

## *Carex xueyingiana* (Cyperaceae), a new species from Hainan Island, China

HAIJUN YANG<sup>1,4</sup>, HAN XU<sup>2\*</sup>, YUNFEI DENG<sup>3</sup> & YIDE LI<sup>2</sup>

<sup>1</sup>College of Forestry and Landscape Architecture and Center of Experimental Teaching for Common Basic Courses, South China Agricultural University, Guangzhou 510640, People's Republic of China

<sup>2</sup>Research Institute of Tropical Forestry, Chinese Academy of Forestry, Longdong, Guangzhou 510520, People's Republic of China

<sup>3</sup>Key Laboratory of Plant Resources Conservation and Sustainable Utilization, South China Botanical Garden, Chinese Academy of Sciences, Guangzhou 510520, People's Republic of China

<sup>4</sup>The Orchid Conservation & Research Center of Shenzhen, Shenzhen 518114, People's Republic of China

\* Corresponding author; E-mail: hanxu81@gmail.com

### Abstract

A new species of *Carex* (Cyperaceae), *Carex xueyingiana*, from section *Radicales*, is described and illustrated from Hainan Island, China. We analyzed 35 morphological characters using Cluster Analysis and Principal Components Analysis to evaluate the relationships between the new species and the 15 species from the same section occurring in China. The new species is similar to *C. chlorocephalula*, displaying pubescent rhizomes, leaves densely hispidulous on both surfaces, and slender tufted culms. *Carex xueyingiana* differs from *C. chlorocephalula* by the leaves distinctly longer than culms (not equaling these), stems 4–6 mm wide (instead 1–3 mm), bracts sheath-like, 5–6 mm long (instead leaf-like and 2–3.5 cm long), spikes 7–10 mm long (instead 10–15 mm), and perigynium beakless (instead beaked). The new species is only known from Hainan Island and is assessed as Vulnerable (VU DD).

**Key words:** *Carex* sect. *Radicales*, conservation status, IUCN, taxonomy

### Introduction

Cyperaceae is a worldwide distributed family with 106 genera and ca. 5,400 species. *Carex* Linnaeus (1753: 972) is the largest genus in the family and one of the largest genera among the Angiosperms (Frodin 2004), comprising approximately 2,000 species (Global *Carex* Group 2016). *Carex* has a cosmopolitan distribution, but the majority of the species are distributed in the north and south temperate regions and the montane tropics (Reznicek 1990). The most recently revision of the genus from China was made by Dai *et al.* (2010), recognizing 527 species. Since then, more than twenty new species of *Carex* have been described from China (Deng 2014, Yang *et al.* 2014, 2015a, 2015b, 2016, Zhou & Jin 2014, Chen & Jin 2015, Jin *et al.* 2015a, 2015b, Jiménez-Mejías & Roalson 2017), six of which were found in Hainan Island (Wang *et al.* 2012, Deng 2014, Yang *et al.* 2014, 2015a, 2015b, 2016).

In the course of a botanical survey in Jianfengling National Nature Reserve on Hainan Island, China, a population of plants belonging to *Carex* sect. *Radicales* (Kükenthal) Nelmès (1951: 389) was found. The plants did not seem to match any known species. In order to formally describe this putative new taxon, we performed a detailed morphological study comparing it with the other 15 Chinese species from section *Radicales*. We studied 35 morphological characters (Table 1) and used numerical taxonomic methods, including Cluster Analysis and Principal Components Analysis. Our data confirm that the newly discovered population is a new species and we describe it as *Carex xueyingiana*.

### Material and Methods

#### *Morphological observations and numerical analyses*

According to our first classification attempts, the new species was identified as a member of *Carex* sect. *Radicales*, a group of mainly Pan-Himalayan distribution. We followed a consensus treatment between the treatment in Flora of China (Dai *et al.*, 2010) and the recent revision of the group by Jin *et al.* (2015), considering a total of 15 species in China.

**TABLE 1.** Coding of the 35 characters studied in the 18 studied species of the genus *Carex* from sections *Clandestinae* and *Radicales*.

