

Updates of Taxonomic Treatments for Ferns of Japan 2. *Athyrium* and *Cyrtomium*

Atsushi Ebihara^{1,*}, Sadamu Matsumoto¹, Jaideep Mazumdar² and Kaoru Yamamoto³

¹ Department of Botany, National Museum of Nature and Science,
Amakubo 4-1-1, Tsukuba, Ibaraki 305-0005, Japan

² Department of Biological Sciences, Burdwan Town School, Burdwan-713101, India

³ Yokosuka City Museum, Fukadadai 95, Yokosuka-shi, Kanagawa 238-0016, Japan

* E-mail: ebihara@kahaku.go.jp

(Received 9 November 2016; accepted 21 December 2016)

Abstract Reflecting the results of recent studies on Japanese ferns, some new taxonomic treatments are proposed including the transfer of two varieties of *Athyrium* to the forma rank (*Athyrium otophorum* f. *okanum* and *A. wardii* f. *inadae*) and recognition of two new subspecies of *Cyrtomium falcatum* (subsp. *littorale* and subsp. *australe*).

Key words: *Athyrium*, *Cyrtomium*, cytotype, ferns, Japan, reproductive mode.

1. Reducing two varieties of *Athyrium* (Athuriaceae) to forma rank

Athyrium otophorum usually has sessile pinnae, but a population found in Yamaguchi Pref. produces fronds with shortly petiolate pinnae. This latter form was described by Kurata (1969) as a variety of the species, and was later listed as a critically endangered taxon on the national red list of Japan (Japanese Ministry of Environment, 2015). Except for petiolules, morphological characters of both forms are exactly alike, and their chloroplast *rbcL* sequences were completely identical with each other (Ebihara, 2011). Considering the information above, it seems more appropriate to transfer the form currently treated as a variety to the forma rank within *A. otophorum*. This taxon is known only from a very limited area of approximately 1 km². Another species to note, *A. oblitescens* Sa.Kurata, was described based on a specimen collected exactly from the same area (Kurata, 1969) as the *A. otophorum* variety just mentioned, and is also distinguished from *A. otophorum* by the petiolate

pinnae. According to the study by Kurihara *et al.* (1996) based on cytological and allozyme patterns, three types of different origins (Type C, Type O and Type W) were included in the species even at its type locality, Kinkei Fall in Yamaguchi-shi. Type C and Type W, which are hexaploids of possible hybrid origin with *A. otophorum* and another species (*A. clivicola* or *A. wardii*) as putative parents, probably match the presently accepted species concept of *A. oblitescens* (e.g. slightly paler color of scales at stipe base, thicker and softer lamina, in comparison with *A. otophorum*). Tetraploid or the O-type, which is genetically indistinguishable from *A. otophorum* including var. *okanum* (Kurihara *et al.*, 1996), would better be included in the range of *A. otophorum* var. *okanum* rather than *A. oblitescens*.

Athyrium otophorum (Miq.) Koidz. f. *okanum* (Sa.Kurata) Ebihara, **stat. nov.**

—*Athyrium otophorum* (Miq.) Koidz. var. *okanum* Sa.Kurata, J. Geobot. 17: 3, 1969.

Typus: JAPAN. Prov. Suwo [Yamaguchi

Pref.], Yamaguchi-shi, Futatsudo Fall, originally collected by K. Oka, cultivated in Koishikawa Botanical Garden (*S. Kurata, s.n.*, Jun. 1968, holo-TOFO).

Jap. Name: Yamaguchi-tani-inuwarabi.

Distribution: Yamaguchi Pref., Yamaguchi-shi, Tengebata. The tetraploid "*A. oblitescens*" reported from Tottori Pref. by Kurihara *et al.* (1996) was probably this species.

Chromosome number: $2n = 160$ (Kurihara *et al.*, 1996), tetraploid.

In the populations of *Athyrium wardii*, a widely distributed species throughout the mainlands of Japan (Honshu to Kyushu), an infraspecific taxon "var. *inadae*" was occasionally recognized by its distinct terminal pinna and somewhat overlapping pinnules. This morphological form is worth recognition, but more suitably at the forma rank than at the varietal rank. In addition, the fact that its chloroplast *rbcL* sequence completely matched one of the sequences of *A. wardii* (Adjie *et al.*, 2008; Ebihara, 2011) supported their close relationship.

***Athyrium wardii* (Hook.) Makino f. *inadae* (Tagawa) Ebihara, stat. nov.**

—*Athyrium wardii* (Hook.) Makino var. *inadae* Tagawa, Acta Phytotax. Geobot. 16: 178, 1956.

