OPEN ACCESS Plant Protection, 10 (02) 2026. 215-223 DOI:10.33804/pp.010.02.6009

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Available Online at EScience Press

Plant Protection

ISSN: 2617-1287 (Online), 2617-1279 (Print)

http://esciencepress.net/journals/PP

Research Article

# Taxonomic Revision of the Threatened Fern Genus *Cyrtomium* C. Presl from the Hazara Division, Khyber Pakhtunkhwa, Pakistan

**[a]Aurangzeb Abbasi, [a]Jan Alam, [a]Alia Gul, [b]Christopher Roy Fraser-Jenkins, [a]Sajida, [a]Ghulam Mujtaba Shah**

[a] *Department of Botany, Hazara University, Mansehra, Khyber Pakhtunkhwa, Pakistan.*

[b] *Rua de São Mateus, 485 S/C Dt., Fontainhas 2750-141, Cascais, Portugal.*

**ARTICLE INFO**

***Article history***

*Received: 24th November, 2025*

*Revised: 8th March, 2026*

*Accepted: 11th March, 2026*

***Keywords***

*Cyrtomium*

*Fern taxonomy*

*Biodiversity assessment*

*Morphological characterization*

*Conservation of threatened species*

**ABSTRACT**

The fern genus *Cyrtomium* C. Presl (Dryopteridaceae) represents an important component of forest understory vegetation in temperate and subtropical regions. However, information regarding its diversity, distribution, and taxonomic status in northern Pakistan remains limited. The present study aimed to conduct a taxonomic revision of *Cyrtomium* species occurring in the Hazara division of Khyber Pakhtunkhwa, Pakistan, in order to clarify their morphological characteristics, distribution patterns, and conservation status. Extensive field surveys were conducted across 38 localities in the study area, and collected specimens were examined using standard taxonomic and morphological approaches. Diagnostic characters such as rhizome scales, frond morphology, pinna structure, venation patterns, and reproductive features including sori, sporangia, and spores were carefully analyzed to delimit species. The study documented three species of *Cyrtomium*: *C. macrophyllum*, *C. caryotideum*, and *C. anomophyllum*. These species were recorded from only eight localities (21%) of the surveyed sites, indicating that the genus is sparsely distributed in the region. The species were mainly associated with cool, moist, and shaded habitats within the herbaceous layer of foothill forests, often growing on rocky substrates and near water sources. Comparative measurements of sori, sporangia, and spores, along with diagnostic morphological features, facilitated reliable species identification. A taxonomic key and detailed descriptions were prepared to assist in accurate identification of the species. Furthermore, *C. falcatum*, previously reported from the region, was excluded from the native flora based on recent taxonomic clarification. The results indicate that *Cyrtomium* species in Hazara division are rare and threatened by habitat loss, highlighting the need for conservation.

*Corresponding Author: Jan Alam; Alia Gul*

*Email: janalam@hu.edu.pk; aliagulbotanist@gmail.com*

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## Introduction

*Cyrtomium* C. Presl is a genus of leptosporangiate, temperate ferns comprising approximately 40 species worldwide (Lu et al., 2006). Members of this genus are commonly referred to as **Asiatic holy ferns** (Jogan et al., 2022). The genus exhibits considerable morphological and cytological variation among species, largely attributed to mechanisms such as apomixis and polyploidy, which play significant roles in the evolutionary diversification of the group (Lu et al., 2006). Species of *Cyrtomium* are

characterized by several distinctive morphological features that differentiate them from other genera within the family. These include an imparipinnate lamina bearing lobate, furcate, or pinnatifid pinnae with a single terminal pinna, and a typically once-pinnate frond architecture. The venation pattern is anastomosing, usually forming two to three rows of areoles with free included veinlets. The sori are relatively large, rounded, and irregularly distributed on the abaxial surface of the pinnae, and are covered by characteristic peltate indusia. These diagnostic morphological traits provide important taxonomic markers for species identification within the genus. Comprehensive taxonomic investigations of *Cyrtomium* were first conducted by Ching et al. (1936), which laid the foundation for subsequent systematic studies and revisions of the genus (Li et al., 2017).

