Chromosome numbers of eight *Carex* taxa in Korea (Cyperaceae)

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ABSTRACT: In the flora of Korea, *Carex* L. is one of the most species-rich genera. Among nearly 157 *Carex* taxa, less than 30 have had their chromosome numbers reported. We report the meiotic chromosome numbers of eight *Carex* taxa from Korean populations, which include the first count for *C. accrescens* Ohwi ($n = 37_{II}$) and the first chromosome investigations of Korean populations for three taxa: *C. bostrychostigma* Maxim. ($n = 22_{II}$), *C. lanceolata* Boott ($n = 36_{II}$), and *C. paxii* Kük. ($n = 38_{II}$). In most species, chromosome counts observed in the study are included within the variation ranges of previous chromosome numbers. However, *C. bostrychostigma* Maxim. ($n = 22_{II}$) and *C. planiculmis* Kom. ($n = 29_{II}$) are assigned new chromosome numbers. *Carex* is known to have holocentric chromosomes, lacking visible primary constrictions and exhibiting great variance in its chromosome number. Further investigations of the diversity of *Carex* chromosomes will provide basic information with which to understand the high species diversity of the genus.

Keywords: *Carex*, meiotic chromosome number, Cyperaceae

Carex L. is one of the most species diverse genera in flowering plants with more than 2,000 species worldwide (Global *Carex* Group, 2015). Along the great species diversity, the genus has high intraspecific variation in chromosome numbers due to holocentric chromosomes, which have diffused or nonlocalized centromeres (Hipp et al., 2009; Escudero et al., 2012). Within the genus, chromosome numbers dramatically vary, from $n = 6$ to $n = 66$; and taxa with high variations in chromosome numbers within species and/or individuals have been detected in recently diverging lineages (Tanaka, 1949; Roalson, 2008; Hipp et al., 2009). The chromosome features can have chromosome number increases (fission, agmatoploidy) and/or decreases (fusion, symploidy) without DNA duplication/deletion events (Hipp et al., 2013). Genome size and chromosome number in *Carex* have been hypothesized to be decoupled evolutionary features (Chung et al., 2012). The cytological features are critical to understand species richness of *Carex* (Hipp et al., 2009; Global *Carex* Group, 2015).

In the flora of Korea, *Carex* is the largest genus with about 157 taxa in Cyperaceae, the second largest family with 246 species in 13 genera (Oh, 2007). Although chromosome

information is critical to understand diversity in *Carex*, most species have not been investigated using cytological tools. Among Korean native taxa, only 24 *Carex* taxa have been reported with chromosome numbers, and the genome sizes of 43 *Carex* taxa have been estimated (Chung and Im, 2019; Lee et al., 2019). The cytological information is too little to understand *Carex* diversity in the flora.

In the present study, we report meiotic chromosome numbers of eight *Carex* taxa observed from Korean populations: *C. accrescens* Ohwi, *C. lanceolata* Boott, *C. bostrychostigma* Maxim., *C. breviculmis* R. Br., *C. polyschoena* H.Lév. & Vaniot, *C. sabynensis* Less. ex Kunth, *C. planiculmis* Kom., and *C. paxii* Kük.

Materials and Methods

Immature male spikes were used for meiotic chromosome number observation. Entire spikes were preserved in a fixative containing methanol, chloroform, and propionic acid (6:3:2) and then transferred to 70% ethanol (Rothrock and Reznicek, 1996; Chung et al., 2016). Fixed anthers were squashed in 1% acetic-

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orcein and observed at 1,000× magnification (Nikon Eclipse 50i, Nikon, Tokyo, Japan). To determine chromosome numbers and variation ranges, more than two meiotic division cells per individual were observed, analyzed, and photographed. Taxon identification followed Park et al. (2016) and Hoshino et al. (2011), and infrageneric classification was adopted from Global Carex Group (2020). Voucher specimens with mature perigynia were stored at Andong National University herbarium (ANH).

Results and Discussion

Meiotic chromosome numbers of eight *Carex* taxa were summarized in Table 1. Sections and species were organized in alphabetical order. All the species exhibited consistent chromosome numbers within individuals and had the normal

bivalents pairing in meiotic division. Among the four species observed more than one population, *C. bostrychostigma* and *C. sabynensis* did not exhibit variation in chromosome number. However, two *C. planiculmis* individuals had variation with $n = 29_{II}$ and 30_{II} , and *C. breviculmis* varied in the meiotic chromosome numbers with 33_{II} , 34_{II} , and 36_{II} . Their chromosomes were about 2 μ m long, and constricted centromeres were not visible (Fig. 1).

