Cytotaxonomy of *Cornopteris**

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Received February 29, 1964

Introduction

The genus *Cornopteris* was established by Nakai¹⁾ who picked up, among athyrioids, certain members which lack indusium and are characterized by a few small processes on costae in the basal, ramified part of pinnae or pinnules. Momose²⁾ investigated prothallia of the ferns and agreed with Nakai's opinion; he proposed that *Cornopteris* should be separated from *Athyrium* as an independent genus. Copeland³⁾ and Holttum⁴⁾, however, put all the athyrioids together into a single genus, *Athyrium*. Of 18 genera compounded by Copeland, at least four, namely *Athyrium*, *Diplazium*, *Deparia*, and *Cornopteris*, are those which were considered by Ching⁵⁾ to be distinct.

Cornopteris decurrenti-alata was once described by Hooker⁶⁾ as a member of *Gymnogramme* and by Diels⁷⁾ as one of *Nephrolepis*, but later a taxonomist treated it as to be closely related to, or belonging to *Athyrium*: Copeland³⁾ considered it a relative of *Athyrium japonicum* (*Lunathyrium japonicum*). The present author, however, believes that this species is more closely allied to *Dryoathyrium* ($x=40$, Kurita^{8), 9)}) in gross morphology rather than to *Lunathyrium*.

More recent studies have revealed that Copeland's *Athyrium* is a heterogenous group which should further be divided into two groups on account of chromosome numbers: Euathyrium group, of which basic chromosome number (x) is 40, and Diplazium group, $x=41$. There is a question whether *Cornopteris* should belong to one or the other of these groups.

Bir¹⁰⁾ studied *Cornopteris birii* Ching from the Himalayas and concluded that the genus is more closely related to *Diplazium* than to *Athyrium*, for he found 82 gametic chromosomes in his species. The question will more fully be discussed in the last part of this paper.

Materials and Methods

More than 10 species of *Cornopteris* have been described in the world. They are mostly distributed in temperate zone of Asia, from the Himalayas to Japan. There are four species with one variety in Japan (Tagawa¹¹⁾), all of which being the materials in the present work. Their name and localities will be seen in the text and figures, or more conveniently in Table 1. Some of them were collected in fields and some were obtained from the green house in the Koishikawa Botanical Garden of the University of Tokyo.

Young fertile fronds were fixed in mixture of one part of glacial acetic acid and three parts of absolute alcohol, for 24 hours or longer. The squash method was used for the observation of chromosomes (Manton¹²⁾).

This work was supported by a Grant in Aid of Scientific Research of the Ministry of Education. No. 35052 (1961).

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Fig. 1. Distribution map of *C. crenuloserrulata* (×), *C. decurrenti-alata* (Δ), and *C. hakonensis* (•). a) Mt. Yamizo. b) Mt. Ozaku. c) Kiyosumi-yama. d) Chichibu-Tama National Park. e) Yugashima. f) Fuji-Hakone National Park. g) Ogasa-yama. h) Oborazawa. i) Owase. j) Nachi. k) Yakushima Island.

Fig. 2. Pinnules of mature fertile pinnae of *Cornopteris*. 1) *C. crenuloserrulata*. 2) *C. hakonensis*. 3) *C. decurrenti-alata*.

Results and Discussion

Cornopteris crenulatoserrulata

Specimens were collected in Chichibu-Tama National Park (Mt. Buko, Mt. Mitsumine, Mt. Ryokami and Mt. Otake), Fuji-Hakone National Park (Gotenba) and at Mt.

Fig. 3. Epidermal cells of the lowest pinnae of *Cornopteris*. 1) *C. crenulatoserrulata*. 2) *C. decurrenti-alata* ($n=80$). 3) *C. decurrenti-alata* ($2n=c. 160$. Irregular meiosis). 4) *C. decurrenti-alata* var. *pilosella*. 5) *C. hakonensis*. 6) *C. opaca* (diploid). 7) *C. opaca* (tetraploid). 8) *C. fluvialis* (normal diploid). 9) *C. fluvialis* (asynaptic diploid).

Yamizo. At diakinesis and metaphase in the first meiotic division 40 bivalent chromosomes were counted (Fig. 4-1). The plants from Mt. Yamizo, however, sometimes showed 40 bivalents and a fragment-like chromosome (Fig. 4-2). There were 16 spore mother cells in a sporangium and they developed into 64 bilateral spores.

