The nodules were distinct in *C. ciliatomarginata*,

but rarely visible in *C. siderosticta* and *C. okamotoi*. Intercostal cell shape in the middle part of perigynia varied from narrowly-oblong or roundly-quadrate to oblong. The costal cells were usually somewhat longer and narrower than those in intercostal zones. The nerve number in each face of perigynia was four to seven. Hairs were present only in *C. ciliatomarginata*.

The shape of achene was trigonous in cross section and ovate to orbicular in outline. Beak and base of achenes varied from short to long. The epidermal cells varied from hexagonal to oblong in shape. The cell walls were concave or convex, and wavy or slightly wavy. Each cell had one convex or conical silica cone.

Table 1. Characteristics of perigynia of three Korean species of *Carex* sect. *Siderostictae*

Character	<i>C. siderosticta</i>	<i>C. ciliatomarginata</i>	<i>C. okamotoi</i>
Shape			
cross section	trigonous	trigonous	trigonous
outline	elliptic	elliptic	oblong
Hair	absent	abundant	absent
Nerve number	5-6	4-6	5-7
Intercostal cell shape	oblong	roundly quadrate to oblong	narrowly oblong
Outer cell walls in the intercostal cells	concave	concave	concave
Cell surface	convex	strongly convex	convex
Loose wax on epidermal cell wall	densely present	sparsely present	present
Beak (μm)	short *(235-271-324), truncate at apex	long (441-444-559), conical at apex	short (306-331-361), 2-cleft at apex
Base (μm)	long (676-709-735)	long, twisted (765-788-824)	short (307-328-361)
Nodules	absent	distinct	absent

*(minimum-average-maximum)

Table 2. Characteristics of achenes of three Korean species of *Carex* sect. *Siderostictae*

Character	<i>C. siderosticta</i>	<i>C. ciliatomarginata</i>	<i>C. okamotoi</i>
Shape			
cross section	trigonous	trigonous	weakly trigonous
outline	ovate	ovate	orbicular
Epidermal cell shape	hexagonal to oblong	hexagonal to circular	long hexagonal to oblong
Cell wall	wavy and concave	slightly wavy and convex	slightly wavy and convex
Silica cone/cell	1	1	usually absent, rarely 1
Silica cone shape	conical	convex	nearly convex when present
Beak(rachilla, μm)	short*(52-63-73)	long(333-354-375)	short(38-42-52)
Base (μm)	short(31-38-42)	short(73-104-135)	long(146-190-208)

*(minimum-average-maximum)