Typus: JAPAN. Hyogo Pref., Siso-gun, Mikawa-mura, Mt. Hunakosi (*M. Tagawa 6309*, Aug. 20, 1954, holo-KYO).

Jap. Name: Ruridera-inuwarabi.

Distribution: W. Honshu, Shikoku and Kyushu. Sporadically occurs in the distribution range of *A. wardii*.

Chromosome number: unknown.

2. Sexually reproducing diploid lineages of *Cyrtomium falcatum* (Dryopteridaceae)

Matsumoto (2003) clarified that "Japanese holly fern" *Cyrtomium falcatum* sensu lato comprises three cytotypes: sexual diploid (type A), apogamous triploid (type B) and sexual tetraploid (type C). The type material of *C. falcatum*

was collected by C. P. Thunberg in Nagasaki in 1775–1776, and two syntype sheets are deposited in the Thunberg herbarium of UPS (THUNB 24493 "*Polypodium falcatum* α " and 24494 "*Polypodium falcatum* β "; Ebihara *et al.*, 2015). We observed specimens on both sheets producing 32 or less spores per sporangium (Fig. 1), and this suggests all the type material corresponds to the apogamous lineage, i.e. type B. The results are partially inconsistent with Matsumoto's (2003) presumption that UPS THUNB 24494 should be assigned to the tetraploid sexual or type C on the basis of the gross morphology. Another syntype UPS THUNB 24493 consists of two fertile fronds showing typical morphological characters of the triploid apogamous (B) type and the left frond was depicted in tab. 36 of Flora

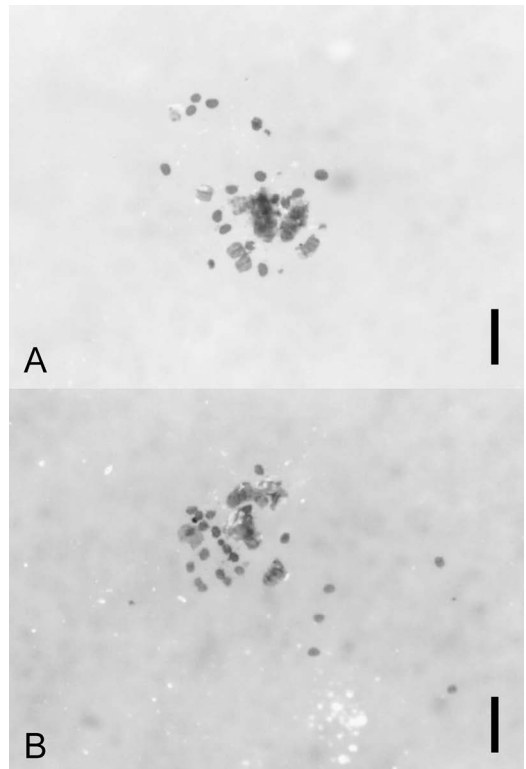


Fig. 1. Spores of the Thunberg's type material of *Polypodium falcatum*, probably not more than 32 spores per sporangium. A. The left frond of UPS THUNB 24493. B. UPS THUNB 24494. Scale bar = 200 μ m.

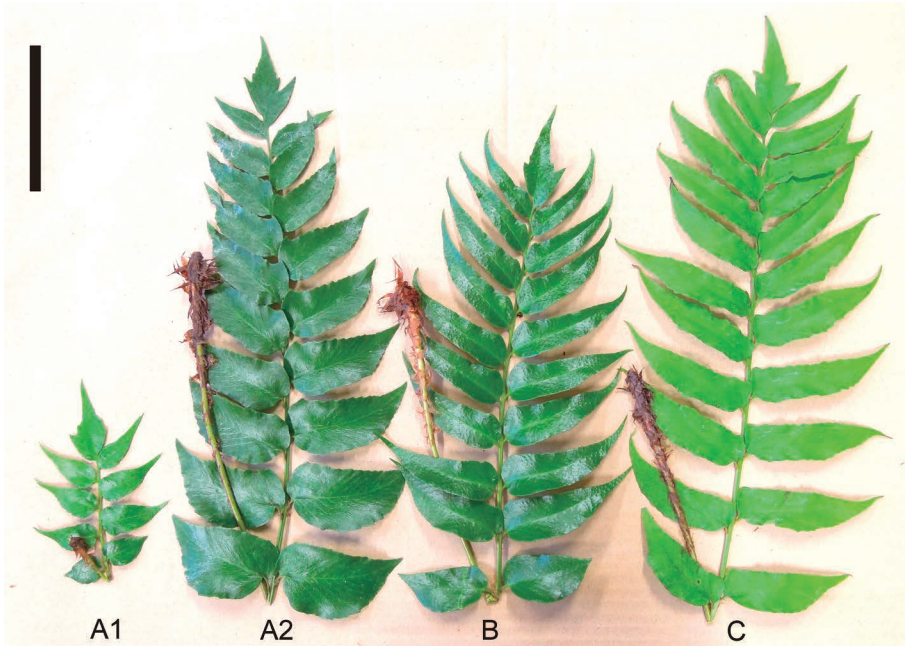


Fig. 2. Gross morphology of the four forms of *Cyrtomium falcatum* defined by Matsumoto (2003). Scale bar = 10 cm.

