Carex paracheniana (Carex sect. Rhomboidales, Cyperaceae), a New Species from Guangxi and Guizhou, China

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Source: Systematic Botany, 37(4) : 929-937

Published By: The American Society of Plant Taxonomists

URL: https://doi.org/10.1600/036364412X656617
**Carex paracheniana** (Carex sect. *Rhomboidales*, Cyperaceae), a New Species from Guangxi and Guizhou, China

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Communicating Editor: Victoria Sosa

**Abstract**—*Carex paracheniana*, a new species of Cyperaceae from China, is described and illustrated. The new species is recognized as a member of *Carex* sect. *Rhomboidales* in having broadly ovoid perigynia and rhombic-ovoid nutlets. It is similar to *C. cheniana* and *C. brevicuspis*, but differs from the former in having narrower leaves 3–5 mm wide, staminate scales that are obtuse at the apex, and nutlets abruptly contracted into a ca. 1 mm long, slightly curved beak at the apex. It differs from *C. brevicuspis* in having ovate-elliptic pistillate scales that are glaucous or pale yellow and long-awned at the apex, and styles that are thickenened at the base. Micromorphological characters of the leaf epidermis, perigynia, and nutlets are compared among taxa.

**Keywords**—Anatomy, Cyperaceae, nutlet, perigynium, SEM, taxonomy.

*Carex* L. is one of the largest genera of monocotyledons, and the largest in Cyperaceae, with ca. 1,800 species (Govaerts et al. 2007). It is easily distinguished from most other genera in the family by having the nutlets enclosed in sac-like perigynia (Nelmes 1951). It is currently divided into three subgenera, namely subg. *Vigneastra* (Tucker.) Kük., subg. *Vignea* (B. Beauv. ex Lesti.) Peterm., and subg. *Carex* (Dai et al. 2000). It is almost cosmopolitan in distribution and found in a wide range of habitats (Dai et al. 2000; Nelmes 1951; Ohwi 1956; Zhang et al. 1998).

Kükenthal (1909) established *Carex* sect. *Rhomboidales* but without designating a type. Wang (1962) later designated the type as *C. thibetica* Franch. The section was distinguished by trigonous, obvoid or ovoid nutlets that are contracted in the middle, and mitrate or hastate at the apex (Kükenthal 1909). Ohwi (1936) and Akiyama (1955) also recognized sect. *Rhomboidales* but assigned taxa with non-beaked nutlets to other sections.

In the *Flora of China*, the treatment for *Carex* (Dai et al. 2000), the 54 species of sect. *Rhomboidales* sensu Kükenthal are divided between sect. *Rhomboidales* and sect. *Careyanae* Tucker. Species with densely-flowered spikes and nutlets that are often constricted at the middle are assigned to sect. *Rhomboidales*, while those with sparsely-flowered spikes and unconstricted nutlets are assigned to sect. *Careyanae*. In addition, the perigynia and nutlets of sect. *Careyanae* are distinct from those of sect. *Careyanae*. The perigynium beak in sect. *Careyanae* has a conspicuously bifid apex, while in sect. *Careyanae* it is obliquely truncate. The nutlets of sect. *Careyanae* (sensu Dai et al. 2000) are conspicuously beaked, with the beaks erect, slightly curved or coiled, and the styles frequently thickened at the base. In sect. *Careyanae* the nutlets are inconspicuously beaked, with non-thickenened styles (Jin et al. unpublished). Recently, six new taxa have been described in sect. *Rhomboidales* (Jin et al. 2004; Jin and Zheng 2010; Oda et al. 2003; Shimizu 2008; Song et al. 2008; Su 2009).

In April 2004 and May 2009, the first author of this paper conducted fieldwork in the montane regions of eastern and southern China. During the fieldwork, an unusual *Carex* was collected from northern Guangxi which is recognized here as a new species in sect. *Rhomboidales* (sensu Dai et al. 2000), with morphological affinities to *Carex cheniana* Tang & F. T. Wang ex S. Yun Liang and C. brevicuspis C. B. Clarke.