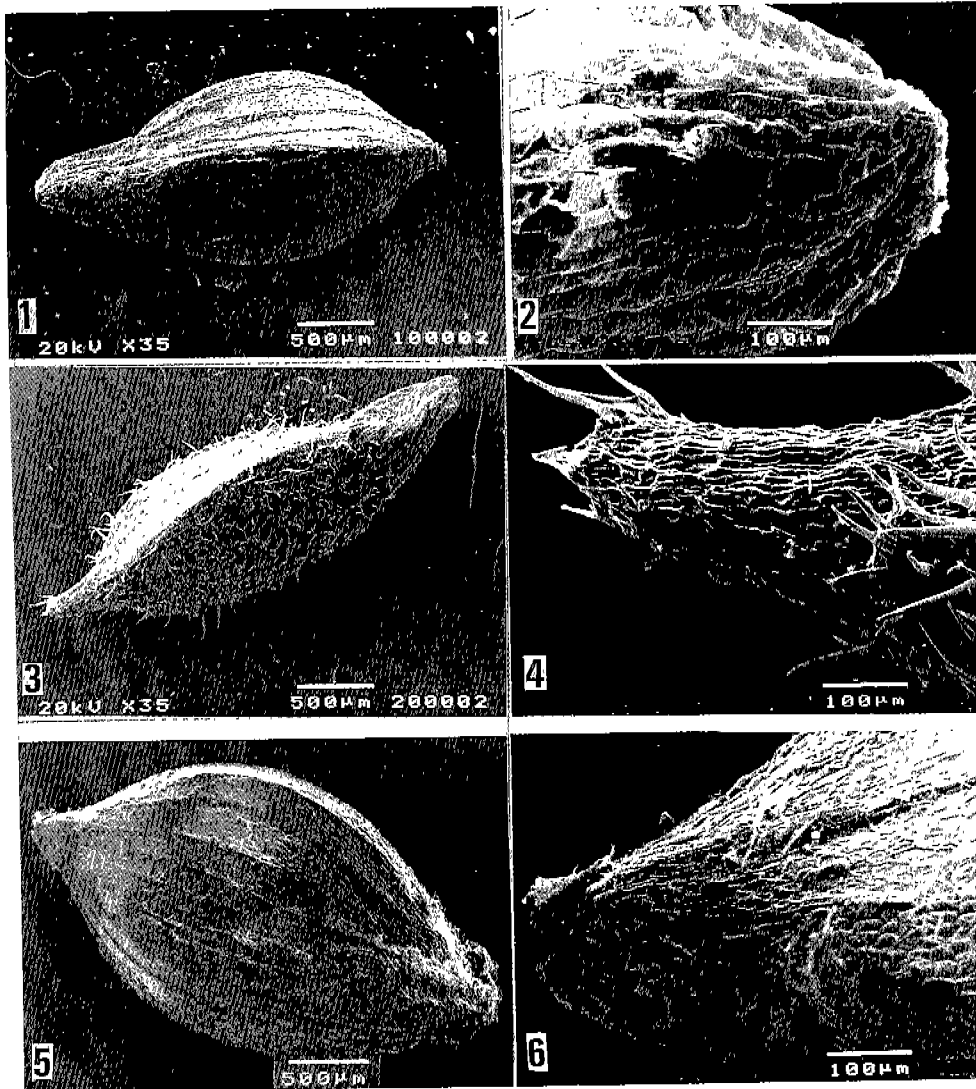


Plate 1. SEM photomicrographs of perigynia of *Carex* sect. *Siderostictae*. Even numbers, perigynium shape; odd numbers, beaks of perigynia. 1, 2. *C. siderosticta* Hance; 3, 4. *C. ciliatmarginata* Nakai; 5, 6. *C. okamotoi* Ohwi.

Carex siderosticta

Perigynia were trigonous in cross section and elliptic in outline. They have short (235-271-324 μm) truncate beaks and long (676-709-735 μm) bases. With 5-6 nerves on each face (Plate 1), and surfaces are glabrous. No teeth were found on the margins. The outer cell walls were concaved and coated with a layer of loose wax. The epidermal cells were convex, oblong, and glabrous (Plate 3). Nodulcs were rarely visible. The costal cells were somewhat longer, and significantly narrower than those in intercostal zones. Achenes were trigonous in cross

section and ovate in outline. They have short (52-63-73 μm) beaks and short (31-38-42 μm) truncated bases (Plate 2). The cell walls were concave and wavy. The epidermal cells were hexagonal to oblong, and each cell had one conical silica cone (Plate 3).

C. ciliatmarginata

Perigynia were trigonous in cross section and elliptic in outline. They have long (441-444-559 μm) conical beaks and long (765-788-824 μm) twist bases. With 4-6 nerves (Plate 1). Hairs were present