Carex accrescens Ohwi 경성사초 ($n = 37_{II}$) (Fig. 1A) – Sect. *Ammoglochin* Dumortier

Meiotic chromosome number of $n = 37_{II}$ was observed in *C. accrescens* (= *C. pallida* C. A. Mey.), which was the first count for the species. The species is characterized with long rhizomes, two types of spikes (male and androgynous) and ovoid perigynia with serrulate margins (Park et al., 2016; Hoshino et al., 2011). It occurs in East Asia, and most populations in

Table 1. Summary of chromosome number of the *Carex* taxa investigated in this study and reported in previous studies.

Section	Species, locality, and voucher information	Chromosome number in this study, $2n$	Previous counts, $2n$
<i>Ammoglochin</i>	<i>C. accrescens</i> 경성사초 (= <i>C. pallida</i> C.A.Mey.) Socheon-myeon, Bonghwa-gun, Gyeongbuk, 22 May 2021, Chung 8023	74 ($n = 37_{II}$)	None
<i>Clandestinae</i>	<i>C. lanceolata</i> 그늘사초 Anseo-dong, Cheonan-si, Chungnam, 15 April 2021, Chung 7006	72 ($n = 36_{II}$)	70 (Hoshino, 1981), 72 (Hoshino and Ikeda, 2003)
<i>Debiles</i>	<i>C. bostrychostigma</i> 길뚝사초 Mt. Baebawisan, Socheon-myeon, Bonghwa-gun, Gyeongbuk, 22 May 2021, Chung 8018 Same locality, 22 May 2021, Chung 8019	44 ($n = 22_{II}$) 44 ($n = 22_{II}$)	46 (Hoshino et al., 2011)
<i>Mitratae</i>	<i>C. breviculmis</i> 청사초 Anseo-dong, Cheonan-si, Chungnam, 11 April 2021, Chung 7176 Baekgok-myeon, Jincheon-gun, Chungbuk, 13 April 2021, Chung 7219 Mt. Baebawisan, Socheon-myeon, Bonghwa-gun, Gyeongbuk, 19 April 2021, Chung 7323 Ihoil-dong, Jeju-si, Jeju, 10 April 2021, Chung 7344	72 ($n = 36_{II}$) 66 ($n = 33_{II}$) 66 ($n = 33_{II}$) 68 ($n = 34_{II}$)	54 (Chung et al., 2016, reported as <i>C. leucochlora</i>), c.64 (de Lange and Murray, 2002), 66 (Chung et al., 2017), 66 (Chung et al., 2018), 64, 68 (Tanaka, 1939), 68 (Hoshino, 1981 reported as <i>C. leucochlora</i>), 68 (Ohkawa and Yokota, 1998 reported as <i>C. leucochlora</i>), 68, 66, 64 (Chung and Im, 2020), 72 (Okuno, 1939)
	<i>C. polyschoena</i> 가지청사초 Baekgok-myeon, Jincheon-gun, Chungbuk, 3 May 2021, Chung 7215	74 ($n = 37_{II}$)	52 (Chung et al., 2016), 72, 74 (Chung et al., 2018), 74, 76 (Chung and Im, 2020)
	<i>C. sabynensis</i> 실청사초 Anseo-dong, Cheonan-si, Chungnam, 15 April 2021, Chung 7200 Same locality, 15 April 2020, Chung 7203	56 ($n = 28_{II}$) 56 ($n = 28_{II}$)	40 (Krogulevich, 1971), 54 (Chung et al., 2016), 54 (Chung and Im, 2020), 54, 56 (Chung et al., 2018), 60 (Yurtsev and Zhukova, 1982), 76 (Chung et al., 2017)
<i>Molliculae</i>	<i>C. planiculmis</i> 그늘흰사초 Socheon-myeon, Bonghwa-gun, Gyeongbuk, 22 May 2021, Chung 8012 Same locality, 22 May 2021, Chung 8016	58 ($n = 29_{II}$) 60 ($n = 30_{II}$)	60 (Chung and Im, 2018), 62 (Tanaka, 1939)
<i>Phleoideae</i>	<i>C. paxii</i> 대구사초 Beopsu-myeon, Haman-gun, Gyeongnam, 30 April 2021, Chung 8047	76 ($n = 38_{II}$)	76 (Hoshino, 1981, 1986)