**Materials and Methods**

**Sampled Materials**—Fieldwork was conducted in eastern, southern, and southwestern China, including Guangxi, Guizhou, Hunan, and Jiangxi provinces. The eight individuals of the new species were collected from Lingui County in Guangxi Zhuangzu Autonomous Region. In addition, 15 and 23 individuals of *Carex cheniana* T. Tang & Wang ex S. Yun Liang and C. brevicuspis C. B. Clarke, respectively, were sampled from Zhejiang.

**Specimen Examination**—Over 1,500 collections of sect. *Rhomboidales* were examined from 25 herbaria (ACM, E, GZTM, HAGS, HHBG, HIB, HNNU, HTC, HZU, IBK, IBSC, K, KUN, KYO, LBG, N, NAS, OSA, P, PE, SYS, TI, WUK, ZJFC, and ZM). Almost all the type specimens of the species in sect. *Rhomboidales* were available for study and comparison. Variation of morphological characters was evaluated from the collections examined, and the diagnostic characters among the new species, *C. brevicuspis*, and *C. cheniana* were compared as well.

**Leaf Epidermis and Anatomy**—The widest mature leaves of five individuals/sample of *Carex brevicuspis*, *C. cheniana*, and the new species were observed. For leaf epidermal studies, 2 cm long leaf sections of each sample were boiled in 1% NaOH solution for 30 minutes, and then rinsed in distilled water. The abaxial and adaxial pieces of epidermis were lightly scraped and released with...
were subquadrate but also had deeply undulate anticlinal walls. The adaxial epidermal cells of Carex cheniana had adaxial epidermal cells that were oblong, with deeply undulate anticlinal walls. All the abaxial epidermal cells of Carex cheniana had silica papillae. The new species and Carex brevicupis had those of Carex brevicupis, while only one silica body was present or silica bodies were absent in each cell of Carex cheniana. The epidermal cells of the new species were regularly 4–6-gonal, and the inner periclinal walls were not undulate. A single silica body was present in each cell. With a test of significance of group comparison, the epidermal cells of the new species (42.253 ± 8.081 µm, mean ± standard deviation) were significantly smaller than those of Carex cheniana (55.070 ± 10.522 µm) and Carex brevicupis (54.933 ± 10.956 µm), with the p values 0.000104 and 0.000313 respectively.

Transverse sections of the leaves are shown in Fig. 2 and Table 1. The bulliform cells of Carex cheniana were in two layers, while those of Carex brevicupis and the new species were in one layer. The sclerenchyma in the costae of the vascular bundles of Carex cheniana was abaxially well developed, as it was in the lateral vascular bundles, both adaxially and abaxially. However, in Carex brevicupis and the new species it was less developed. The vascular bundles of Carex cheniana had two cell layers, the inner one being sclerenchymatous, while in Carex brevicupis and the new species the bundles had only one, non-sclerenchymatous layer.

**SEM of Perigynia and Nutlets**—The perigynia are illustrated in Fig. 3. All were broadly ovoid, many-veined, sparsely pubescent, shortly stipitate at base, and abruptly beaked at the apex. The beak orifice was bifid, and the teeth of Carex brevicupis (0.798 ± 0.062 mm, mean ± standard deviation) were significantly longer than those of Carex cheniana (0.553 ± 0.056 mm) and the new species (0.572 ± 0.032 mm) with a test of significance of group comparison. The p values respectively were 0.000362 and 0.000123. Nutlet shape and surface sculpturing in the three species are shown in Fig. 4. The nutlets were rhombic-ovoid, trigonous, with the three angles constricted at the middle, shortly curved stipitate at the base, with a beak at the apex. The epidermal cells of the nutlets of Carex cheniana and Carex brevicupis were regularly 4–6-gonal, with slightly undulate inner periclinal walls. One or two silica bodies (central bodies) were present in each cell of Carex brevicupis, while only one silica body was present or silica bodies were absent in each cell of Carex cheniana. The epidermal cells of the new species were regularly 4–6-gonal, and the inner periclinal walls were not undulate. A single silica body was present in each cell. With a test of significance of group comparison, the epidermal cells of the new species (42.253 ± 8.081 µm, mean ± standard deviation) were significantly smaller than those of Carex cheniana (55.070 ± 10.522 µm) and Carex brevicupis (54.933 ± 10.956 µm), with the p values 0.000104 and 0.000313 respectively.