Characters	Status and coding	Type of characters
1. Rhizome	short (0), elongate (1), long (2)	ordered multistate
2. Culms tufted status	loosely (0), densely (1)	binary
3. Minimum culm height	value (measured directly)	continuous
4. Maximum culm height	value (measured directly)	continuous
5. Culm shape	triquetrous (0), compressed triquetrous (1)	binary
6. Minimum culm thick	value (measured directly)	continuous
7. Maximum culm thick	value (measured directly)	continuous
8. Culm surface	smooth (0), scabrous (1), hairy (2)	ordered multistate
9. Culm flexibility	soft (0), stiff (1)	binary
10. Relative length of leaves and culms	leaves shorter than culms (0), shorter to longer (1), longer (2)	ordered multistate
11. Minimum leaf width	value (measured directly)	continuous
12. Maximum leaf width	value (measured directly)	continuous
13. Leaf trichomes	absent (0), present (1)	binary
14. Relative length of lowermost bract and inflorescence	bract shorter than inflorescence (0), equal (1), longer (2)	ordered multistate
15. Lowermost bract shape	sheathlike (0), leaflike (1), spathe-like (2)	ordered multistate
16. Blade shape of lowermost bract	setiform (0), scalelike (1), leaflike (2)	ordered multistate
17. Lowermost bract trichomes	absent (0), present (1)	binary
18. Minimum spike number	value (measured directly)	continuous
19. Maximum spike number	value (measured directly)	continuous
20. Minimum spike length	value (measured directly)	continuous
21. Maximum spike length	value (measured directly)	continuous
22. Minimum spike width	value (measured directly)	continuous
23. Maximum spike width	value (measured directly)	continuous
24. Relative length of male and female parts of spike	male part shorter than female part (0), shorter to equal (1); longer (2)	ordered multistate
25. Pistillate scale color	green or yellow laterally (0), purple-brown laterally (1)	binary
26. Minimum length of pistillate scales	value (measured directly)	continuous
27. Maximum length of pistillate scales	value (measured directly)	continuous
28. Scale texture of female part	membranous (0), papery (1), subcoriaceous (2)	ordered multistate
29. Minimum perigynium length	value (measured directly)	continuous
30. Maximum perigynium length	value (measured directly)	continuous
31. Perigynium texture	membranous (0), papery (1), subcoriaceous (2)	ordered multistate
32. Perigynium trichome	without (0), sparsely (1), densely (2)	ordered multistate
33. Perigynium orifice	obliquely truncate (0), emarginate (1), bidentate (2)	ordered multistate
34. Style base	not thickened (0), thickened (1)	binary
35. Spike sex distribution	unisexual (0), bisexual (1)	binary

Two specimens of the new species were collected from the only known wild population. 35 morphological characters (Table 1) were measured. Plant height, culm height and leaf length were measured using a ruler. The remaining morphological characters were measured using image measuring technology. Images were obtained by micro photography using a stereomicroscope (ZEISS Stemi 2000-C) with a photometrics CoolSNAP CCD camera, and measurements were taken with the software Motic Image-Pro Plus 5.1. The morphological data of 15 related species were taken from Flora of China (Dai *et al.* 2010), and the additional works of Li (1990), Jin *et al.* (2015), and Zhou & Jin (2014). Since section *Radicales* is related to section *Clandestinae* G. Don (Sweet 1830: 376) (Dai *et al.* 2010, Jin *et al.* 2015, Global Carex Group 2016), two species of this section (*C. lancifolia* C.B. Clarke (Forbes & Hemsley 1903: 293) and *C. lanceolata* Boott (Gray 1857: 326)) were selected as accurate outgroups for comparison.

Cluster Analysis (CA) and Principal Components Analysis (PCA) were carried out on the standardized data matrix (Table 2). The coding strategy of these characters followed Sneath & Sokal (1973) and Xu (1999). The 35 characters were coded as three types: sixteen continuous characters, eight binary characters, and eleven ordered multistate characters. Binary characters were scored as 0–1. Ordered multistate characters were scored with ordinal numbers (Table 1). CA and PCA were carried out with the software package NTSYS-pc (Rohlf 1990). In CA, Euclidean distance coefficient and UPGMA clustering methods were used to obtain a dendrogram (Sokal and Michener 1958). In PCA, the correlation coefficient was used to compute a correlation matrix among the 35 characters. According, the studied samples were plotted using the two first components on a 2-dimensional scatter-plot.