The genus *Cyrtomium* comprises approximately 35-40 species and is predominantly distributed in East Asia. Its primary center of diversity lies in China, India, and neighboring regions, although its range extends to East Africa, southern Japan, parts of Europe, and North America (Kung, 2001; Zhang and Barrington, 2013). According to Lu et al. (2006), nearly 40 species have been recognized globally, of which around 30 species occur in China, highlighting the region as the principal center of speciation and diversity for the genus.

In Pakistan, the occurrence of *Cyrtomium* species has been documented gradually through botanical explorations and taxonomic studies. Initially, only one species, *Cyrtomium caryotideum* (Wall. ex-Hook. & Grev.) C. Presl, was reported from Nathia Gali in the Hazara Division by Nasir and Ali, as cited in Stewart (1972), *An Annotated Catalogue of the Vascular Plants of Pakistan*. Subsequently, another species, *C. macrophyllum* (Makino) Tagawa was recorded for Pakistan by Nakaike and Malik (1993. Later floristic accounts expanded the known diversity of the genus in the region; Gul et al. (2016a, b, c) listed three species for Pakistan, including Kashmir, namely *C. caryotideum* (Wall. ex Hook. & Grev.) C. Presl, *C. falcatum* (L. f.) C. Presl, and *C. macrophyllum* (Makino) Tagawa. More recently, an additional species, *C. anomophyllum* (Zenker) Fraser-Jenkins, was reported for Pakistan, while the presence of the previously recorded species *C. caryotideum* and *C. macrophyllum* was reconfirmed (Fraser-Jenkins, 2013, 2014; Irfan et al., 2022).

In the present study, an attempt has been made to provide a detailed taxonomic account of three known *Cyrtomium* species occurring in the Hazara Division. This work is based on extensive field surveys, careful examination of morphological characteristics, and comprehensive documentation of specimens collected from the study area. The findings contribute to a clearer understanding of the taxonomy, distribution, and morphological variability of *Cyrtomium* species in this ecologically significant region of Pakistan. The classification system proposed by PPG I (2016) was followed in the present study.

## Material and Methods

### Field sampling and morphological study

The field study was conducted during the fertile seasons over three consecutive years (2020-2022), spanning from the pre-summer months of April-May to the onset of winter (October-November). Specimens of the genus were collected from more than 30 localities across the Hazara division, Khyber Pakhtunkhwa (KP), Pakistan. All districts of the division were extensively surveyed, and samples were collected along the rhizome-bearing habitats. Each collected specimen was assigned a separate voucher number.

Important taxonomic, ecological, and geographical attributes were recorded in the field. Photographs documenting the habit and habitat of the plants were taken, and geographic coordinates of each sampling site were recorded. The collected specimens were properly pressed using a plant presser with blotting papers, dried at room temperature, mounted, and labeled on standard-sized herbarium sheets (17.5 × 11.5 inches) with detailed descriptive labels.

Mounted voucher specimens were identified using several important literature sources, published papers, including Nakaike and Malik (1992a; 1993a, b), Khullar (1994a, b), Fraser-Jenkins et al., 2013, 2023), and Khullar (2024). Regional literature (Gul et al., 2016a, b, c, 2017, Ullah 2022; Tariq et al., 2024a, b) and authentic recent published Floras of the world were consulted including the Pteridophytes Flora of China, (Zhang and Barrington et al., 2013) and the Pteridophyte Flora of North America (1993), were also consulted for accurate identification.

A stereomicroscope was used for the examination of superficial microcharacters such as integuments, trichomes, hairs, cilia, microscales, venation patterns, areolation, and margin serrations at the segment level. Furthermore, sori, sporangia, and indusia were examined under the stereomicroscope. A compound microscope was used for detailed micro characterization of sporangia, indusia, microscales, and spore morphology.

Mature spores were collected, cleaned with bleach, rinsed thoroughly with distilled water, and examined under a compound microscope to evaluate their morphology, shape, sculpturing, and surface ornamentation. Micrometric techniques were applied to measure spore size following the procedures described by Li et al. (2017) and Roux (2011).

Specimens housed at the National Herbarium, National Agricultural Research Center (NARC), Islamabad; the Herbarium of the Pakistan Museum of Natural History (PMNH), Islamabad; and the Herbarium of Quaid-i-Azam University, Islamabad, were also examined for comparative analysis.