Japonica (Thunberg, 1784). It is, thus, suitable for the lectotype.

According to Matsumoto (2003), the sexual diploid can be subdivided into two forms (A1 and A2) based on their morphology, habitat preferences and mating systems. Although the two forms never grow sympatrically, artificial hybrids between them (including a hybrid between their type stocks) are almost completely fertile (Matsumoto, 2003). Thus, the two forms would better be recognized as infraspecific taxa—actually Matsumoto (2003) proposed their names at the subspecific rank, but they were not validly published due to lack of Latin diagnosis.

The sexual tetraploid (Type C) is an allopolyploid originated from a hybridization between *C. falcatum* and an unknown paternal parent species (Matsumoto, 2003; Ebihara and Matsumoto, unpublished), and should be treated as an independent species, *C. devexiscapulae* (Koidz.) Tagawa.

Cyrtomium falcatum* (L.f.) C.Presl subsp. *falca-

tum Tent. Pterid. 86, 1836.

—*Polypodium falcatum* L.f., Suppl. Pl. 446, 1781.

Jap. Name: Oni-yabusotetsu

Typus: JAPAN. “in Kosido montibus, prope Nagasaki” (*Thunberg s.n.*, 1775–1776, lecto-UPS [THUNB 24493], designate here).

Distribution: Japan (Honshu, Shikoku, Kyushu and Ryukyu; Fig. 5), Korea, S. China, Taiwan, and Indochina. Naturalized worldwide.

Habitat: grassland and forest edges in coastal areas. Occasionally occurs in dry artificial habitats in inland urban areas.

Reproductive mode: apogamous triploid producing 32 spores per sporangium with chromosome number ‘*n*’ = 123 (Mitui, 1968; Nakaike and Matsumoto, 1990).

Cyrtomium falcatum* (L.f.) C.Presl subsp. *littorale S.Matsumoto ex S.Matsumoto et Ebihara, **subsp. nov.** (Figs. 2, 3)

—*C. falcatum* (L.f.) C.Presl subsp. *littorale* S.Matsumoto, nom. nud., Ann. Tsukuba Bot.



Fig. 3. Holotype of *Cyrtomium falcatum* subsp. *littorale*.

Gard. 22: 70, 2003.

Jap. Name: Hime-oni-yabusotetsu

Differs from *Cyrtomium falcatum* subsp. *falcatum* in producing 64 spores per sporangium

and smaller lamina of fronds that are hard-coriaceous and more or less fleshy.

Typus: JAPAN. Shizuoka Pref., Shimoda-shi, Tsumeki-saki (*S. Matsumoto* 730527-15, origi-



Fig. 4. Holotype of *Cyrtomium falcatum* subsp. *australe*.

nally collected on May 27, 1973, specimen collected from a cultivated stock in Tsukuba Botanical Garden on Apr. 21, 1981, holo-TNS [VS-9507781]).

An evergreen fern. Rhizome erect or ascending. Fronds monomorphic. Stipes pale green, (2-)6-14(-26) cm long, bearing yellowish brown scales, densely at base, sparsely at upper portion,