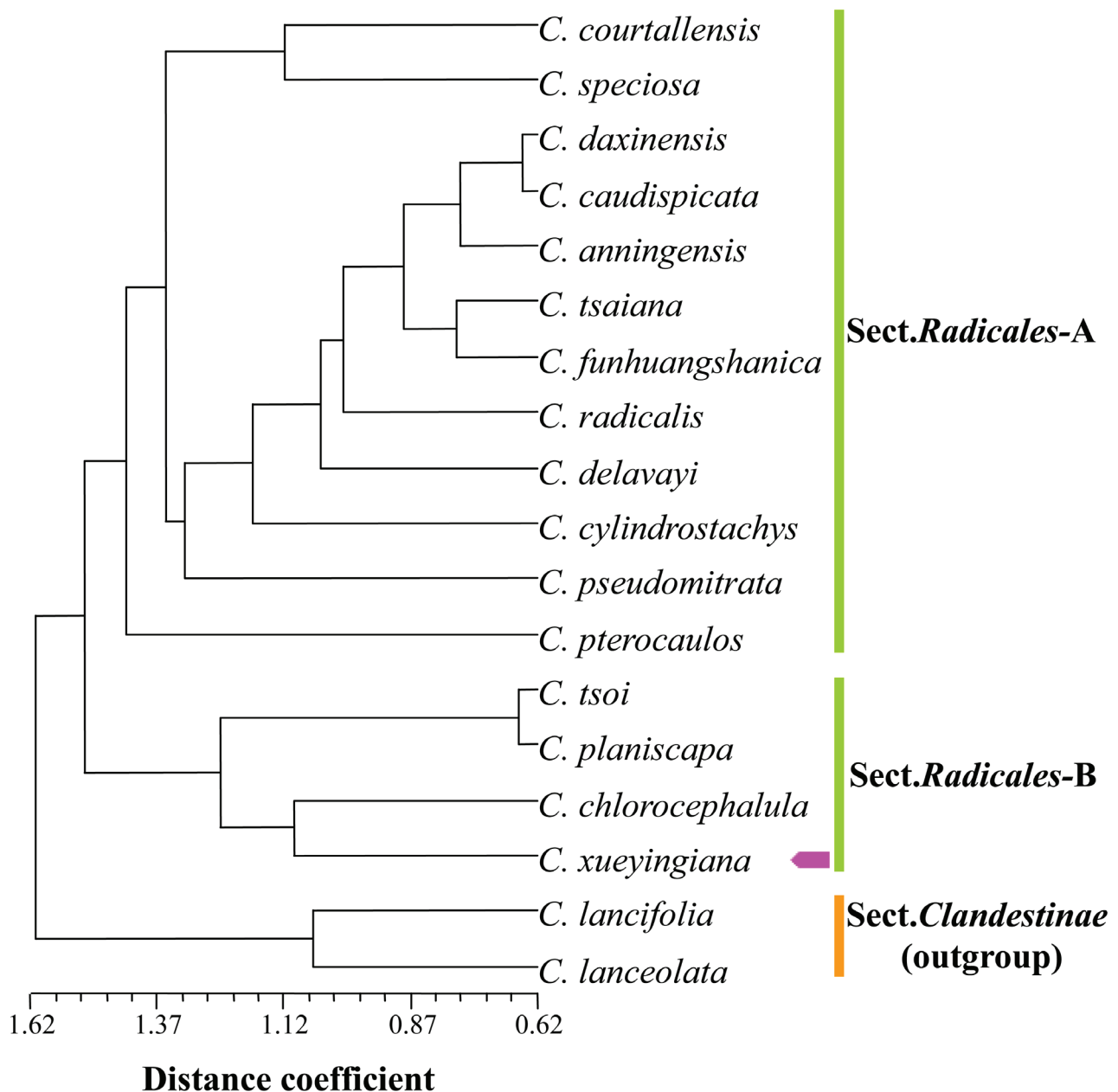
**TABLE 2.** Scoring of the 35 characters studied in the 18 studied species of the genus *Carex* from sections *Clandestinae* and *Radicales*.. Characters and coding are referred to Table 1.

Species	Plant morphology characters																																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
C. anningensis	2	0	250	300	0	1.5	1.5	0	1	2	1	1	0	2	1	2	0	2	3	25	40	4	5	0	0	3	3.5	2	3.8	4.2	2	1	2	1	1	1
C. caudispicata	1	0	100	300	0	1	1.5	0	1	1	3	5	0	1	1	2	0	1	3	20	30	5	5	1	0	4	4.5	2	5	5.5	2	1	2	1	1	1
C. chlorocephalula	0	1	60	300	0	1	1	2	0	1	1.5	3	1	0	1	2	1	2	3	10	15	3	3.5	1	0	3.4	3.6	1	4	4	1	2	1	0	1	1
C. courtallensis	1	0	35	55	0	1.5	2	0	1	0	8	20	0	2	1	2	0	2	6	40	60	3	5	0	0	3.5	4	1	4.8	5	1	0	2	0	1	1
C. cylindrostachys	2	0	120	200	0	1.5	2	1	1	2	2	3	0	2	1	2	0	4	6	20	30	2.5	2.5	2	0	4	4.5	1	4.5	5	1	2	2	1	1	1
C. daxinensis	0	0	100	500	0	0.5	1	0	1	1	2	3.5	0	1	1	2	0	1	3	10	20	3	4	0	0	2.8	3	2	4	4.5	2	1	2	1	1	1
C. delavayi	2	0	100	300	0	0.7	0.8	1	1	2	3	5	0	0	1	2	0	1	3	8	20	6	10	2	0	4	4	1	5	5	2	0	2	1	1	1
C. funhuangshanica	0	1	230	260	0	0.5	0.5	0	1	2	2	4	0	2	1	2	0	2	2	10	14	3	4	0	0	2.5	3	2	4	4.5	2	0	2	1	1	1
C. lanceolata	2	1	100	350	1	1.5	1.5	1	0	1	1	2.5	0	1	2	0	0	3	6	5	17	1.5	2	1	1	5	6	1	3	3	1	2	0	0	0	0
C. lancifolia	0	1	100	150	1	1	1	0	0	1	6	7	0	0	2	0	0	4	5	10	15	1.5	2	1	1	3.5	3.5	0	5	5	0	2	2	0	0	0
C. planiscapa	0	1	80	180	1	1	1	0	0	2	3.5	7	0	0	0	1	0	1	2	5	10	2	3	2	0	1.5	2	1	2	3	1	1	0	1	1	1
C. pseudomitata	0	0	250	550	0	0.5	1	0	1	0	1.5	3	0	2	1	1	0	4	6	10	30	3	4	0	0	6.5	7	2	4	4.5	0	2	2	1	1	1
C. pterocaulos	0	1	400	450	0	1.2	1.5	1	1	2	10	11	0	2	1	2	0	1	3	25	30	8	10	1	0	4.5	5.5	0	6	6.5	1	1	2	1	1	1
C. radicalis	0	1	100	250	0	1	1	1	0	2	2	3	0	2	1	2	0	1	2	5	8	4	6	0	0	1.8	3	0	4	6	2	2	2	1	1	1
C. speciosa	2	1	150	300	1	1	1.5	1	0	1	4	16	0	2	1	2	0	1	7	10	40	3	5	0	0	2	4.4	1	4	5	1	1	2	0	1	1
C. tsaiana	0	1	130	160	0	0.6	0.8	0	0	0	1	1.5	0	0	1	2	0	1	1	10	15	2	3	0	0	2.8	3.2	2	4	4.2	2	1	2	1	1	1
C. tsoi	2	1	30	150	1	0.5	0.7	0	0	2	1	5.5	0	0	0	0	0	1	5	2	5	3.5	3.5	1	0	1.2	1.5	1	2	2.5	1	1	0	1	1	1
C. xueyingiana	0	0	6	12	1	0.3	0.8	2	0	2	4	6	1	0	0	0	1	1	2	7	10	2	2.5	2	0	2.5	2.8	1	2.3	2.5	1	2	0	1	1	1