**Conservation assessment**

Conservation assessment of the genus *Cyrtomium* was carried out using plant abundance criteria to evaluate its conservation status. According to this criterion, plant species were categorized into different abundance classes based on their frequency across surveyed localities: widespread (present in > 90% of localities), very common (71-90%), common (51-70%), frequent (31-50%), rare (20-30%), and extremely rare (< 10%) (Gul et al., 2017).

The criteria for threat assessment of the species are presented in Table 1. The rarity of the species was explained and determined for the genus *Cyrtomium* according to the six rarity conditions provided. The rarity of these ferns has also been described by other workers, including Fraser-Jenkins (2012), whose work remained helpful in assessing the rarity of the *Cyrtomium* genus in the Hazara division.

Table 1. Criteria for abundance classification.

| Sr. No. | Abundance class | Classification criteria |
|---|---|---|
| 1 | Wide spread (WS) | Above 90 % |
| 2 | Very common (VC) | 71-90 % |
| 3 | Common (CM) | 51-70 % |
| 4 | Frequent (FQ) | 31-50 % |
| 5 | Rare (R) | 20 -30 % |
| 6 | Extremly rare (ER) | Less than 10 % |

**Results and Discussion**

The present study recorded three species of *Cyrtomium* in the Hazara division. Although the Hazara Division is characterized by rich biodiversity, the genus *Cyrtomium* is sparsely distributed in the region. It is mainly found in the herbaceous layer of forests at the foothills, particularly in cool, moist, and shaded habitats. The loss of forest habitats due to anthropogenic activities poses a major threat to this genus, highlighting the need for its conservation and propagation. In the present study, the genus *Cyrtomium* is considered rare because it was recorded from only eight localities (21%) out of the total 38 surveyed sites in the study area.

**Description of *Cyrtomium***

Plants evergreen, terrestrial, and perennial. Rhizome erect, short, and stout, continuous with the stipe, densely covered with scales; scales concolorous, dark brown to blackish-brown, ovate to lanceolate, with margins toothed, ciliate, or entire, and with an acuminate to acute apex. Fronds caespitose, 2-8 arising from a common rhizome, monomorphic. Stipe sulcate, canaliculate, stramineous, and scaly; scales on the proximal part similar to those on the rhizome but smaller and sparser toward the distal part of the stipe. Lamina deltoid-ovate, lanceolate, or linear-lanceolate, imparipinnate. Rachis sulcate, scaly, without proliferous bulbils. Pinnae lanceolate to ovate-lanceolate, opposite or alternate, ascending to ascendant, falcate; margins entire to subentire, serrulate or dentate; apex acute to acuminate. Bases acroscopically auriculate, auricles prominent, distinct or sometimes indistinct, occasionally exauriculate; basiscopically rounded to cuneate. Apical pinna conform but larger, rarely rhombic-ovate, sometimes bisected or bi-trifurcate. Texture leathery, papery, or thinly papery; adaxially glabrous. Venation reticulate, forming 2-8 rows of polygonal, oblique areoles with free veinlets. Sori orbicular, terminal on veinlets, irregularly distributed on the abaxial surface. Indusiate; indusia peltate, usually smaller than the sori (rarely larger and covering the entire soral surface), typically attached near the center of the sori.

The diagnostic key to species and other attributes are provided below:

1 + Pinnae with small, blunt shoulder-like auricle or ex-auriculate……..2

- Pinnae with large, prominent auricle……..2. *C. caryotideum*

2 + Pinna-margins rarely with few teeth or entire; indusia margin fine dentate,

Without dark spot in its center……1. *C. macrophyllum*

- Pinna-margins with teeth, more prominent in the apical half of the pinna; indusia circular, with dark spot in its center; margin entire……..3. *C. anomophyllum*

***Cyrtomium macrophyllum* (Makino) Tagawa, Acta Phytotaxonomica et Geobotanica 3(2): 62. 1934.**

**Synonyms**

*Aspidium falcatum* Sw. var. *macrophyllum* Makino; *Cyrtomium falcatum* (L.) C. Presl var. *macrophyllum* (Diels) Christ; *C. muticum* (Christ) Ching, non sensu Fraser-Jenkins; *Polystichum falcatum* var. *macrophyllum* (Makino) Makino.

