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Chromosome numbers of *Carex* section *Siderostictae* from Korea populations (Cyperaceae)

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한국산 사초과 대사초절의 염색체 수

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ABSTRACT: We report somatic chromosome numbers 2n = 12 for three *Carex* sect. *Siderostictae* Franch. ex Ohwi (Cyperaceae) from Korean populations: *Carex ciliatomarginata* Nakai, *C. okamotoi* Ohwi, and *C. siderosticta* Hance. This study is the first chromosome number report for the species *C. ciliatomarginata* from Korean populations. As found in other *Carex* species, all the chromosomes examined in the section exhibit non-localized centromere (polycentric or holocentric) and large (more than ca. 1 μm long) chromosomes. Considering the basal phylogenetic position of the section in tribe Cariceae Pax, small numbers of large chromosomes have been hypothesized as primitive characters in Cariceae, and our observation supports the hypothesis. Further investigations of chromosomes in *Carex* are needed for a better understanding of species richness in the genus.

Keywords: *Carex*, Chromosome number, *Carex* sect. *Siderostictae*, holocentric chromosome

적 요: 한국산 사초과 *Carex* sect. *Siderostictae* Franch. ex Ohwi(대사초절, 3종), *Carex ciliatomarginata* Nakai(털대사초), *C. okamotoi* Ohwi(지리대사초), and *C. siderosticta* Hance(대사초)의 염색체 수를 2n = 12으로 밝힌다. 본 연구에서 한반도 자생 *C. ciliatomarginata*의 염색체 수를 최초로 보고한다. 해외의 다른 사초속 식물에서 보고된 바와 같이, 관찰된 모든 염색체에서 응축된 동원체가 관찰되지 않았으므로 크기는 다른 종들에서 관찰된 것보다는 길었다(1 μm이상). 대사초절의 종들도 모두 전부염색체(全部染色體, holocentric chromosome)를 가지며, 본 절이 tribe Cariceae Pax(사초족)에서 가장 먼저 분화된 분류군임을 감안할 때, 염색체 수가 적고(보고된 사초속 염색체 수의 변이 2n = 12 – 132) 크기가 큰 염색체가 Cariceae에서 원시적인 형질로 여겨진다. 사초속의 종 다양성에 크게 기여한 것으로 알려진 염색체 종 분화에 대한 이해를 위하여 한반도에 자생하는 사초속을 대상으로 하는 지속적인 세포학적 연구가 요구된다.

주요어: 사초속, 염색체 수, 대사초절, 전부염색체

Genus *Carex* L. (Cyperaceae) is one of the most species-rich genera in flowering plants composed of more than 2,000 species worldwide (Reznicek, 1990; Oh, 2007). In addition to species richness, the genus exhibits high variance in chromosome numbers varying from n = 6 to n = 66 with every haploid number between n = 6 and n = 48 (Tanaka, 1949; Davies, 1956; Roalson et al., 2007; Roalson, 2008; Hipp et al., 2009). High chromosome number variation in the genus

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has been postulated to explain high species diversity in the genus (Hipp, 2007; Hipp et al., 2009; Hipp et al., 2010; Chung et al., 2012; Escudero et al., 2012). The cytogenetic variance is hypothesized to be due to the diffuse or non-localized centromeres (holocentric chromosomes), which facilitate chromosome fission and fusion (agmatoploidy and symploidy, respectively; Luceño and Guerra, 1996). According to the hypothesis, chromosome numbers can be changed without gene duplications and/or deletions, and recent cytogenetic studies revealed high genetic diversity in *Carex* agmatoploidy species (Hipp et al., 2009; Chung et al., 2011).

Chromosome numbers have been useful characters to distinguish morphologically variable taxa in *Carex* and also provided critical information for understanding taxonomic and/or phylogenetic relationships in the genus (e.g., Hipp, 2007; Rothrock et al., 2009; Yano et al., 2010). Despite taxonomic and evolutionary significance of cytological characters in *Carex*, only a few chromosome numbers of *Carex* in Korea have been investigated (out of ca.157 taxa; Oh, 2007): *C. blepharicarpa* Franch. var. *stenocarpa* Ohwi, 2n = 20; C. siderosticta Hance, 2n = 12; C. okamotoi Ohwi, 2n = 12 (Kim, 2006; Lee and Kim, 2008). Lack of chromosomal information of Korean *Carex* species has resulted in not only difficulty on understanding Korean species in cytological perspectives, but also interpreting cytological characters in *Carex* as a whole since many *Carex* species are endemic to Asia (Oh, 2007; Dai et al., 2010; Hoshino et al., 2011).