## Results and discussion

**Relationships:**—The new species *C. xueyingiana* was initially evaluated to belong to *Carex* sect. *Radicales*, a group characterized by having 1–6 androgynous spikes, the remote lateral ones arising from the middle or at the base of the culms, compressed trigonous perigynia that are contracted at apex into a short beak, and styles frequently thickened at the base (Dai *et al.* 2010, Jin *et al.* 2015a). It consists of about twenty species, mainly distributed in the Himalayas, extending to south China and Indochina to Malaysia. 15 species and two varieties have been recognized from China (Dai *et al.* 2010, Jin *et al.* 2015a).

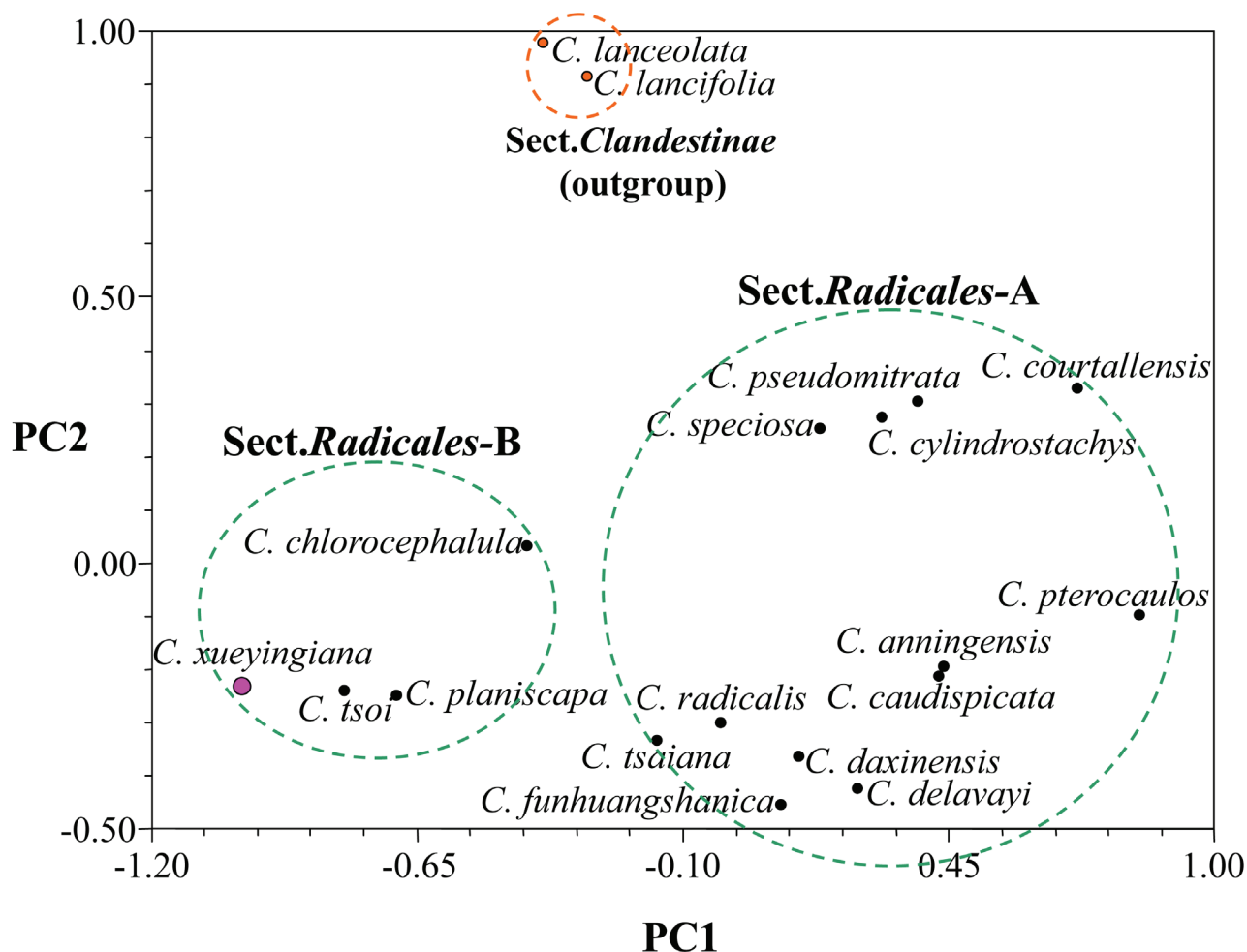
On the basis of our CA analysis, the 18 studied taxa clustered into two main clades (Fig. 1). One clade was formed by the two outgroup species from section *Clandestinae*, while *C. xueyingiana* and the 15 species of the sect. *Radicales* formed together the second clade. The distance between the two clades was 1.5612. The analysis also revealed that the new species *C. xueyingiana* formed a small subclade (*Radicales-B*) with *C. chlorocephalula* F.T. Wang & Tang ex Li (1990: 143), *C. planiscapa* Chun & How (1958: 82) and *C. tsoi* Merrill & Chun (1935: 207). The rest of the studied species from section *Radicales* formed another subclade (*Radicales-A*).