**Description**

Fronds 30-70 cm tall. Rhizome erect, covered with ovate to lanceolate, blackish-brown scales. Stipe 20-36 cm long, 2-3 mm in diameter; proximal portion densely covered with ovate-lanceolate, blackish-brown, denticulate scales; apex slightly twisted. Lamina lanceolate to oblong-ovate, 28-60 × 14-25 cm, once pinnate, imparipinnate; base not contracted, rather slightly broader; rachis scaly with small linear-lanceolate scales.

Pinnae 5-8 pairs, shortly stalked, alternate, slightly ascending, oblong-lanceolate to narrowly ovate; margins sparsely serrulate or entire; middle pinnae about 10 × 4 cm; base rounded to cuneate; apex caudate or acuminate. Terminal pinna rhombic-ovate, trifurcate or forked, 7-15 × 4-5 cm, papery in texture; surface adaxially glabrous, abaxially sometimes bearing sparse brown lanceolate microscales.

Venation pinnate, indistinct on the adaxial surface and slightly visible abaxially; costa prominent; veinlets anastomosing to form multiple rows of areoles. Sori 0.2-0.3 mm in diameter (Table 2), rounded, distributed over the entire surface of the pinnae. Indusia small, centrally attached within the sori margins finely dentate. Spores oval to rounded, sculptured with ridges on the surface, approximately 15 × 12 µm.

Table 2. Comparative size of sori, sporangia, and spores.

| Sr. No. | Name of Species | Sorus size | Sporangium size | Spore size |
|---|---|---|---|---|
| 1 | *Cyrtomium macrophyllum* (Makino) Tagawa | 0.8 – 1 mm | 90 -112 µm | 15x12 µm |
| 2 | *Cyrtomium caryotideum* (Wall. ex-Hook. & Greville) C. | 0.3 -0.5 mm | 75 – 90 µm | 16x12 µm |
| 3 | *Cyrtomium anomophyllum* (Zenker) Fraser-Jenk | 0..2 -0.5 mm | 80 – 90 µm | 16x14 µm |

**Habitat**

Shady, cool, and moist rocky places in deciduous forests.

**Altitude**

1000-1300 m a.s.l.

**Specimens examined**

Pakistan, Khyber Pakhtunkhwa: Abbottabad district, Kharperh Sherwan, 1000 m, rocky moist shady habitat, 20 Aug 2020, Isra Khan 45 (HUP); Abbottabad, Kumharan, 1300 m, shady moist nullah, 15 Sept 2020, Isra Khan 131 (HUP). Mansehra District, Jabori, 1800 m, moist shady blue pine forest, 7 Jan 2014, Alia Gul 250 (HUP); Mansehra, Manda Gusha, 1800 m, shady wet forest floor, 4 Jan 2014, Alia Gul 716 (HUP); Mansehra, Jabori, 1800 m, moist shady blue pine forest, 31 Oct 2015, Alia Gul 1023 (HUP); Abbottabad, Qalader Abad, 1000 m, shady moist forest floor, 15 Aug 2015, Alia Gul 806 (HUP).

**Notes**

*C. macrophyllum* is characterized by relatively large fronds bearing fewer pinnae (5-8 pairs) and by the absence or weak development of an auricle at the acroscopic base of the pinnae. The lamina texture ranges from leathery to papery. In the study area, this species was found to be comparatively more frequent than other species of the genus.

*C. macrophyllum* closely resembles *C. anomophyllum*, particularly in having fewer pinnae and a broad, rounded pinna base. However, it can be distinguished by the absence of prominent teeth along the pinna margins and by its glossier lamina surface (Khullar, 2024).

**Distribution**

Native to China (Chongqing, Guizhou, Hunan, Sichuan, Taiwan, and Yunnan) and Japan. In Pakistan, this species occurs in the lower hilly areas of the Hazara division at elevations of 1000-1300 m above sea level, usually on northern slopes.

***Cyrtomium caryotideum* (Wall. ex Hook. & Grev.) C. Presl, Tent. Pterid. 86. 1836 (Figure 1)**

**Synonyms**

*Aspidium caryotideum* Wall. ex Hook. & Grev.; *A. falcatum* var. *caryotideum* (Wall. ex Hook. & Grev.) Baker; *C. falcatum* var. *caryotideum* (Wall. ex Hook. & Grev.) Baker; *Polystichum caryotideum* (Wall. ex Hook. & Grev.) Diels; *C. caryotideum* var. *intermedium* (Diels) C. Chr.; *P. falcatum* var. *caryotideum* (Wall. ex Hook. & Grev.) Makino ex Matsu.