Fig. 1. Photomicrographs of *Carex* meiotic chromosomes. **A.** *C. accrescens* ($n = 37_{II}$, Chung 8023). **B.** *C. lanceolata* ($n = 36_{II}$, Chung 7006). **C.** *C. bostrychostigma* ($n = 22_{II}$, Chung 8018). **D.** *C. bostrychostigma* ($n = 22_{II}$, Chung 8019). **E.** *C. breviculmis* ($n = 36_{II}$, Chung 7176). **F.** *C. breviculmis* ($n = 33_{II}$, Chung 7219). **G.** *C. breviculmis* ($n = 33_{II}$, Chung 7323). **H.** *C. breviculmis* ($n = 34_{II}$, Chung 7344). **I.** *C. polyschoena* ($n = 37_{II}$, Chung 7215). **J.** *C. sabynensis* ($n = 28_{II}$, Chung 7200). **K.** *C. sabynensis* ($n = 28_{II}$, Chung 7203). **L.** *C. planiculmis* ($n = 29_{II}$, Chung 8012). **M.** *C. planiculmis* ($n = 30_{II}$, Chung 8016). **N, O.** *C. paxii* ($n = 38_{II}$, Chung 8047). Scale bars = 10 μ m.

Korea are found in wet and sandy habitats (Hoshino et al., 2011; Park et al., 2016; Japanese Society of Cyperology, 2018). Global Carex Group (2020) places the species in Disticha clade with total 27 taxa, which are treated in various traditional sections, *Ammoglochin*, *Divisae*, *Holarrhenae*, *Foetidae*, *Phaestoglochin*, and *Phleoideae*.

***Carex lanceolata* Boott 그늘사초 ($n = 36_{II}$) (Fig. 1B) – Sect. *Clandestinae* G. Don**

For the first time, chromosome number of *C. lanceolata* from a Korean population was counted, $n = 36_{II}$. Previous counts from Japanese populations are two numbers, $2n = 70$ and $2n = 72$ (Hoshino, 1981; Hoshino and Ikeda, 2003). In both South Korea and Japan, the species commonly grows (Park et al., 2016; Japanese Society of Cyperology, 2018). The species is classified in sect. *Clandestinae* by traditional and phylogenetic criteria (Global Carex Group, 2020).

***Carex bostrychostigma* Maxim. 길뚝사초 ($n = 22_{II}$) (Fig. 1C, D) – Sect. *Debiles* (J. Carey) Ohwi**

From two individuals of *C. bostrychostigma*, chromosome numbers of $n = 22_{II}$ were observed, which were first counts from Korean populations and different from the previous report from a Japanese population ($2n = 46$ in Hoshino et al., 2011). In South Korea, the species is very common occurring throughout the country, whereas it is found only in Honshu and Kyushu in Japan (Park et al., 2016; Japanese Society of Cyperology, 2018). More investigations targeting broad distribution areas should be conducted to determine chromosome number variation range in the species. Global Carex Group (2020) places the species in Dissitiflora clade with *C. dissitiflora* Franch., which is endemic to Japan and traditionally in sect. *Mundae* ($2n = 36, 38$) (Hoshino et al., 2011).

***Carex breviculmis* R.Br. 청사초 ($n = 33_{II}, 34_{II}, 36_{II}$) (Fig. 1E–H) – Sect. *Mitratae* Kükenthal**

Three different chromosome numbers were observed from four populations. Chromosome numbers of $n = 33_{II}$ and $n = 34_{II}$ are previously reported from Korean populations (Chung et al., 2017, 2018; Chung and Im, 2020), but $n = 36_{II}$ is the first count from a Korean population, which is previously reported from Japanese populations (Okuno, 1939). The species relatively common in Korea and Japan, occurring in Asia such as Taiwan, Russia, and Himalaya (Park et al., 2016; Japanese Society of Cyperology, 2018). Traditionally the species is classified in sect. *Mitratae* Kük., and recent classification shows that the species forms a clade named Mitrata with majority of *Mitratae* members (Global Carex

Group, 2020). High chromosome variation in the species, from $2n = 54$ to $2n = 72$ (not continuous), might be related with broad distribution or with confuse of taxonomic complex such as species delimitation.