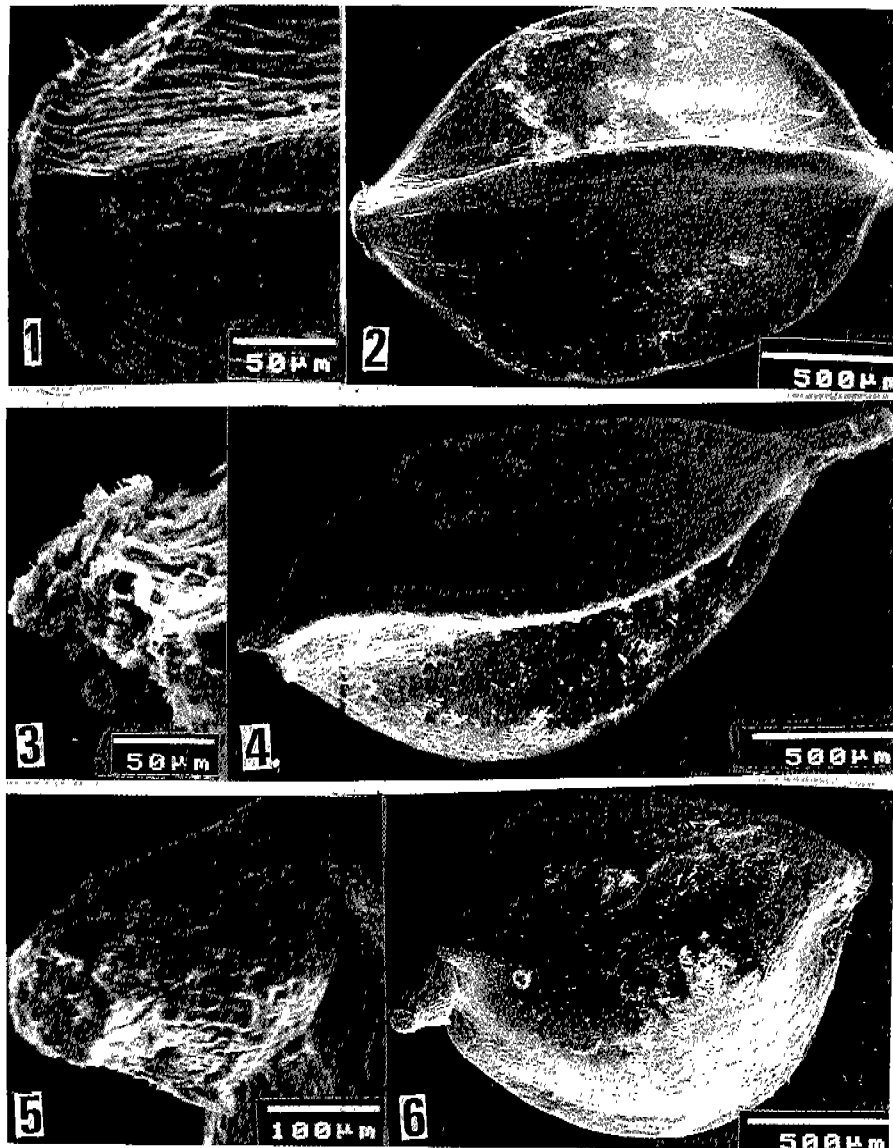


Plate 2. SEM photomicrographs of achenes of *Carex* sect. *Siderostictae*. Even numbers, base of achenes: odd numbers, achene shape. 1, 2. *C. siderosticta* Hance: 3, 4. *C. ciliatomarginata* Nakai: 5, 6. *C. okamotoi* Ohwi.

on the surfaces. No teeth were found on the margin. The outer cell walls were concave and coated with a layer of loose wax. The epidermal cells were strongly convex, roundly quadrate, and pilose (Plate 3). Nodules were clearly visible. The costal cells were somewhat longer, and significantly narrower than those in intercostal zones. Achenes were trigonous in cross section and ovate in outline. They have long (333-354-375 μm) beaks and short (73-104-135 μm) bases (Plate 2). The cell walls were convex and slightly wavy. The epidermal cells were hexagonal to circular-shaped, and each cell had one convex sil-

ica cone (Plate 3).

C. okamotoi

Perigynia were trigonous in cross section and ovate to oblong in outline. They have short (306-331-361 μm) two-clefted beaks and short (307-328-361 μm) bases, with 5-7 nerves (Plate 1). No hair were present on the surface. No teeth were found on the margins. The outer cell walls were concave, and coated with a layer of loose wax. The epidermal cells were convex, narrowly oblong, and glabrous