**Description**

Fronds 45-90 cm long. Rhizome erect, covered with blackish-brown lanceolate scales. Stipe 20-31 cm long, 2-5 mm in diameter; base densely scaly; scales brown, similar

to those of the rhizome, with a central blackish stripe, ovate-lanceolate with ciliate margins. Lamina lanceolate-oblong, 25-60 × 19-20 cm, base slightly contracted or not; unipinnate, imparipinnate; rachis bearing sparse brown linear scales.

Pinnae 3-7 pairs, opposite to alternate, shortly stalked, slightly ascending, falcate, deltoid-lanceolate, 10-16 × 3-7 cm; base broadly cuneate; acroscopic margins auriculate, auricle long and acute; apex acuminate or caudate; margins serrulate, occasionally dentate. Terminal pinna trifurcate, rhombic-ovate, 13-16 × 8-10 cm. Texture coriaceous to chartaceous; brown microscales present abaxially, adaxial surface glabrous.

Venation anastomosing, forming multiple rows of areoles on both sides of the midrib; in the proximal row each areole with a single free veinlet, whereas in other rows each areole contains 2-3 free veinlets Indusia white to light brown, with toothed margins. Spores oval, sculptured with surface ridges, 16.4 × 12 µm.

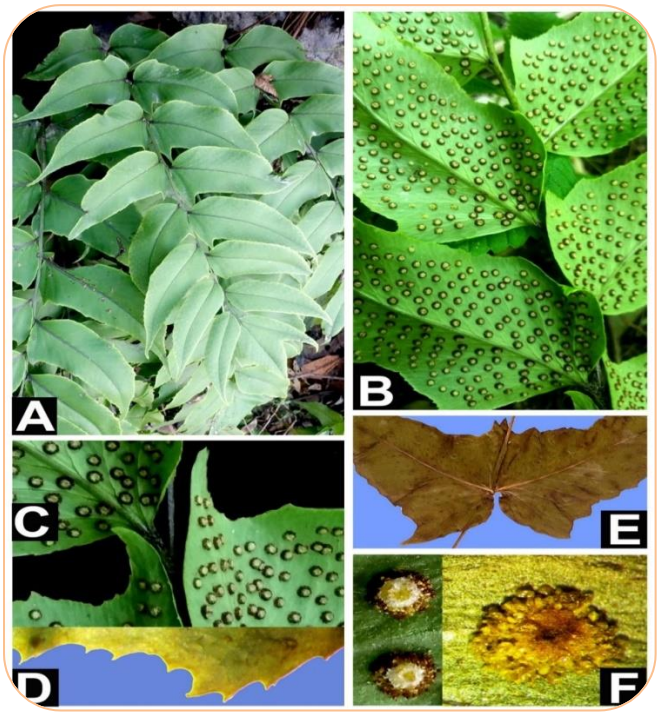



Figure 1. *C. caryotideum*: (A) Habit, (B) Sori on abaxial surface, (C) Auricle, (D) Dentate pinna margins, (E) Basal cuneate pinnae, (F) Sori.

**Habitat**

Occurs in cool, shady, and moist habitats, particularly near running water, springs, or wetlands.

**Altitude**

1100-1800 m.

**Specimens examined**

**Pakistan: District Abbottabad**

Raskhola-Dalola, 1561 m, cool shady moist place with running water, 8 Jul 2020, Aurangzeb Abbasi 255b (HUP); Raskhola-Dalola, 1570 m, cool shady moist habitat with flowing water, 8 Jul 2020, Aurangzeb Abbasi 255a (HUP); Chamhati-Sherwan, 1500 m, shady moist sandy soil, 15 Sep 2020, Isra Khan 123 (HUP); Jalmaly, 1270 m, shady moist northern slope, 16 Aug 2020, Isra Khan 10 (HUP); Kamila-Sherwan, 1700 m, shady moist cleft under deciduous forest, 2 Sep 2020, Isra Khan 121 (HUP); Sherwan, 1200 m, shady wetland with broad-leaved flora, 16 Aug 2020, Isra Khan 3 (HUP); Kharperh-Sherwan, 1100 m, shady cleft near a flowing tributary, 16 Aug 2020, Isra Khan 40 (HUP); Thall-Sherwan, 1300 m, shady moist habitat, 16 Aug 2020, Isra Khan 22 (HUP); Kharperh-Sherwan, 1000 m, shady cleft near flowing tributary, 20 Aug 2020, Isra Khan 41 (HUP); Kalar–Khaitar, 1800 m, cool shady moist habitat, 20 Sep 2020, Isra Khan 144 (HUP).