***Carex polyschoena* H.Lév. & Vaniot 가지청사초 ($n = 37_{II}$) (Fig. 1I) – Sect. *Mitratae* Kükenthal**

Chromosome number of $n = 37_{II}$ was observed for *C. polyschoena*. The species is only found in Korea and Japan. In South Korea, the species is very common occurring throughout the country, whereas the species occurs only in Tsushima, Kyushu, Japan (Hoshino et al., 2011; Park et al., 2016). Various chromosome numbers for the species have been reported from Korean populations ($2n = 52, 72, 74, 76$) (Chung et al., 2016, 2018; Chung and Im, 2020). The species is classified in Conica clade with 48 species, which are mainly *Mitratae* members distributed in Asia (Global Carex Group, 2020).

***Carex sabynensis* Less. ex Kunth 실청사초 ($n = 28_{II}$) (Fig. 1J, K) – Sect. *Mitratae* Kükenthal**

Chromosome number of $n = 28_{II}$ was observed from two individuals of *C. sabynensis*, which was identical to the previous report from a Korean population in Chung et al. (2016). Five different chromosome numbers have been reported for the species ($2n = 40, 54, 56, 60, 76$) (Table 1). The species occurs throughout the country in South Korea, whereas it grows in Hokkaido, Honshu, and Kyushu in Japan (Hoshino et al., 2011; Park et al., 2016). It is also found in China and Russia (Park et al., 2016). Global Carex Group (2020) classifies the species in Conica clade, where *C. polyschoena* belonging to.

***Carex planiculmis* Kom. 그늘썩사초 ($n = 29_{II}, 30_{II}$) (Fig. 1L, M) – Sect. *Molliculae* Ohwi**

Two chromosome numbers for *C. planiculmis* were observed, $n = 29_{II}$ and $n = 30_{II}$. The chromosome number of $n = 29_{II}$ is a new count for the species. Chromosome number of the species ranges from $2n = 58$ to $2n = 62$, including observations made from Japanese and Korean populations ($2n = 62$, Tanaka, 1939; $2n = 60$, Chung and Im, 2018). The species occurs in East Asia including north part of Japan (Honshu and Hokkaido) and most provinces in Korea (Park et al., 2016; Japanese Society of Cyperology, 2018). Traditionally, the species is classified in sect. *Molliculae* and the section is well supported in phylogenetic research. However, *C. planiculmis* position in the section is not supported by phylogenetic data and remains unresolved (Global Carex Group, 2020).

***Carex paxii* Kük. 대구사초 ($n = 38_{II}$) (Fig. 1N, O) – Sect. *Phleioideae* Meinshausen**

For the first time, a chromosome number of *C. paxii* from a Korean population was counted, which was identical to the previous count made from Japanese populations (Hoshino, 1981, 1986). In both Japan and Korea, only a few natural populations have been reported, and the species also occurs in China (Park et al., 2016; Japanese Society of Cyperology, 2018). The species has been classified in sect. *Phleioideae* in traditional classification, but the phylogenetic data have moved it to Disticha clade composed of some numbers of six traditional sections (two *Ammoglochin*, one *Divisae*, ten *Holarrhenae*, nine *Foetidae*, four *Phaestoglochin*, and one *Phleioideae* taxa) (Global Carex Group, 2020). Among nine taxa in the traditional section *Phleioideae*, *C. paxii* is the only species not supported by the sectional classification but is grouped with North American and Eurasian species in Disticha clade (Global Carex Group, 2020).

Most *Carex* species are assigned in revised phylogenetic classification, but many clades miss morphological and/or geographic synapomorphies (Global Carex Group, 2020). It is unlikely that a single character would explain lineage divergences, but combinations of characters might be able to interpret current lineages. Chromosome variation within species is common in the genus, and genetic diversity explains lineage diversity and limitations in some lineages with enough cytological data available (Hipp et al., 2009; Chung et al., 2012). It is challenging to obtain cytological information due to living material availability and maintenance. However, further work on cytological data is critical to understand infrageneric lineage and species diversity in the genus.

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Conflict of Interest

The authors declare that there are no conflicts of interest.

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