Table 1. Chromosome number of *Cornopteris*.

Species	Chromosome number	Worker
<i>Cornopteris birii</i>	n=82	Bir (1961)
<i>C. crenuloserrulata</i>	n=40	Kurita
<i>C. decurrenti-alata</i>	n=80 and 2n=ca. 160 (irregular meiosis)	—
— var. <i>pilosella</i>	n=ca. 80	—
<i>C. hakonensis</i>	2n=ca. 120 (40 II+40 I)	—
<i>C. opaca</i>	n=41 and n=ca. 82	—
<i>C. fluvialis</i>	n=40 and 2n=80 (80 I, asynaptic diploid)	—

Cornopteris decurrenti-alata

Specimens were collected in Ogasa-yama, Yugashima, Kiyosumi-yama, and also in Owase and Nachi. There were 80 bivalent chromosomes in meiosis (Fig. 4-3). One plant from Yugashima assumably representing a form *latifrons* H. Ito¹³⁾ in gross morphology, showed about 160 chromosomes in root tip cells, and it showed both bivalents and univalents at diakinesis and metaphase in the first meiotic division. An example of such feature is in Fig. 4-4 which shows about 60 bivalents and about 40 univalents. These bivalents will be separated irregularly at anaphase I and will produce some micronuclei in spore mother cell which then will grow directly into an abnormally large and spherical spore. Such a spore appears to be abortive. Hence, this plant might be a tetraploid hybrid of two cytological, tetraploid races of *C. decurrenti-alata*.

Cornopteris decurrenti-alata var. *pilosella*

This variety has multicellular hair on the under-surface of the frond especially along rachises and veins. Though less common, this variety is distributed nearly like the mother species, *C. decurrenti-alata*.

Specimens were from Kiyosumi-yama, Oborazawa, and Chichibu-Tama National Park (Mt. Otake). Approximately 80 bivalent chromosomes were observed in many spore mother cells at the first meiotic division (Fig. 4-5). Meiosis is normal and 64 bilateral spores are produced in each sporangium.

Cornopteris hakonensis

Materials from Mt. Yamizo, Mt. Ozaku, and Chichibu-Tama National Park (Mt. Otake) were examined. This species seems to be a triploid hybrid, for it shows about 40 bivalents and about 40 univalents in the first meiotic division (Fig. 4-6). Approximately 120 chromosomes were counted in root tip cells. In the first meiotic anaphase, each bivalent is separated regularly while univalents scatter around both poles, and then two resting nuclei are formed. Although the second meiotic division makes tetrads, almost all the spores except a few seem to be abortive.

This species was regarded by Makino¹⁴⁾ as a form of *C. crenuloserrulata*, but more recently it has been treated as an independent species, and Kurata¹⁵⁾ pointed out that it is an intermediate species of *C. crenuloserrulata* and *C. decurrenti-alata*. His suggestion would be supported on the basis that it shows approximately 40 bivalents

and 40 univalents in meiosis. Probably it is a triploid hybrid between a diploid and a tetraploid. In fact, *C. decurrenti-alata* is tetraploid and *C. crenuloserrulata*, diploid. While young, the present species much resembles *C. crenuloserrulata*.

The present species is really intermediate of the above two species with regards to distribution, either horizontal or vertical: it is frequent in regions where *C. crenuloser-*

Fig. 4. 1) *C. crenuloserrulata*. $n=40$. 2) *C. crenuloserrulata* from Mt. Yamizo, showing 40 bivalents (in black) and one fragment-like chromosome (in outline). 3) *C. decurrenti-alata*. $n=80$. 4) A spore mother cell of *C. decurrenti-alata* from Yugashima. $2n=\text{ca. } 60$ bivalents (in black) and 40 univalent chromosomes (in outline). 5) *C. decurrenti-alata* var. *pilosella*. $n=\text{ca. } 80$. 6) Meiosis in a spore mother cell of *C. hakonensis*, showing bivalents (in black) and univalents (in outline). 7) Diploid *C. opaca*. $n=41$. 8) Tetraploid *C. opaca*. $n=\text{ca. } 82$. 9) A spore mother cell of diploid *C. fluvialis* which performs normal meiosis. $n=40$. 10) Meiosis in a spore mother cell of asynaptic diploid of *C. fluvialis*, showing 80 univalent chromosomes.

mulata and *C. decurrenti-alata* meet (Fig. 1). Also morphologically, *C. hakonensis* takes position in between; it has an elliptic sorus whereas *C. crenuloserrulata* has a circular and *C. decurrenti-alata* a linear one. Serration and decurrentism of pinnules in *C. hakonensis* are also of intermediate nature (Fig. 2). All these support Kurata's opinion, and the present author proposes that *C. hakonensis* is a vicarious species induced by hybridization between *C. crenuloserrulata* and *C. decurrenti-alata*.