Carex section *Siderostictae* Franch. ex Ohwi (Cariceae) is distributed in East and Southeast Asia consists of thirteen species (Table 2; Egorova, 1999; Oh, 2007; Dai et al., 2010). The section is characterized by androgynous spikes (androgynous spikes with staminate flowers at the tip and pistillate flowers

Table 1. Chromosome numbers of *Carex* sect. *Siderostictae* studied. All vouchers are archived at the Korea National Arboretum Herbarium (KH).

Taxon	Collection locality	Voucher	Chromosome number (2n)
C. ciliatomarginata Nakai	Mt. Songnisan (Yeojeogam), Boeun-gun, Chungcheongbuk-do	*Chung* 59	12
	Mt. Hwangaksan (Tmeple Jikjisa) Gimhae, Gyeongsangbuk-do	*Chung* 70	12
C. okamotoi Ohwi	Mt. Hwangaksan (Tmeple Jikjisa) Gimhae, Gyeongsangbuk-do	*Chung* 71	12
C. siderosticta Hance	Mt. Odaesan Pyeongchang, Gangwon-do	*Chung* 42	12
	Mt. Hwangaksan (Tmeple Jikjisa) Gimhae, Gyeongsangbuk-do	*Chung* 76	12
	Mt. Seonunsan, Gochang, Jeollanam-do	*Chung* 206	12

Table 2. Major Characters of *Carex* sect. *Siderostictae* (Dai et al., 2010; Hoshino et al., 2011; Kang et al., 2012).

Taxon	Inflorescence		Perigynium		Distribution	Chromosome Number (2*n*)
	Terminal spike	Lateral spike	Shape	Length (mm)		
Carex ciliatomarginata Nakai	staminate	androgynous	obovate	3.5-4.5	Japan, Korea, China	12
C. esquiroliana H. Léveillé	staminate	pistillate or androgynous	narrowly elliptic	ca. 3.5	China, Vietnam	Unknown
C. glossostigma Handel-Mazzetti	androgynous	androgynous	ovate-elliptic	ca. 3	China	Unknown
C. grandiligulata Kükenthal	androgynous	androgynous	elliptic	4-5	China	Unknown
C. longshengensis Y. C. Yang & S. Yun Liang	androgynous	androgynous	oblong-elliptic	4.5-5.5	China	Unknown
C. oblanceolata T. Koyama	androgynous	androgynous	oblong to elliptic	ca. 3	China	Unknown
C. okamotoi Ohwi	staminate	androgynous	broadly obovate	ca. 2.5	Korea	12
C. pachygyna Franch. & Sav.	androgynous	androgynous	obovate	2-2.8	Japan	12
C. siderosticta Hance	androgynous	androgynous	obovate or elliptic	3-4	Japan, China, Korea, Russia	12, 24
C. splendentissima U. Kang & J. M. Chung	staminate	androgynous	narrowly elliptic or elliptic	2.8-3.2	Korea	Unknown
C. subcapitata X. F. Jin	androgynous	androgynous	broadly elliptic	ca. 4	China	Unknown
C. tumidula Franch. et Sav.	staminate or androgynous	androgynous	ovate	ca. 3	Japan	12
C. wuyishanensis S. Yun Liang	androgynous	androgynous	broadly ovate	ca. 3	China	Unknown

at the base), multiple spikes at a single node, and persistent rachillae (Egorova, 1999; Dai et al., 2010; Hoshino et al., 2011). Because molecular phylogenetic studies revealed the section is basal to the rest of tribe Cariceae Pax, morphological characters of the section have been postulated as primitive characters in the tribe (Starr and Ford, 2009; Waterway et al., 2009; Jung and Choi, 2012). Including a recently described species from Korea, four species in the section have been recognized in Korea: *Carex ciliatomarginata* Nakai, *C. siderosticta* Hance, *C. okamotoi* Ohwi, and *C. splendentissima* U. Kang & J. M. Chung. The latter of two species are endemic to Korea (Table 2; Oh, 1971; Oh, 2007; Kang et al., 2012; Moon et al., 2012).

In this paper, we report chromosome numbers of three species of *Carex* sect. *Siderostictae* from multiple Korean populations and discuss their taxonomic and phylogenetic significance. The live plant materials of *C. splendentissima* was not available in this investigation.

Materials and Methods

Somatic chromosomes of *Carex* sect. *Siderostictae* were observed. Live plants of the section were collected from natural populations and then cultivated at the Jungwon University, Goesan-gun, Chungbuk. The methods used for chromosome observation mainly followed Chang and Chung (2011) by treating fresh root tips in D.W and Carnoy solution (glacial acetic acid : absolute alcohol = 1:3). Cells squashed in 2% acetic-orcein were observed at 1,000x magnification and photographed. At least three meristematic cells per sample were analyzed to determine somatic chromosome numbers. All image captures and voucher specimens are archived at the Jungwon University and The Korea National Arboretum Herbarium (KH), respectively (Table 1).