**FIGURE 1.** Dendrogram of the 18 studied species of the genus *Carex* from sections *Clandestinae* and *Radicales*. The position of the new species *C. xueyingiana* is indicated with a purple arrow.

A similar result was obtained from PCA analysis (Fig. 2). The first three principal components (PCs) accounted for 55.7595% of the total variation (Table 2). The scatterplot of PC1 vs. PC2 (Fig. 2) revealed that *C. xueyingiana* and the other species in *Radicales-B* formed a cluster distinct from section *Clandestinae* and *Radicales-A*.

According to the above multivariate analyses, *C. xueyingiana* is morphologically most closely related to *C. chlorocephalula*, *C. planiscapa* and *C. tsoi*. *Carex chlorocephalula* has a pubescent rhizome and slender tufted culms, but this can be distinguished from *C. xueyingiana* by the much narrower leaves equaling culms, involucre bracts leaflike, larger and laxer spikes, and perigynium almost twice in size with the apex abruptly contracted into a short beak. On the other hand, *C. planiscapa* and *C. tsoi* are endemic to Hainan Island, but they differ from the new species by being glabrous, the culms densely tufted, and perigynium apex attenuated into an indistinct short beak. Our data support the independence of *C. xueyingiana* and accordingly, we proceed to formally describe it as a new species.



**FIGURE 2.** Scatterplot of the two first components of the PCA performed over the 18 studied species of the genus *Carex* from sections *Clandestinae* and *Radicales*. The new species *C. xueyingiana* is indicated with a purple dot.

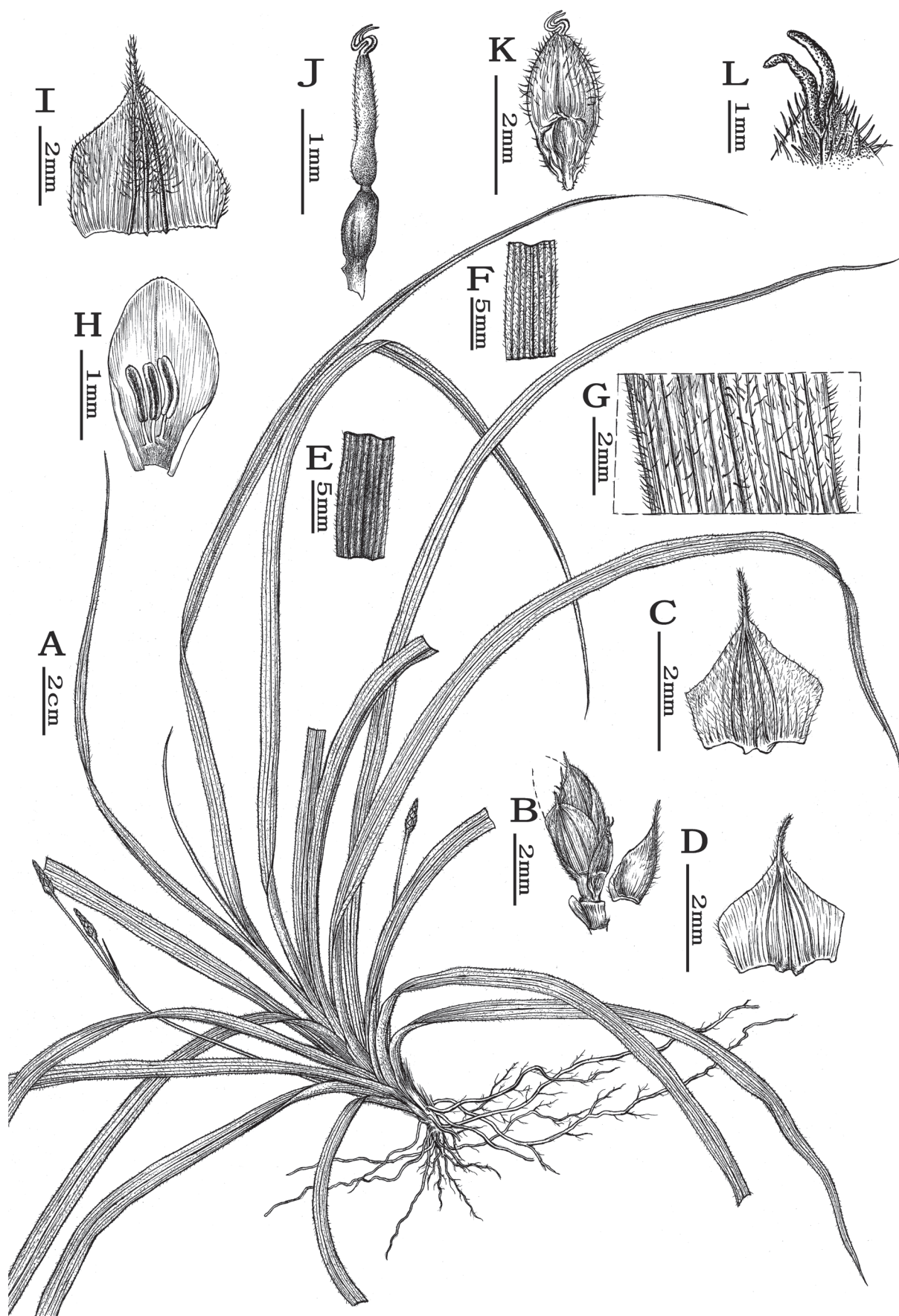
#### Key to the four species in *Carex* sect. *Radicales-B* group