**District Mansehra**

Jabori, 1800 m, shady moist area near waterfall retaining wall, 7 Oct 2013, Alia Gul 251 (HUP).

**Distribution**

Widely distributed in China (Sichuan, Taiwan, Yunnan), Bhutan, India, Pakistan, Japan, Nepal, Philippines, and Vietnam. In Pakistan, this species occurs at elevations of 1100-1800 m in the hilly regions of the Hazara division, including Abbottabad, Thandiani, Nathiagali, Sherwan, and Battagram. Depending on habitat conditions, soil type, slope, altitude, and associated vegetation, the species exhibits variation in frond size, auricle development, and the distribution of sori on the abaxial surface of the pinnae. It appears to be relatively common within the study area.

**Diagnostic characters**

The species is characterized by the acroscopic base of the pinna with a long, acute auricle, serrulate to dentate margins, white indusia with toothed margins, and anastomosing venation in which the first row of areoles contains a single free veinlet.

***Cyrtomium anomophyllum* (Zenker) Fraser-Jenk., Taxon Revis. Three Hundred Indian Subcont. Pterid., 330 (2008) (Figures 2, 3).**

**Synonyms**

*Aspidium anomophyllum* Zenker, 1835; *Cyrtomium beddomei* S.R. Ghosh; *C. caryotideum* (Wall. ex Hook. & Grev.) C. Presl var. *anomophyllum* (Zenker) T. Moore; *C. microindusium* Sa. Kurata; *C. nervosum* Ching & K.H. Shing; *Polystichum nervosum* (Ching & K.H. Shing) C.M. Kuo.

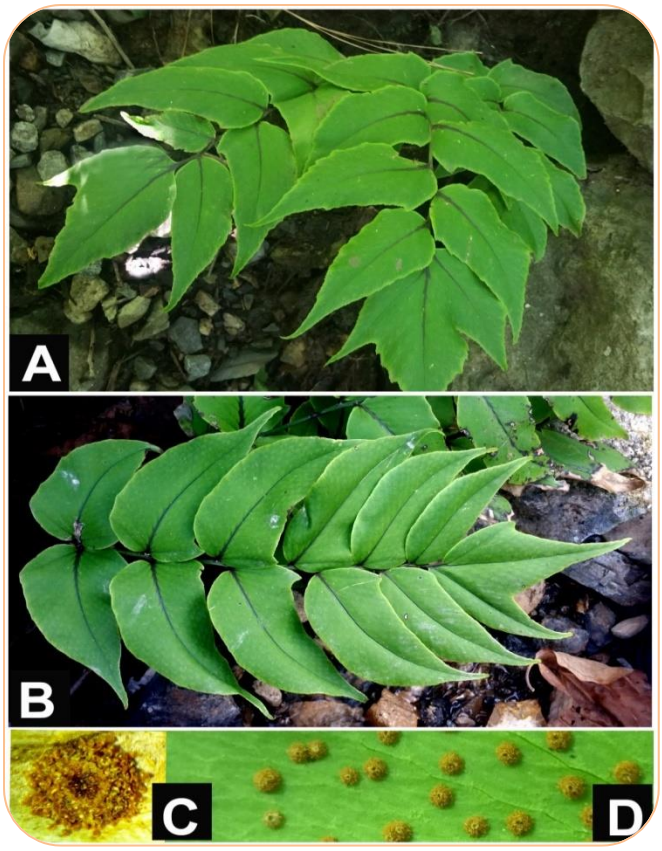



Figure 2. *C. anomophyllum*: A: Habitat, B: Habit, C: Sorus, D: Sori.