Cornopteris opaca

Materials from Yakushima Island were examined. The two cytological races, diploid and tetraploid, were found in the present species. The diploid race has 41 gametic chromosomes and the tetraploid has approximately 82 bivalents (Fig. 4-7, 8). As shown in Fig. 3-6 and -7, the epidermal cells of this species are peculiar and much different from those of other species of the genus.

The present species name was treated by Tagawa¹⁶⁾ as synonymous with *C. decurrenti-alata* which, however, represents a tetraploid species (based on $x=40$) with much different epidermal cells. Moreover, *C. opaca* has an erect or oblique rhizome, in contrast with the creeping one in *C. decurrenti-alata*. Accordingly, the present species complex should be distinguished from *C. decurrenti-alata* complex. It may be a specified taxon among Japanese *Cornopteris*.

Cornopteris fluvialis

The plants were collected in Yakushima Island. Two cytological races were found; a diploid which performs normal meiosis and an asynaptic diploid. The normal diploid which is typically *C. fluvialis* in gross morphology has 40 gametic chromosomes (Fig. 4-9). The asynaptic diploid which, as pointed out by Kurata¹⁷⁾, somewhat resembles *C. opaca*, shows 80 univalents in the first meiotic metaphase as there occurs no pairing of homologous chromosomes during prophase (Fig. 4-10). These univalents may make

some micronuclei in anaphase which sometimes may fuse into a large chromosome clump. No indication of cytokinesis could be observed throughout meiotic division, and 16 spore mother cells change into 16 spherical spores which eventually will be disintegrated. It is interesting that the asynaptic race shows two very large chromosomes in metaphase, largest among others of the chromosome complement of the race. They can hardly be stained with acetocarmine and may consist largely of heterochromatin like usual B-chromosomes. They characterize the karyotype of this race. The epidermal cells are not much different in shape between the asynaptic and normal races as shown in Fig. 3-8 and -9.

Giving consideration to these cytological characteristics, the author supposes that the asynaptic species is a structural hybrid, or a hybrid of certain two different cytological races of *C. fluvialis*.

The basic chromosome number of the genus

Bir¹⁰⁾ described the basic number of *Cornopteris* as 41, for he counted 82 gametic chromosomes in *C. birii* from the Himalayas, and concluded that the genus is closer to *Diplazium* which has 41 basic chromosomes than to *Athyrium* which has 40. However, *Athyrium* (*Lunathyrium*) *japonicum* complex should be subdivided into two groups, for a complex of $x=41$ is reported from Malayan flora by Manton and Sledge¹⁸⁾ and Manton¹⁹⁾, and another with $x=40$ is found in the Himalayas and Japan by Bir¹⁰⁾ and Kurita⁸⁾. Hence, it is not adequate to separate *Diplazium* from *Athyrium* only by the basic number which, however, seems to be useful in segregating *Euathyrium* and *Diplazium* within Copeland's *Athyrium*. The present author found two kinds of basic number in *Cornopteris*, $x=41$ in *C. opaca* and $x=40$ in *C. crenuloserrulata*, *C. fluvialis*, and *C. decurrenti-alata*.

Therefore, it can not be concluded that *Cornopteris* is close to *Diplazium* as mentioned by Bir¹⁰⁾. It may rather be adequate to treat *Cornopteris* as an independent genus as Nakai¹⁾ and Tagawa¹¹⁾ did. The strain with $x=40$ may be considered a derivative of the strain based on $x=41$.

Summary

Four species with one variety of Japanese *Cornopteris* were studied. Cytological results are summarized in Table 1. As shown in Table 1, there are two cytological races in *C. decurrenti-alata* and in *C. opaca*. The latter species name was treated by Tagawa¹⁶⁾ as synonymous with *C. decurrenti-alata*, but *C. opaca* should be distinguished from *C. decurrenti-alata* judging from cytological and morphological point of view.