1. Leaves densely hispidulous or pubescent on both surfaces; perigynium attenuate at base and stipitate; style smooth or hairy ..... 2
- 1' Leaves glabrous on both surfaces; perigynium base cuneate or subrounded, indistinctly stipitate; style densely brown granular-punctate ..... 3
- 2 Culms densely tufted, longer than or equaling leaves; lowermost bract leaf-like; perigynium 3.5–6.5 mm ..... *C. chlorocephalula*
- 2' Culms loosely tufted, distinctly shorter than leaves; lowermost bract sheath-like, sometimes with a very short setaceous blade; perigynium 2.3–2.5 mm ..... *C. xueyingiana*
- 3 Culms not exceeding 0.5 mm thick; lowermost bract setaceous; spikes ovate or ovate-oblong, 2–5 mm long; style flat ..... *C. tsoi*
- 3' Culms ca. 1 mm thick; lowermost bract leaf scalelike; spikes cylindric, 5–10 mm long; style cylindric ..... *C. planiscapa*





**FIGURE 3.** *Carex xueyingiana*. A. Habit of a living flowering plant; B. Inflorescence with two androgynous spikes; C. Female flower inside perigynium; D. Male flower and scale.



**FIGURE 4.** *Carex xueyingiana*. A. Flowering plant; B. Female part of spike; C. Pistillate scale, abaxial view; D. Pistillate scale, adaxial view; E. Leaf, adaxial surface; F–G. Leaf, abaxial surface; H. Male flower; I. Involucral bract; J. Pistil; K. Perigynium with pistil inside; L. Apex of perigynium.



## Taxonomic treatment

### *Carex xueyingiana* H. J. Yang & Han Xu, *sp. nov.* (Figs. 3, 4) 雪影臺草

**Diagnosis:**—The new species is similar to *C. chlorocephala*, but it differs from it by 1-leaves much longer than culms vs equaling these, densely long-pubescent on both sides vs hispidulous; 2-involucral bracts sheath-like, 5–6 mm long vs leaf-like and 8–10 cm long; 3- inflorescence with 1–2 dense spikes vs 2–3 laxer spikes; 4-spikes 7–10 mm long vs 10–15 mm; and 5-perigynium apex beakless vs shortly beaked.

**Type:**—CHINA. Hainan: Ledong County, Jianfengling Nature Reserve, 920 m, 18°46'56.0"N, 108°59'42.7"E, 13 April 2012, *Han Xu JFL001525* (holotype, IBSC; isotype, CANT).

Perennial herb, 20–30 cm tall; rhizomes long. Culms loosely tufted, 6–12 cm tall, 0.3–0.8 mm thick, lateral, ascending to erect, trigonous, with up to three closed sheaths at base. Leaves basal, significantly longer than culms, 25–40 cm long, 4–6 mm wide, papery, flat, comprising a linear blade and an short sheath, densely long pubescent on both sides. Some fibrous sheaths persistent at the base of shoots. Inflorescence racemose, comprising 1–2 spikes. Bracts sheath-like, sometimes with a very short setaceous blade, 5–6 mm long, much shorter than inflorescence, adaxially glabrous, abaxially pubescent. Spikes 1–2, androgynous, 7–10 × 2–2.5 mm, oblong, the male part shorter or equaling the female part, both densely flowered; male part cylindric, 3–5 × 1–1.5 mm; female part obovate-lanceolate, 4–5 × 2–2.5 mm. Staminate scales broadly ovate, 2–2.3 × 1.2–1.6 mm, pale yellowish green, glabrous, blunt at apex. Stamens 3, 1 mm long; the anther remarkably longer than the filament. Pistillate scales 3.5–3.8 × 3–3.2 mm including awn, triangular-ovate, green, abaxially pubescent, 3-veined, the middle-nerve extending at apex into a 1 mm long awn. Style hairy, thickened at base, stigmas 2 or 3. Perigynium 2.3–2.5 × 1.2–1.5 mm, broadly elliptic, compressed-trigonous, membranous, shorter than the pistillate scales, beakless, the orifice obliquely truncate. Ovary 0.7–0.8 × 0.3–0.4 mm, elliptic, glabrous, ripe achenes not known.