**RESULTS**

**Leaf Epidermis and Anatomy**—Leaf epidermal sections of Carex cheniana, Carex brevicupis, and the new species are shown in Fig. 1 and Table 1. The abaxial epidermal cells of the new species were oblong, with undulate anticlinal walls, while those of Carex brevicupis and Carex cheniana had deeply undulate anticlinal walls. All the abaxial epidermal cells of Carex cheniana had silica papillae. The new species and Carex brevicupis both had adaxial epidermal cells that were oblong, with deeply undulate anticlinal walls. The adaxial epidermal cells of Carex cheniana were subquadrate but also had deeply undulate anticlinal walls.

**Fig. 1.** Light microscope photographs of leaf epidermis. A, D. Carex paracheniana. B, E. Carex cheniana. C, F. Carex brevicupis. A, B. C. Adaxial epidermis. D, E, F. Abaxial epidermis.
Table 1. Different characters of Leaf epidermis and anatomy in *Carex paracheniana*, *C. cheniana* and *C. brevicuspis* (* Mean and standard deviation; ** Inner layer).

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Leaf epidermal characters</th>
<th>Leaf anatomy characters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Adaxial epidermal cells</td>
<td>Abaxial epidermal cells</td>
</tr>
<tr>
<td><em>Carex paracheniana</em></td>
<td>Anticlinal wall: Oblong, Deeply undulate</td>
<td>Anticlinal wall: Oblong, Undulate</td>
</tr>
<tr>
<td></td>
<td>Size (μm): 25.2 ± 3.7*</td>
<td>Size (μm): 46.5 ± 7.9</td>
</tr>
<tr>
<td></td>
<td>Silica papillae: 180 ± 4.2</td>
<td>Sclerenchyma in costae: Absent</td>
</tr>
<tr>
<td><em>Carex cheniana</em></td>
<td>Anticlinal wall: Subquadrate, Deeply undulate</td>
<td>Anticlinal wall: Oblong, Undulate</td>
</tr>
<tr>
<td></td>
<td>Size (μm): 417 ± 9.6</td>
<td>Size (μm): 304 ± 4.3</td>
</tr>
<tr>
<td></td>
<td>Sclerenchyma in costae: Absent</td>
<td>Sclerenchyma in costae: Present</td>
</tr>
<tr>
<td><em>Carex brevicuspis</em></td>
<td>Anticlinal wall: Oblong, Deeply undulate</td>
<td>Anticlinal wall: Oblong, Undulate</td>
</tr>
<tr>
<td></td>
<td>Size (μm): 624 ± 16.7</td>
<td>Size (μm): 254 ± 16.6</td>
</tr>
<tr>
<td></td>
<td>Sclerenchyma in costae: Absent</td>
<td>Sclerenchyma in costae: Present</td>
</tr>
</tbody>
</table>