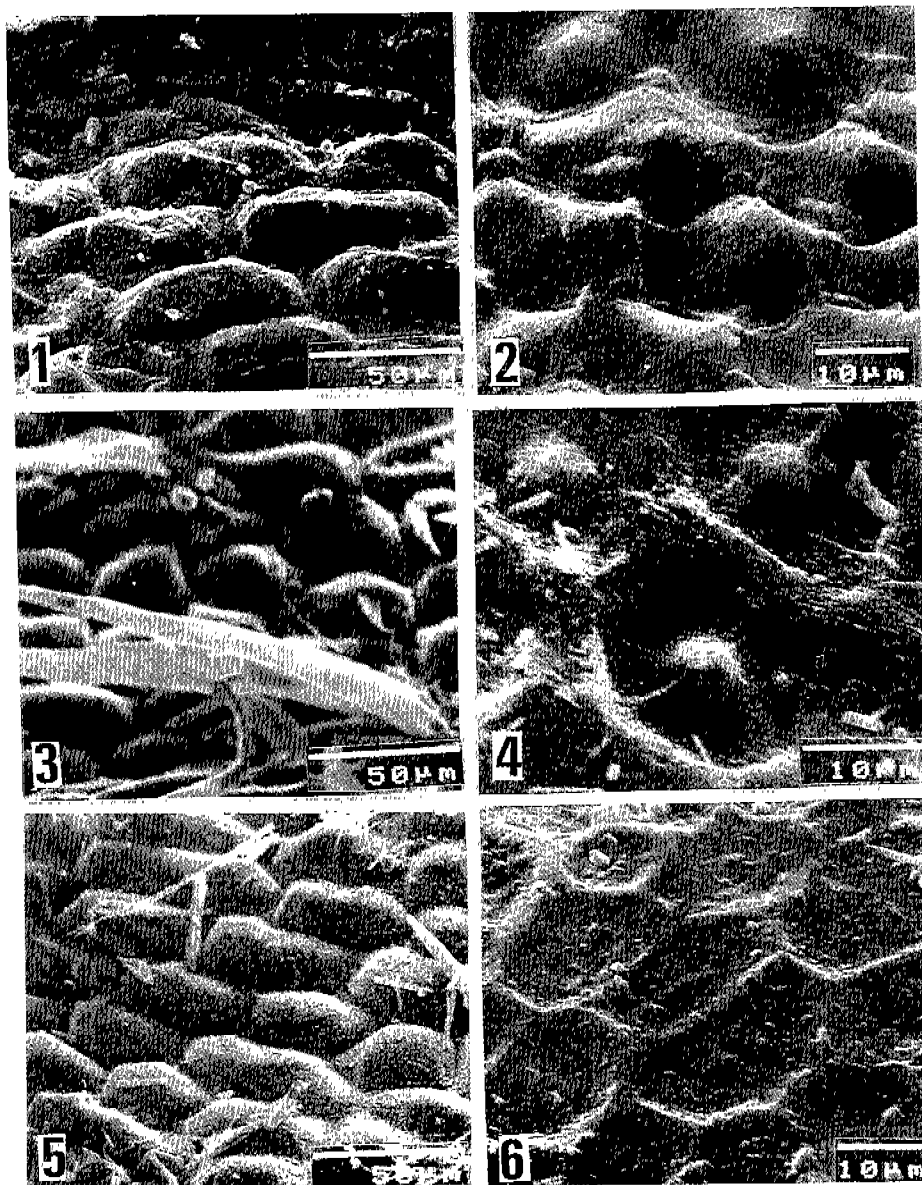


Plate 3. SEM photomicrographs of epidermis of perigynia and achenes of *Carex* sect. *Siderostictae*. Even numbers, epidermis of perigynia; odd numbers, epidermis of achenes. 1, 2. *C. siderosticta* Hance; 3, 4. *C. ciliatomarginata* Nakai; 5, 6. *C. okamotoi* Ohwi.

(Plate 3). The costal cells were somewhat longer, and significantly narrower than those in intercostal zones. Achenes were weakly trigonous in cross section and orbicular in outline. They have short (38-42-52 μm) beak and long (146-190-208 μm) base (Plate 2). The cell walls were convex and slightly wavy. The epidermal cells were long hexagonal to oblong in shape. The epidermal cells sometimes possessed one nearly convex silica cone (Plate 3).

DISCUSSION

Perigynia

Perigynia of *C. siderosticta* and *C. ciliatomarginata* were trigonous and elliptic in shape, whereas those of *C. okamotoi* were trigonous and oblong. Perigynia of *C. ciliatomarginata* were pilose, while those of other species were glabrous. The co-

stal cells of perigynia bore nodules in *C. ciliatomarginata*, as in leaves (Oh, 1987), but nodules were absent in *C. siderosticta* and *C. okamotoi*. While the beak shape of *C. siderosticta* were short and truncate at apex, that of *C. ciliatomarginata* were long and conical at apex. In addition, the beak shape of *C. okamotoi* were short and 2-cleft at apex. The shape of base (rachilla) in *C. siderosticta* and *C. ciliatomarginata* were long, especially base of *C. ciliatomarginata* twisted.