**Distribution and habitat:**—The species has been found so far in Jianfengling National Nature Reserve on Hainan Island, China. It grows in tropical monsoon rainforest at an elevation of about 920 m. Accompanying species include trees of *Cryptocarya chinensis* (Lauraceae), *Alseodaphne hainanensis* (Lauraceae), *Lithocarpus fenzelianus* (Fagaceae), *Prismatomeris tetrandra* (Rubiaceae), *Livistona saribus* (Palmae) (Zeng *et al.* 1995). In recent years, several new species have been found from Jianfengling Natural Reserve (Xu *et al.* 2011, Xu *et al.* 2012, Yang *et al.* 2015a). The finding of *C. xueyingiana* remarks the need of additional taxonomic studies for a better understanding of the diversity of Hainan Island.

**Phenology:**—It flowers in the period from middle spring to early summer between March and May.

**Etymology:**—The species is named in honor of Professor Xueying Zhuang (1961–2016), botanist at South China Agricultural University. She contributed greatly to the botanical research in South China.

**Conservation status:**—Since 1993, logging has been prohibited and the habitats have been protected within the nature reserve. Base on the current field survey, only one population with about ten individuals was found. Taking into account the ability to reproduce of *Carex*, more populations may be found in the future. Therefore, the new species can be assigned as Vulnerable (VU DD) according to IUCN Red List criteria (IUCN, 2010), indicating a population data deficient when there is inadequate information to make a direct, or indirect, assessment of its risk of extinction based on its distribution and/or population status.

**TABLE 3.** Eigenvalue, percentage of variation, and cumulative variation of the first five principal components of the PCA performed on the 18 studied species of the genus *Carex* from sections *Clandestinae* and *Radicales*.

Principal component	Eigenvalue	Proportion / %	Cumulative proportion / %
1	9.4358	26.9594	26.9594
2	6.4169	18.3341	45.2935
3	3.6631	10.4660	55.7595
4	3.0913	8.8322	64.5917
5	2.8134	8.0383	72.6300



## Acknowledgements

This paper is financially supported by the National Nonprofit Institute Research Grant of CAF (Grant number: RITFYWZX201505). The authors are very grateful to technicians from Jianfengling National Nature Reserve for the help of specimen collection, and also to two anonymous reviewers for their constructive suggestions. The authors are also very grateful to Ms. Liu Yunxiao from South China Botanical Garden for the help of plant drawing.