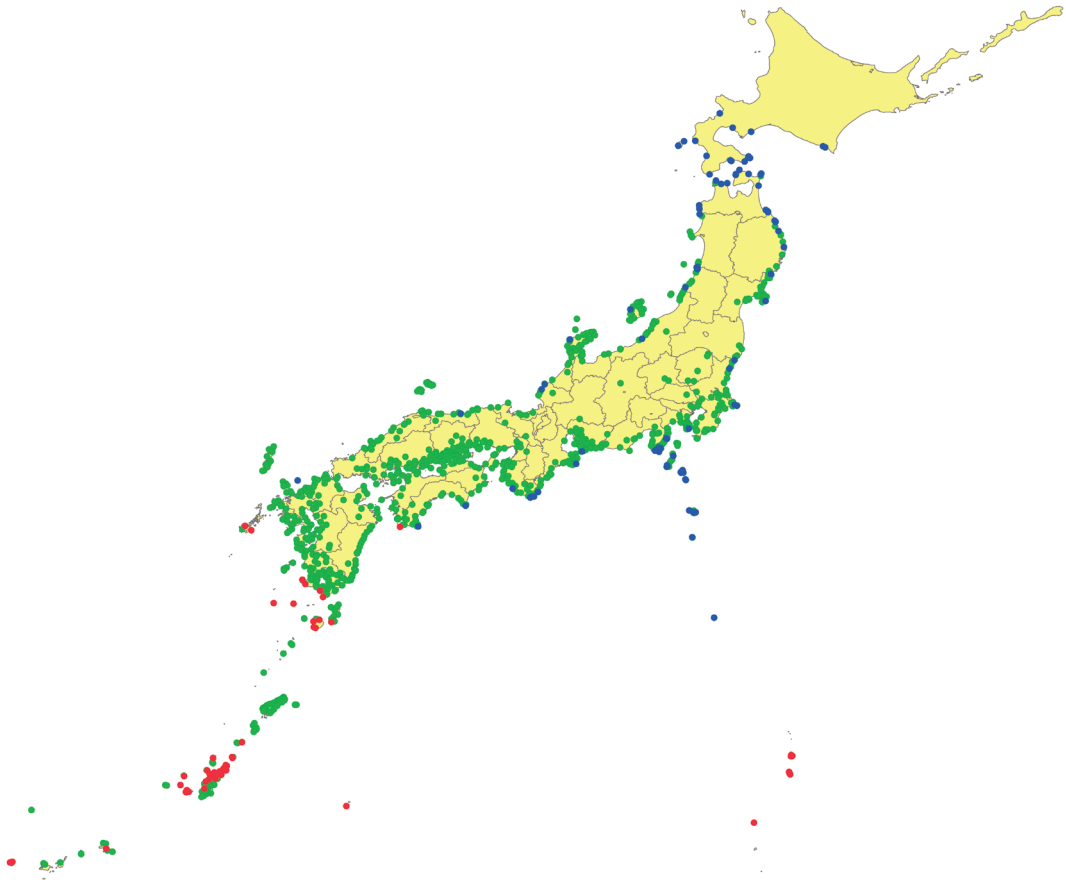


Fig. 5. A distribution map of three subspecies of *Cyrtomium falcatum* in Japan. Green: subsp. *falcatum*; blue: subsp. *littorale*; red: subsp. *australe*.

almost glabrous. Scales of the stipe base ovate-lanceolate, (8–)11–13(–15) mm long, apex more or less caudate, margin irregularly toothed. Lamina hard-coriaceous, upper-side shiny dark-green, 1-pinnate, broad oblong-lanceolate in outline, (8–)11–17(–24) × (7–)9–13(–16) cm, terminal pinna present, lateral pinna (3–)4–6(–8) pairs, ovate to narrowly ovate, lowest one (2.4–)3.5–6.0(–9.3) × (1.3–)2.3–3.3(–4.2) cm, short-stalked, margin entire to undulate. Sori scattered on lower surface excepting around midribs of pinna base, circular, indusiate. Indusia circular, peltate, ash-whitish, almost entire, (0.9–)1.0–1.2(–1.3) mm in diameter.

Distribution: Japan (S. Hokkaido, Honshu [Tottori Pref. eastward], Shikoku [Kochi Pref.] and Kyushu [Oronoshima Isl., Fukuoka-shi,

Fukuoka Pref.] (Fig. 5).

Habitat: On sea cliffs or in sea caves exposed to splash.

Reproductive mode: sexual diploid producing 64 spores per sporangium with chromosome number $n=41$ (Mitui, 1980 as *C. falcatum*; Matsumoto, 2003), usually reproducing by intra-gametophytic selfing (Matsumoto, 2003).

***Cyrtomium falcatum* (L.f.) C.Presl subsp. australe** S.Matsumoto ex S.Matsumoto et Ebihara, **subsp. nov.** (Figs. 2, 4)

—*C. falcatum* (L.f.) C.Presl subsp. *australe* S.Matsumoto, nom. nud., Ann. Tsukuba Bot. Gard. 22: 70, 2003.

Jap. Name: Munin-oni-yabusotetsu

Differs from *Cyrtomium falcatum* subsp. *fal-*

catum in producing 64 spores per sporangium and thinner lamina of fronds.

Typus: JAPAN. Tokyo Pref, Bonin Islands., Ogasawara-mura, Isl. Chichijima, northern part of Mt. Mikazuki-yama, alt. 74 m (*R. Hirayama s.n.*, originally collected on Jan. 29, 1981, specimen collected from a cultivated stock in Tsukuba Botanical Garden (stock No. 13613) on May 14, 1988, holo-TNS [VS-1268928]).