Herbaceous perennial. Rhizome brownish-black, woody, thick, short, with many yellowish-brown, fibrous adventitious roots. Culms caespitose, central, 8–35 cm tall, trigonous, smooth, covered with purplish-brown fibrous sheaths at base. Leaves longer or equal to culms; leaf-blade 3–5 mm wide, flat, smooth on lower half, scabrous on upper margins; sheaths brown, fibrofibril at apex. Involutr bracts leaf-like, shorter than inflorescence, sheathed; sheaths 0.5–1.5 cm long, obliquely truncate at orifice. Inflorescence paniculate, with 3–4 spikes; terminal spike staminate, cylindrical or clavate, yellowish-brown, 2–3 cm long, 2–2.5 mm wide, with a 2.5–4 cm long scabrous peduncle at base; lateral spikes pistillate, bearing a few staminate flowers at apex, cylindrical, 1–3 cm long, 7–9 mm wide, densely flowered, pedunculate; peduncles 1.5–3 cm long, slightly exerted from sheaths. Stamine scales ovate-oblong, pale brown, membranous, 4–4.5 mm long, 1.5–1.8 mm wide, obtuse at apex, green 3-veined costa on dorsal surface. Pistillate scales ovate-elliptic, 6.5–7 mm long (including awn), ca. 1.5 mm wide, glaucous or pale yellow, acuminate at apex, green 3-veined costa excurrent into a ca. 2 mm long scabrous awn. Perigynia broadly ovoid (excluding beak), 7–7.5 mm long, slightly longer than pistillate scales (including beak), ca. 3 mm wide, obliquely patent, obtusely trigonous, herbaceous, brownish-green, distinctly veined, sparsely pubescent on upper veins, abruptly contracted into a ca. 2 mm long beak at apex; beak sparsely pubescent at margin, orifice 2-lobed with short teeth. Stigmas 3; style thickened at base. Nutlets tightly enveloped by the perigynia, rhombic-ovoid, trigonous, 4.5–5 mm long (including beak), 2–2.5 mm wide, castaneous, with 3 angles constricted at middle, sides concaave above and below, shortly curved, stipitate at base, abruptly contracted into a ca. 1 mm long cylindrical beak at apex, beak slightly curved, slightly annulate at orifice. Figure 5: B, C and Figure 6.

**Representative Specimens Examined**—CHINA. Guangxi Zhuangzu Autonomous Region: Lingui County, Wantian Township, Baishi Village, on slope, alt. 1.000 m, 22 Apr 2004, X. F. Jin 943 (PE); the same locality, under forest, alt. 550 m, 14 May 2009, X. F. Jin 2379 (HTC, ZM), 2380 (HTC, HZU), Pingla County, Chaotian, on slope, alt. 1.440 m, 11 Apr 1987, Pingla Exped. 380 (CZTM).

**Distribution and Habitat**—*Carex paracheniana* is only known from two localities in southern China (Fig. 7). It grows in moist places under evergreen broad-leaved forest at 500–1,000 m (Fig. 5: A).

**Phenology**—Flowering and fruiting April-May.

**Etymology**—The specific epithet alludes to the morphological similarity of the new species to *C. cheniana* Tang & F. T. Wang ex S. Yun Liang.

**Comments**—The circumscription of sect. *Rhomboidales* by Ohwi (1936) excluded species with oblique beak orifices on the perigynia. *Carex matsumurae* was included in the section by Koyama (1962), Katsuyama (2005), and Hoshino and Masaki (2011), although it has perigynium beaks notched at the orifice, plano-convex nutlets, and...

two stigmas. These characters are different from those of other members of sect. *Rhomboidales*. Chang and Yang (1976) placed related species from northeastern China in two sections. The species with erect pistillate spikes and pubescent perigynia were placed in sect. *Rhomboidales*, while those with pendulous pistillate spikes and glabrous perigynia were placed in sect. *Laxiflorae* Kunth ex Mackenzie. Dai et al. (2000) also considered these two sections to identify the Chinese species of sect. *Rhomboidales*, but the name of sect. *Laxiflorae* was replaced by sect. *Careyanae* (Jin et al. 2011). Based on all species of sect. *Rhomboidales* in China and Japan, as well as by considering the characters of leaf anatomy, epidermis, perigynium and nutlet, we emend the circumscription of sect. *Rhomboidales* as follows:

Culms lateral or central; terminal spike staminate, lateral spikes androgynous, usually with a long or short staminate part at apex, or pistillate. Perigynia ovoid to broadly ovoid, trigonous, glabrous or pubescent, tenuously venose, apex contracted into a long beak, beak orifice...
Fig. 5. Photographs of *Carex paracheniana*. A. Natural habitat of the forest beside Baishi Village, Wantian Township, Lingui County, Guangxi Zhuangzhu Autonomous Region, China. B. Habit. C. Spikes, terminal one staminate and lateral pistillate. Scale bar = 2 cm in Fig. 5B, 1 cm in Fig. 5C.
Nutlets Contracted into a ca. 1 mm long, Perigynia Brownish-green, pubescent