## References

- Chen, W.J. & Jin, X.F. (2015) *Carex huangshanica* (sect. *Rhomboidales*, Cyperaceae), a new species from Anhui, eastern China. *Phytotaxa* 233: 281–287.  
<http://doi.org/10.11646/phytotaxa.233.3.5>
- Chun, W.Y. & How, F.C. (1958) Contributions to the flora of south China. *Acta Phytotaxonomica Sinica* 7: 1–90.
- Dai, L.K., Liang, S.Y., Zhang, S.R., Tang, Y.C., Koyama, T., Tucker, G.C., Simpson, D.A., Noltie, H.J., Strong, M.T., Bruhl, J.J., Wilson, K.L. & Muasya, A.M. (2010) Cyperaceae. In: Wu, Z.Y., Raven, P.H. & Hong, D.Y. (Eds.) *Flora of China* 23. Science Press, Beijing & Missouri Botanical Garden Press, St. Louis, pp. 164–475.
- Deng, Y.F. (2014) *Carex longicolla* (Cyperaceae), a new sedge from China. *Phytotaxa* 178: 181–188.  
<https://doi.org/10.11646/phytotaxa.178.3.3>
- Forbes, F.B. & Hemsley, W.B. (1903) An enumeration of all the plants known from China Proper, Formosa, Hainan, Corea, the Luchu Archipelago, and the Island of Hongkong, together with their distribution and synonymy, Part XVII. *Journal of the Linnean Society, Botany* 36: 217–296.  
<https://doi.org/10.1111/j.1095-8339.1903.tb00652.x>
- Global Carex Group (2016) Megaphylogenetic specimen-level approaches to the *Carex* (Cyperaceae) phylogeny using ITS, ETS, and matK sequences: implications for classification. *Systematic Botany* 41: 500–518.  
<https://doi.org/10.1600/036364416X692497>
- Gray, A. (1857) Descriptions of the botanical specimens. In: Perry, M.C. (Eds.) *Narrative of the Expedition of an American Squadron to the China Seas and Japan* 2. Beverley Tucker, Washington, pp. 305–336.  
<http://doi.org/10.5962/bhl.title.1806>
- IUCN. (2010) *The IUCN red list of threatened species, version 2010.4*. IUCN Red List Unit, Cambridge U.K. Available from: <http://www.iucnredlist.org/> (accessed 1 June 2017)
- Jiménez-Mejías, P. & Roalson, E.H. (2017) Two new Asian species of *Carex* (Cyperaceae). *Phytotaxa* 298: 283–288.  
<http://doi.org/10.11646/phytotaxa.298.3.8>
- Jin, X.F., Cen, J.M., Hahn M., Lu, Y.F. & He, J.J. (2015a) Notes on *Carex* (Cyperaceae) from China (II): a taxonomic revision of sect. *Radicales* (Kük.) Nelmes. *Phytotaxa* 217: 117–132.  
<http://doi.org/10.11646/phytotaxa.217.2.2>
- Jin, X.F., Chen, W.J. & Cen, J.M. (2015b) Notes on *Carex* (Cyperaceae) from China (III): the description of four new species. *Phytotaxa* 231: 165–174.  
<http://doi.org/10.11646/phytotaxa.231.2.5>
- Li, P.C. (1990) New taxa of the Cyperaceae from Hengduan Mountains (2). *Acta Botanica Yunnanica* 12: 137–150.
- Merrill, E.D. & Chun, W.Y. (1935) Additions to our knowledge of the Hainan flora (II). *Sunyatsenia* 2: 203–344.
- Nelmes, E. (1951) The genus *Carex* in Malaysia. *Reinwardtia* 1: 221–450.
- Reznicek, A.A. (1990) Evolution in sedges (*Carex*, Cyperaceae). *Canadian Journal of Botany* 68: 1409–1432.  
<https://doi.org/10.1139/b90-180>
- Rohlf, F.J. (1990) *NTSYS-pc Numerical Taxonomy and Multivariate Analysis System, version 1.80*. Exeter Publication, New York.
- Sneath, P.H.A. & Sokal, R.R. (1973) *Numerical Taxonomy: The Principles and Practice of Numerical Classification*. W. H. Freeman and Company, San Francisco.
- Sweet, R. (1830) *Hortus Britannicus. 2nd edition*. James Ridgway, London, 623 pp.
- Wang, Q.L., Yang, H.B., Deng, Y.F., Wang, Z.N. & Liu, G.D. (2012) *Carex longipetiolata* (Cyperaceae), a new sedge from Hainan, China. *Phytotaxa* 75: 65–69.  
<http://doi.org/10.11646/phytotaxa.75.1.6>
- Xu, H., Li, Y.D., Yang, H.J. & Chen, H.Q. (2011) Two new species of *Aristolochia* (Aristolochiaceae) from Hainan Island, China. *Novon* 21: 285–289.

<https://doi.org/10.3417/2009116>

- Xu, H., Yang, H.J. & Li, Y.D. (2012) *Zeuxine hainanensis* (Orchidaceae), a new species from Hainan Island, China. *Annales Botanici Fennici* 49 (1–2): 134–136.  
<http://doi.org/10.5735/085.049.0123>
- Xu, K.X. (1999) *Numerical Taxonomy*. Science Press, Beijing, 340 pp.
- Yang, H.B., Li, X.X., Bai, C.J., Wang, W.Q. & Liu G.D. (2016) *Carex concava* (*Carex* sect. *Rhomboidales*, Cyperaceae), a new species from Hainan, China. *Phytotaxa* 283: 155–162.  
<http://doi.org/10.11646/phytotaxa.283.2.4>
- Yang, H.B., Li, X.X., Chang, J.B., Wang, W.Q., Wang, Q.L., Yu, D.G., Dong, R.S. & Liu, G.D. (2015a) *Carex procumbens* (*Carex* sect. *Rhomboidales*, Cyperaceae), a new species from Hainan, China. *Phytotaxa* 201: 207–213.  
<http://doi.org/10.11646/phytotaxa.201.3.4>
- Yang, H.B., Li, X.X., Wang, W.Q., Bai, C.J. & Liu, G.D. (2015b) *Carex jianfengensis* (*Carex* sect. *Rhomboidales*, Cyperaceae), a new species from Hainan, China. *PLoS ONE* 10: e0136373.  
<http://doi.org/10.1371/journal.pone.0136373>
- Yang, H.B., Wang, Q.L., Bai, C.J., Li, X.X. & Liu, G.D. (2014) *Carex diaoluoshanica* (*Carex* sect. *Lageniformes*, Cyperaceae), a new species from Hainan, China. *PloS ONE* 9: e97658.  
<http://doi.org/10.1371/journal.pone.0097658.g003>
- Zeng, Q.B., Li, Y.D., Chen, B.F., Zhou, G.Y. & Wu, Z.M. (1995) *A list of bio-species in Jianfengling of China*. China Forestry Publishing House, Beijing, 311 pp.
- Zhou, Y.Y. & Jin, X.F. (2014) Notes on *Carex* (Cyperaceae) from China: three new species. *Phytotaxa* 164: 133–140.  
<http://doi.org/10.11646/phytotaxa.164.2.7>