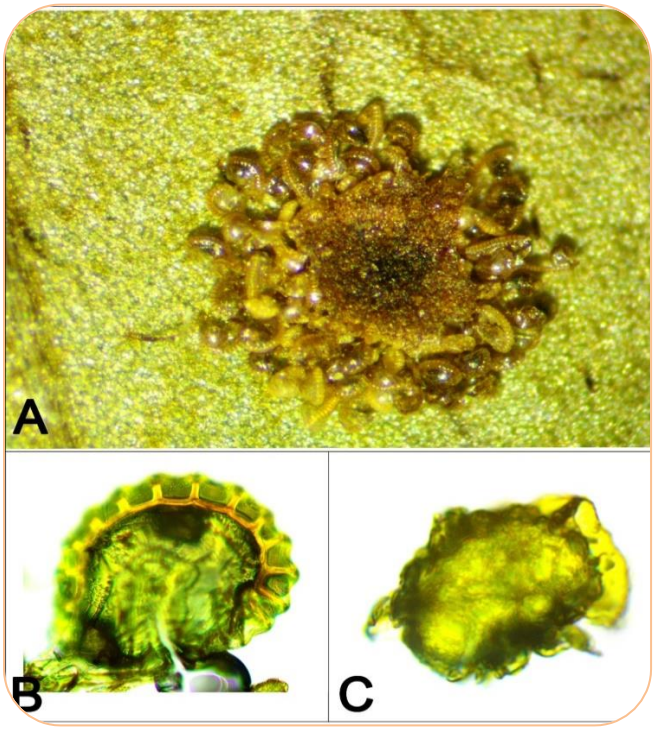



Figure 3. *C. anomophyllum*: (A) Sorus, (B) Sporangium, (C) Spore.

**Description**

Fronds 20-75 cm long. Rhizome short, erect, covered with brown scales. Stipe 10-36 cm long, stramineous, the base covered with ovate to lanceolate brown scales with toothed margins. Lamina lanceolate to oblong, 15-45 × 8-14 cm, 1-imparipinnate. Rachis covered with linear-lanceolate, curved brown scales, sometimes glabrous. Pinnae 3-6 pairs of lateral pinnae, opposite to alternate, shortly stalked, slightly ascending, oblong-lanceolate, 6-14 × 2.2-4.2 cm; basiscopic base rounded to cuneate; acroscopic base auriculate with a weakly developed, blunt or short semicircular auricle; margins serrulate; apex acuminate to caudate and curved upward. Terminal pinna trifurcate, obovate, 5-12 × 4-10 cm. Texture papery; surfaces glabrous on both sides. Venation pinnate; veins indistinct on the adaxial surface and slightly raised abaxially; veinlets anastomosing, forming multiple rows of areoles on both sides of the costae. Sori irregularly distributed on the abaxial surface. Indusia small, about one-fourth the size of the sori, with a black spot in the center and entire margins. The descriptions of sori are given in more details in Table 2.

**Distribution**

*C. anomophyllum* is thought to have originated in southwestern China and is widely distributed in the Sino-Himalayan and Sino-Japanese regions. Its native range includes the Indian subcontinent, China, Japan, Taiwan, India, and Pakistan.

**Specimens examined**

**Pakistan**

**Khyber Pakhtunkhwa**

Abbottabad district, Raskhola-Dalola, alt. 1551 m, cool, moist, and shady habitat with running water, 8 July 2020, Aurangzeb Abbasi 255 (HUP); Abbottabad, Raskhola-Dalola, alt. 1587 m, cool, moist, and shady habitat with running water, 31 Jan 2021, Aurangzeb Abbasi 388 (HUP); Abbottabad, Raskhola-Dalola, alt. 1525 m, cool, moist, and shady habitat with running water, 31 Jan 2021, Aurangzeb Abbasi 398 (HUP); Abbottabad, Kalar Khaitar, alt. 1800 m, cool, moist, shady habitat, 20 Sept 2020, Isra Khan 144 (HUP); Batagram district, Neelshung, alt. 1217 m, cool, moist, and shady habitat with running water, 16 Mar 2024, Aurangzeb Abbasi & Jan Alam 425 (HUP); ibid., alt. 1187 m, 16 Mar 2024, Aurangzeb Abbasi & Jan Alam 430 (HUP); ibid., alt. 1187 m, 16 Mar 2024, Aurangzeb Abbasi & Jan Alam 431 (HUP).