An evergreen fern. Rhizome erect or ascending. Fronds monomorphic. Stipes pale green, (13–)19–29(–36) cm long, bearing yellowish brown scales, densely at base, sparsely at upper portion, almost glabrous. Scales of the stipe base ovate-lanceolate, (13–)16–20(–22) mm long, apex more or less caudate, margin irregularly toothed. Lamina soft-coriaceous, upper-side shiny dark-green, 1-pinnate, oblong-lanceolate to broad oblong-lanceolate in outline, (15–)30–42(–50) × (11–)14–18(–23) cm, terminal pinna present, lateral pinna (6–)9–12(–17) pairs, deltoid-ovate to narrowly deltoid-ovate, lowest one (5.6–)7.0–9.5(–11) × (2.9–)3.4–4.4(–5.4) cm, short-stalked, margin entire to undulate. Sori scattered on lower surface, often absent in lower pinna and in basal part of lateral pinna, circular, indusiate. Indusia circular, peltate, usually blackish with ash-whitish margin, occasionally ash-whitish in whole, almost entire, (0.9–)1.1–1.3(–1.5) mm in diameter. Diploid, sexually reproducing with 64 spores per sporangium.

Distribution: Japan (Bonin Islands, Shikoku [Okinoshima Isl., Sukumo-shi, Kochi Pref.], Kyushu [Nagasaki Pref. and Kagoshima Pref.], Ryukyu [throughout, excluding Amami-oshima Isl., Ishigaki Isl. and Iriomote Isl.; Fig. 5) and Taiwan (Lanyu Isl.).

Habitat: Dry forest floors.

Reproductive mode: sexual diploid producing 64 spores per sporangium with chromosome number $n = 41$ (Mitui, 1973 as *C. falcatum*; Matsumoto, 2003), usually reproducing by intergametophytic crossing (Matsumoto, 2003).

Acknowledgments

The authors thank the curators of UPS for the permission of spore observation, T. Oka for providing information on *Athyrium* species. This study was supported by JSPS KAKENHI (Grant Nos. 24770083 and 15K07204 to AE) and JSPS-Vinnova Bilateral Joint Research Project (2013–2015).

References

- Adjie, B., Takamiya, M., Ohta, M., Ohsawa, T. A. and Watano, Y. 2008. Molecular phylogeny of the lady fern genus *Athyrium* in Japan, based on chloroplast *rbcL* and *trnL-trnF* sequences. *Acta Phytotaxonomica et Geobotanica* 59: 79–95.
- Ebihara, A. 2011. *rbcL* phylogeny of Japanese pteridophyte flora and implications on infrafamilial systematics. *Bulletin of the National Museum of Nature and Science, Series B* 37: 63–74.
- Ebihara, A., Ekman, S., Hjertson, M., Myrdal, M. and Jinbo, U. 2015 onwards. *Thunberg's Japanese Plants*, <http://www.thunberg.uu.se>
- Japanese Ministry of Environment 2015. *Red Data Book 2014. 8. Plants 1 (Vascular Plants)*.
- Kurata, S. 1969. Notes on Japanese ferns (46). *Journal of Geobotany* 17: 2–5.
- Kurihara, T., Watano, Y., Takamiya, M. and Shimizu, T. 1996. Electrophoretic and cytological evidence for genetic heterogeneity and the hybrid origin of *Athyrium oblitescens*. *Journal of Plant Research* 109: 29–36.
- Matsumoto, S. 2003. Species ecological study on reproductive systems and speciation of *Cyrtomium falcatum* complex (Dryopteridaceae) in Japanese Archipelago. *Annals of the Tsukuba Botanical Garden* 22: 1–141.
- Mitui, K. 1968. Chromosomes and speciation in fern. *Science Report of Tokyo Kyoiku Daigaku, Section B* 13: 285–333.
- Mitui, K. 1973. A cytological survey on the pteridophytes of the Bonin Islands. *Journal of Japanese Botany* 48: 247–254.
- Mitui, K. 1980. Chromosome numbers of Japanese pteridophytes (2). *Bulletin of Nippon Dental University, General Education* 9: 217–229.
- Nakaike, T. and Matsumoto, S. 1990. A note on the reproductive type, distribution, habit, and character variation of *Cyrtomium falcatum* (Dryopteridaceae) in Amami-Oshima Isl., Japan. *Memoirs of the National Science Museum* 23: 33–41 (in Japanese with English summary).
- Thunberg, C. P. 1784. *Flora Japonica* In bibliopolio I.G. Mülleriano, Lipsiae.