Staminate scales Ovate-oblong, obtuse at apex Elliptic-lanceolate, long-awned

Length of pistillate spikes 1–3 cm 3.5–6 cm 3.5–7 cm

Length of staminate spikes 2–3 cm 1–2.5 cm 2.5–4 cm

Leaf width 3–5 mm 5–9 mm 5–10 mm

Pistillate scales Ovate-elliptic, glaucous or pale yellow, apex acuminate, with a ca. 2 mm long scabrous awn

Perigynia Brownish-green, pubescent on upper part

Nutlets Contracted into a ca. 1 mm long, slightly curved beak at apex

Table 2. Morphological characters of Carex paracheniana, C. cheniana and C. brevicuspis

<table>
<thead>
<tr>
<th>Characters</th>
<th>Carex paracheniana</th>
<th>Carex cheniana</th>
<th>Carex brevicuspis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culm height</td>
<td>8–35 cm</td>
<td>40–50 cm</td>
<td>20–55 cm</td>
</tr>
<tr>
<td>Leaf width</td>
<td>3–5 mm</td>
<td>5–9 mm</td>
<td>5–10 mm</td>
</tr>
<tr>
<td>Length of staminate spikes</td>
<td>2–3 cm</td>
<td>1–2.5 cm</td>
<td>2.5–4 cm</td>
</tr>
<tr>
<td>Length of pistillate spikes</td>
<td>1–3 cm</td>
<td>3.5–6 cm</td>
<td>3.5–7 cm</td>
</tr>
<tr>
<td>Staminate scales</td>
<td>Ovate-oblong, obtuse at apex</td>
<td>Elliptic-lanceolate, long-awned at apex</td>
<td>Lanceolate, acuminate at apex</td>
</tr>
<tr>
<td>Pistillate scales</td>
<td>Ovate-elliptic, glaucous or pale yellow, long-awned at apex</td>
<td>Narrowly ovate, glaucous, long-awned at apex</td>
<td>Lanceolate, yellowish brown, acuminate at apex</td>
</tr>
<tr>
<td>Perigynia</td>
<td>Brownish-green, pubescent on upper part</td>
<td>Yellowish-brown, pubescent</td>
<td>Dark-brown, sub-glabrous or sparsely pubescent</td>
</tr>
<tr>
<td>Nutlets</td>
<td>Contracted into a ca. 1 mm long, slightly curved beak at apex</td>
<td>Contracted into a ca. 1 mm long, slightly curved beak at apex</td>
<td></td>
</tr>
</tbody>
</table>