*C. anomophyllum* may represent a hybrid between *C. macrophyllum* and *C. caryotideum* and exhibits distinctive frond morphology. The margins of the pinnae are weakly toothed, serrulate, or sometimes entire. The basiscopic base is rounded, whereas the acroscopic base bears a blunt, obtuse, shoulder-like auricle that is smaller than that of *C. caryotideum*. The pinna apex is acuminate or caudate (Fraser-Jenkins, 2008). The important taxonomic features of the three species and the comparative analysis of auricles in *C. caryotideum*, *C. macrophyllum*, and *C. anomophyllum* are presented in Figure 4.

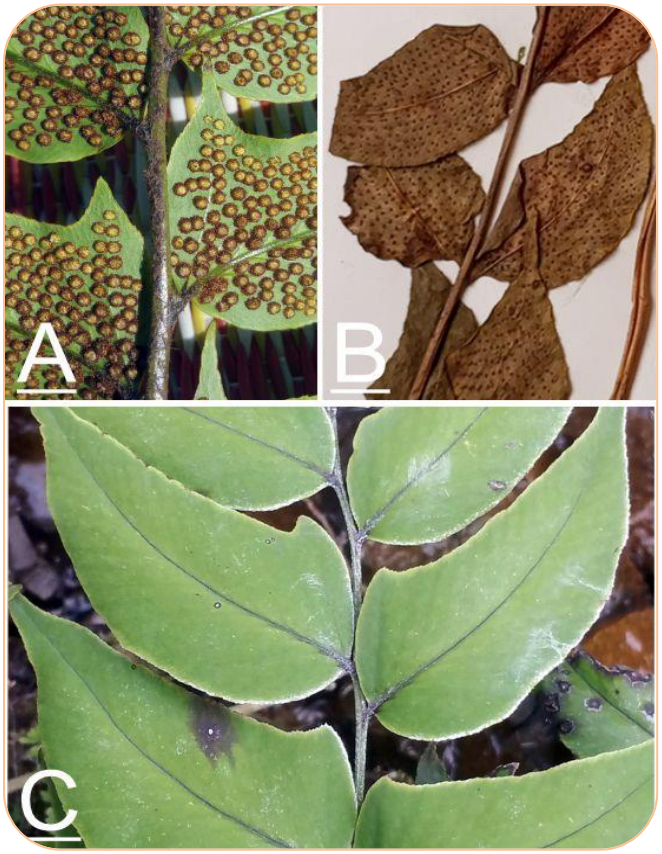



Figure 4. Comparative analysis of auricles in three *Cyrtomium* Species: (A) *C. caryotideum*, (B) *C. macrophyllum*, (C) *C. anomophyllum*.

**Excluded species**

*C. falcatum* (L.f.) C. Presl was previously reported from the Hazara division. However, according to Fraser-Jenkins (2023), this species is strictly a Sino-Japanese element distributed in the Far East. Earlier reports from the region are likely based on cultivated specimens. Therefore, it should not be considered a component of the native flora of the Hazara division and is excluded from the present treatment.

**Acknowledgements**

The authors acknowledge the financial support provided by the Higher Education Commission (HEC) of Pakistan through the National Research Program for Universities (NRPU-14667), which supported certain aspects of this study. Herbarium Hazara University Pakistan (HUP) provided access to the collected specimens housed at HUP. National Agricultural Research Center (NARC), Islamabad and the Herbarium of the Pakistan Museum of Natural History (PMNH) are acknowledged for reference material access and identification, Allelopathy and Biodiversity research Lab provided faciliatation of LM and required facilities whil CRL UOP is specially acknowledged for SEM facilitation.

**Authors' Contributions**

AA conducted the experimental work, collected and analyzed the data, and prepared the initial draft of the manuscript. JA supervised the entire project, developed the study design, and critically edited and revised the manuscript. AG co-supervised the study and supported certain aspects of the research through funded projects. S assisted in conducting the experimental and laboratory work. GMS provided necessary materials, facilitated field surveys, and supported various research activities. CRFJ reviewed the results for technical accuracy, contributed to the taxonomic revision, confirmed species identifications, and provided relevant literature also helped to exclude the irrelevant reports for the study area and the cultivated species during this study.

**Research Funding**

This research was supported by the Higher Education Commission (HEC) of Pakistan under the National Research Program for Universities (NRPU), Grant No. NRPU-14667.

**Conflict of Interest**

The authors declare no conflict of interest.

**Sustainable Development Goals Targeted**

SDG 4: Quality Education
SDG 13: Climate Action
SDG 15: Life on Land

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