The shape of beaks and bases varied from short to long in these species. Considering these characters, *C. siderosticta* and *C. ciliatomarginata* are identical in perigynium shape. *Carex siderosticta* and *C. okamotoi* had possess identical characters in absence of hairs, cell surface and situation of nodules. Therefore, microstructure and shape of perigynia in these species suggest that *C. okamotoi* is probably more closely related to *C. siderosticta* than to *C. ciliatomarginata*. The shape of perigynia, the presence or absence of hairs, the shape of intercostal cells, nodules, beaks and bases were found to be important for classification and identification of *Carex* species of sect. *Siderosticta* in Korea. These results are in a good agreement with those of Toivonen and Timonen (1976) that microscopic characters being useful in *Carex* taxonomy both at the species and sectional level.

Achenes

Achenes of *C. siderosticta* and *C. ciliatomarginata* are trigonous and ovate, whereas those of *C. okamotoi* are weakly trigonous and orbicular in shape. The epidermal cells varies from hexagonal to oblong in shape. The three species examined could be identified on the basis of ultrastructure of the achene epidermis. The epidermal cells were smaller in *C. ciliatomarginata* and *C. okamotoi* than in *C. siderosticta*. Also, the cell walls of *C. siderosticta* are concave, whereas those of other species are convex.

As in many other groups of *Carex*, the epidermal cells of achene usually bear one distinct silica cone (Plate 3). In sect. *Siderostictae*, silica cones are relatively large, and cover the whole inner cell wall. In *C. siderosticta* and *C. ciliatomarginata*, silica cones are conical and convex, respectively. In *C. okamotoi*, however, most of the epidermal cells do not bear silica cones or very rarely have developed ones.

Carex siderosticta and *C. ciliatomarginata* are identical in shape and base of achenes. *Carex siderosticta* and *C. okamotoi* are identical in shape of achene beaks. *Carex ciliatomarginata* and *C. okamotoi* are identical in cell wall waviness, cell wall situation, and silica cone shape of achenes. Thus, *C. okamotoi* in Korea is more similar to *C. ciliatomarginata* than to *C. siderosticta* in achene shape and microstructure.

Carex siderostictae complex is represented in Korea by three species. On the basis of the results of this current observation of perigynia and achene morphology, epidermal cell types (Oh, 1987), and other morphological features (Oh, 1972), *C. siderosticta* was most similar to *C. ciliatomarginata* because of perigynia shape, base shape and outer cell walls in the intercostal cell, cell surface, loose wax on epidermal cell wall, and achene shape, epidermis, base of achene, hair presence or absence, shape of intercostal cell, interstomata and cell wall wavy.

On the other hand, *C. ciliatomarginata* and *C. okamotoi* shared several characters, such as intercostal cell shape of perigynia, outer cell wall, loose wax of epidermal cell wall, and epidermis of achene, cell wall wavy, silica cone in achene, shape and size of utricle, subsidiary cell of stomata, shape of interstomatales, length of sheath, rhizome and stolon.

In both species of *Carex siderosticta* and *C. okamotoi*, the absence of hair on perigynia, shape of perigynia beak, absence of nodule, achene beak and size of leafblade were found as common characters. Chromosomes as a result of the careful comparative observation, similarities between *C. ciliatomarginata* ($2n=12$, Hoshino and Shimizu, 1986) and *C. okamotoi* ($2n=?$) supported the affinities of both species. On the other hand, *C. siderosticta*, which differed strikingly in several respects, such as polyploids ($2n=12/24$, Darlington, 1955; Hoshino and Tanaka, 1977, 1981), probably arose from *C. ciliatomarginata* and *C. okamotoi* couples. These three species are also different with respect to habitats. *C. siderosticta* prevailed in humus soil and moisture lowland, while *C. ciliatomarginata* occupied the rocks of high elevated mountains with nearby streams and *C. okamotoi* extended along the shady mountain slopes with relatively rich soils. All these results supported that *C. siderosticta* is a relatively recent derivative of *C. okamotoi* and *C. ciliatomarginata*.