Results and Discussion

Chromosome number variation in *Carex* sect. *Siderostictae*: Primary constrictions are not recognized in the meristematic chromosomes observed, suggesting the chromosomes are polycentic or holocentic as reported in other *Carex* species (Fig. 1). All species investigated, *Carex ciliatomarginata*, *C. okamotoi*, and *C. siderosticta*, exhibit somatic chromosome numbers of 2n = 12 (Table 1, Fig. 1). Chromosome numbers for *C. ciliatomarginata* from Korean populations are reported here for the first time, and the chromosome numbers for *C. okamotoi* and *C. siderosticta* are consistent with the previous observations made from other Korean populations (*C. siderosticta*, 2n = 12, Kim, 2006; *C. okamotoi*, 2n = 12, Lee and Kim, 2008). Although previously both diploidy and tetraploidy in the species were reported from Japan (Tanaka, 1939; Nishikawa et al., 1984), only diploid individuals of *C. siderosticta* are found in this study, which merits further investigation of the species with more population sampling covering broad distribution areas.

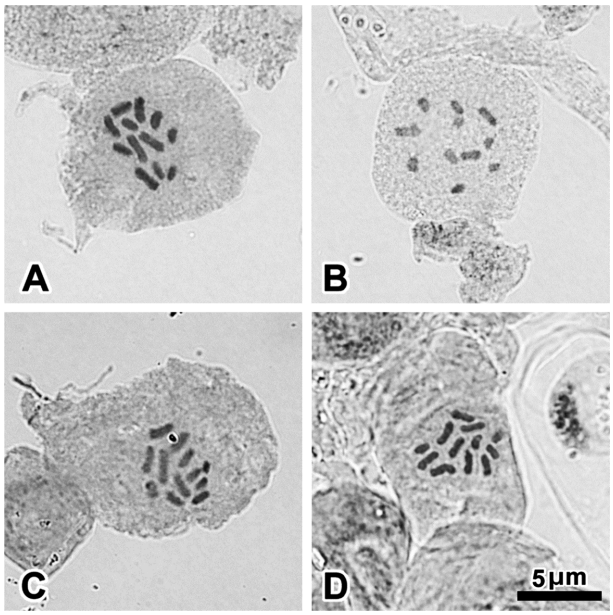

Fig. 1. Somatic chromosomes of *Carex* sect. *Siderostictae.* A. *Carex ciliatomarginata* Nakai (2n = 12, *Chung 59*); B. *C. okamotoi* Ohwi (2n = 12, *Chung 71*); C, D. *C. siderosticta* Hance (2n = 12, *Chung 42* and *Chung 206*, respectively).

Chromosome size variation in *Carex* sect. *Siderostictae*: Chromosomes vary in cell size (Fig. 1). Although karyotypic analyses are not practicable, at least two different sizes are observed in all cells (Fig. 1). In comparison of the very small chromosomes (ca. 1 μm long) reported chromosomes from other *Carex* species, chromosomes in *Carex* sect. *Siderostictae* are rather large, which indirectly supports agmatoploidy (chromosome number increases by fission, without gene duplications; Luceño and Guerra, 1996) in other species. Only a few species in *Carex* have been reported as polyploidy, and many species with high chromosome numbers were hypothesized as agmatoploidy because of holocentric chromosomes in the genus (Hipp et al., 2008; Hipp et al., 2010; Chung et al., 2011). In molecular phylogenetic studies, the section is monophyletic and basal in the tribe Cariceae (Waterway et al., 2009; Jung and Choi, 2012). Considering the basal phyplogenetic position of the section, Waterway et al. (2009) hypothesized that small-numbered, large chromosomes are primitive characters in

Cariceae, and our study supports the chromosomal hypothesis in *Carex*.

Phylogeny of *Carex* sect. *Siderostictae*: Due to the basal phylogenetic position of the section, morphological characters in the section are hypothesized as the most early derived characters: androgynous spikes, multiple spikes at a single node, persistent rachillae bearing male flowers (Starr and Ford, 2009; Waterway et al., 2009). In *Carex,* unisexual spikes have been hypothesized as an ancestral character (Starr and Ford, 2009). Within the *Carex* sect *Siderostictae*, both unisexual and sexual spikes are found, and other floristic characters are variable (Table 2). Previous molecular studies of the section were limited in taxon sampling and genetic markers (e.g., Moon et al., 2012; Jung and Choi, 2012). A robust phylogeny of more complete taxon sampling of species in the section with variable genetic markers is needed to test morphological character evolution in the section. In addition, chromosome investigations of entire *Carex* sect *Siderostictae* taxa covering geographic distribution areas need to be analyzed for a better understanding of the phylogenetic relationships and chromosomal evolution in the section as well as *Carex*.

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