Key to Carex paracheniana and the Related Species of Sect. Rhomboidales in China

1. Nutlet beaks slightly curved or erect, annulate at apex ........................................... 2
2. Perigynia densely pubescent; pistillate scales, involucral bracts, bract sheaths, culms and leaves pubescent ........................................... C. pseudolaticeps
2. Perigynia sparsely pubescent or glabrous; pistillate scales, involucral bracts, bract sheaths, culms and leaves glabrous ........................................................................ 3
3. Perigynia pubescent; nutlets coiled-stipitate at base .............................................. 4
4. Lateral spikes androgynous, with a long staminate part at apex ........................................... 5
5. Pistillate scales ovate-lanceolate, pale yellow, acuminate, with a ca. 2 mm long scabrous awn ........................................... C. saxicola
6. Rhizomes long-creeping; leaves trabeculate; pistillate scales with a glabrous awn at apex ........................................... C. yandangshanica
7. Perigynia subcoriaceous, glaucous; nutlet beaks erect .................................................. C. chaofangii
8. Perigynia herbaceous, brownish-green or dark brown; nutlet beaks slightly curved ........................................... 8
9. Perigynia brownish-green, pubescent on upper part; pistillate scales ovate-lanceolate, glaucous or pale yellow, apex long-awned; styles thickened at base ........................................... C. paracheniana
10. Perigynia brown, sparsely pubescent or subglabrous; pistillate scales lanceolate, yellowish-brown, apex acuminate; styles not thickened at base ........................................... C. brevicuspis
11. Lateral spikes androgynous, with a long staminate part at apex ........................................... 12
12. Nutlets long-beaked at apex, beaks erect ................................................................. C. rychnophora
13. Nutlets not beaked, but disc-annulate at apex ............................................................. C. chorda
14. Lateral spikes pistillate; nutlets deeply constricted on middle angles ........................................... C. harlandii
15. Leaves 4–6 mm wide; culms 10–30 cm in height, slightly shorter than leaves ........................................... C. cimina
16. Leaves 8–15 mm wide; culms 7–13 cm in height, far shorter than leaves ........................................... C. kaoi
17. Pistillate scales reddish brown; nutlets coiled-stipitate at base; plants brown or reddish brown when dried ........................................... 14
18. Spikes 4–7, lateral ones androgynous; nutlets 3–3.5 mm long ........................................... C. calcicola
19. Spikes 4, lateral spikes pistillate; nutlets 2 mm long .................................................. C. lijiangii
20. Spikes 4–7, lateral ones androgynous; nutlets 3–3.5 mm long ........................................... C. calcicola
1. Nutlet beaks coiled, not annulate at apex ........................................................................................................ 15
15. Perigynia densely pubescent; pistillate scales, involucral bracts, bract sheaths, culms and leaves all pubescent .......................................................................................... C. laticeps
15. Perigynia pubescent or glabrous; pistillate scales, involucral bracts, bract sheaths, culms and leaves glabrous ............................................................................. 16
16. Lateral spikes cylindrical-globose, 2–3 cm long, with peduncles enclosed in sheaths ................................................................................................................... C. manca
17. Leaves 6–10 mm wide; nutlets constricted on all middle angles ................................................................. C. buhleriica
17. Leaves 2–4 mm wide; nutlets constricted on one middle angle ................................................................ C. jiuhuansensis
18. Lateral spikes cylindrical, 3–6 cm long, with peduncles exerted from sheaths ........................................... 18
18. Pistillate scales glaucous, long-awned at apex; stamineate scales long-awned at apex .................................. C. cheniana
18. Pistillate scales pale yellow, acuminate or short-awned at apex; stamineate scales acuminate at apex .... 19
19. Lateral spikes 12–15 mm wide; leaves 12–18 mm wide ................................................................................ C. nanacuansensis
19. Lateral spikes 7–10 mm wide; leaves 3–10(–17) mm wide ........................................................................ 20
20. Lateral spikes with a long staminate part at apex, the staminate part equal to the pistillate part ................ 21
21. Perigynia pubescent, with a 2.5–3 mm long beak at apex, obliquely patent at maturity ........................... C. kuchuensis
21. Perigynia glabrous, with a ca. 4 mm long beak at apex, horizontally patent at maturity ..................... C. kuchuensis
20. Lateral spikes with a short staminate part at apex, the staminate part rather shorter than the pistillate part .... 22
22. Leaves 7–10(–17) mm wide; perigynia horizontally patent at maturity .................................................. C. heudesii
22. Leaves 3–7 mm wide; perigynia obliquely patent at maturity .............................................................. C. basiflora

Acknowledgments. This work was supported by the National Natural Science Foundation of China (Grants No. 31170183, 30870150), and the project of State Key Laboratory of Systematic and Evolutionary Botany (Grant No. LSEB2011-04). We are most grateful to Professors LIANG Song-Yun and DAI Lun-Kai for their kind help and continuous encouragement, to Professor WANG Wen-Tsai for his modifying the draft, to the curators of ACM, E, GZTM, HAGS, HHBG, HIB, HNNU, HTC, HZU, IBK, IBSC, K, KUN, KYO, LBG, N, NAS, OSA, P, PE, SYS, TI, WUK, ZJFC, and ZM for permitting the first author to visit their herbaria.

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