Schuyler (1971) and Walter (1975) showed that the achene epidermis was rather similar in tax-

onomically closely related species in sedge. But in sect. *Siderostictae*, achene shape, epidermal cell shape, cell wall waviness, situation of cell walls, silica cone shape, and beak and base of achenes were found to be unique and important for classification and identification of species (Toivonen and Timonen, 1976; Bruederle and Fairbrothers, 1983; Standley, 1985).

The results of this study strongly suggested that the three taxa are distinct species. In conclusion, the perigynia and achenes epidermal patterns of *Carex* seem to be very useful characters for classification of species.

<Key to the species of *Carex* sect. *Siderostictae* in Korea based on microstructure of perigynia and achenes>

1. Perigynia trigonous and elliptic in shape, with long bases, shape of achene trigonous and ovate with short bases.
2. Perigynia glabrous, with long truncate beaks and rarely with nodules, cell wall of achenes concave, beak of achene short (52-63-73 μm), with a conical silica cone *C. siderosticta*
2. Perigynia pubescent, with long conical beaks and distinct nodules, cell walls of achenes convex, beak of achene long (333-354-375 μm), with a convex silica cone.....
.....*C. ciliatomarginata*
1. Perigynia trigonous and ovate to oblong in shape, with short (307-328-361 μm) bases, achenes weakly trigonous and orbicular, with long (145-190-208 μm) bases *C. okamotoi*

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Appendix. Collection data for materials used in this study

Species	Localities
<i>C. siderosticta</i> Hance	KW: Mt. Sorak, Mt. Munlae, Mt. Backbongryong, Mt. Taeback, Mt. Daeam, SE: Saigumehung (EW), KG: Mt. Tobong (EW), Kwangnung, Isl. Kangwhado (EW), Isl. Chakyakdo (EW) Mt. Chonma (EW), Mt. Chukryong, Mt. Soyo (EW), Mt. Surak, Paju (EW), Chuan (EW), Mt. Sang, Mt. Juckreup (EW), Mt. Koryong (Temple) Bokwangsa), Mt. Meungji, Mt. Backun, CHB: Mt. Sokri, Mt. Soback, CHN: Mt. Kyeryong, Mt. Kaya (EW), CLB: Mt. Duckyoo, Mt. Mai, Mt. Naejang, CLN: Mt. Chiri, Isl. Wando (EW), Mt. Chogae, Mt. Backyang, KB: Mt. Toham (EW), Mt. Palkong, Mt. Juwhang, KN: Mt. Chiri, Hamyang (EW), CH: Mt. Halla (EW)
<i>C. ciliatomarginata</i> Nakai	KW: Mt. Sorak, SE: Chinkwansa (Temple, EW), Gupabal (EW), Bulamsa (Temple, EW), Chongnung (EW), KG: Mt. Tobong (EW), Mt. Pukhan (EW), Ildong-Myoen, Eunkogae, Eunchungbu, Kangnung, Mt. Chukryong, Mt. Sang, Mt. Surak, CHB: Mt. Sobak, Youngdong-gun, Chumaryong, Mt. Minjuji (EW), CHN: Mt. Kaya (EW), Mt. Kyeryong, Mt. Sokri, CLB: Mt. Naejang, CLN: Mt. Mudung, Mt. Chiri, Mt. Backyang, KB: Mt. Juwhang, Mt. Keumoh (Gumi), Mt. Toham (EW) KN: Isl. Kojedo (Changsunpo, EW), CH: Mt. Halla
<i>C. okamotoi</i> Ohwi	KW: Mt. Sorak (Hankaeryong), Mt. Odae, KG: Mt. Backun, CHB: Mt. Soback, Mt. Minjuji (EW), Mt. Gakho (Yongdong-gun, EW), CHN: Mt. Kyeryong, Mt. Sokri, CLB: Mt. Duckyoo, Mt. Naejang, Chunggeup, CLN: Mt. Chiri, Mt. Backyang, Mt. Chogae, KB: Mt. Juwhang Mt. Kaya (Temple Hacinsa)

KW: Kwangwondo, SE: Seoul, KG: Kyonggido, CHB: Chungchoungbukdo, CHN: Chungchoungnamdo, CLB: Chollabukdo, CLN: Chollanamdo, KB: Kyongsangbukdo, KN: Kyongsangnamdo, CH: Chejudo

*All specimens were preserved at Sungshin Women's University (SWU), otherwise preserved at Ewha Womens University (EW).