In *C. fluvialis*, also two cytological races were found: a diploid which performs normal meiosis and an asynaptic diploid which shows two very large chromosomes characterizing the karyotype of this race.

C. hakonensis is supposed as a vicarious species induced by hybridization of *C. crenuloserrulata* and *C. decurrenti-alata*.

Counting 82 gametic chromosomes in *C. birii*, Bir¹⁰⁾ concluded that *Cornopteris* is closer to *Diplazium* ($x=41$) than to *Athyrium* ($x=40$). The present author, however, found two kinds of basic number, 40 and 41, in *Cornopteris*. So, it may rather be adequate to treat *Cornopteris* as an independent genus as Nakai¹⁾ and Tagawa¹¹⁾ did.

I wish to express my cordial thanks to Dr. M. Nishida, Assist. Prof. of the Chiba University, for his kind guidance given during the course of the work. I am also grateful to Assist. Prof. S. Kurata, University of Tokyo, and Mr. M. Kawabata who were very helpful in getting the material used in the work.

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摘 要

栗 田 子 郎: シケチンダ属の細胞分類学

Bir は *Cornopteris birii* で $n=82$ を観察したことから、シケチンダ属はメンダ属 ($x=40$) よりもヘラシダ属 ($x=41$) に近いものだという見解を述べた。しかし筆者は $x=40$ と $x=41$ の二系を観察できたので、シケチンダ属は独自の一群としてあつかうのが妥当と考える。

個々の種については、イッポンワラビが $n=40$ の二倍体で、シケチンダは $n=80$ の四倍体である。しかし伊豆湯ヶ島産のシケチンダは $2n=ca. 160$ で四倍体と思われるが、減数分裂に異常があり第一分裂で一価染色体と二価染色体とがみられる。稔性をもった胞子は形成されぬらしい。この個体は、いわゆるヒロバシケチンダに相当するものと考ええる。一方、タカオシケチンダは $2n=ca. 80$ であった。

ハコネシケチンダは形態的にイッポンワラビとシケチンダの中間型を示しているが、染色体数 $2n=ca. 120$ で明らかに三倍体である。第一減数分裂においても約 40 の二価染色体と約 40 の一価染色体とがみられる。分布などをも考慮すると、ハコネシケチンダはイッポンワラビとシケチンダとの交雑によって生じた種といえると思う。

田川博士が *C. decurrenti-alata* (シケチンダ) の異名と考えた *C. opaca* (ナンゴクシケチンダ、倉田氏仮称) には $n=41$ のものと $n=ca. 82$ のものがある。染色体数、表皮細胞の形態その他の点を考慮すると *C. opaca* は独立種とするのが妥当だろう。

ホソバシケチンダにも二系がある。典型的なホソバシケチンダは $n=40$ の二倍体で、いまいつ(ヤクシケチンダ、倉田氏仮称) は同様に二倍体ではあるが、第一減数分裂における相同染色体の対合がまったく見られない。80 個の染色体の内、一対は大型で大部分がヘテロクロマチンから構成されている。ヤクシケチンダは形態的にはホソバシケチンダとナンゴクシケチンダの中間型を示すといわれるが、染色体数、表皮細胞の形態などからみて、ホソバシケチンダの構造雑種だろうと考える。(千葉大学留学生部生物学教室)

Plate I. 1) Diakinesis of *C. crenulatoserrulata*, showing 40 bivalent chromosomes. 2) Metaphase in the first meiotic division of *C. crenulatoserrulata* from Mt. Yamizo, showing 40 bivalents and one fragment-like chromosome. 3) A spore mother cell of the normal tetraploid *C. decurrenti-alata* showing 80 bivalents. 4) *C. decurrenti-alata* var. *pilosella*. $n \approx 80$. 5) and 6) Meiosis in the spore mother cell of *C. hakonensis* showing 40 bivalents and 40 lagging univalent chromosomes.

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Plate II. 7) *C. opaca*. $n=41$. 8) A spore mother cell of diploid *C. fluvialis* which performs normal meiosis. $n=40$. 9) and 10) Meiosis in the spore mother cell of asynaptic diploid of *C. fluvialis* showing 80 univalent chromosomes. 11) Spore mother cells of asynaptic *C. fluvialis* showing the formation of micronuclei and chromosome clump. 12) A spore mother cell of tetraploid *C. opaca*. $n=\text{ca. } 82$.

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