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Notes on the lichen genus *Pyrenodesmia* (Teloschistaceae) on the dry slopes of the Binaloud Mountain, Northeastern Iran

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ABSTRACT

Aims: The genus *Pyrenodesmia* (Teloschistaceae) is a species-rich group of calcicolous crustose lichens with a Holarctic distribution, but its diversity in the calcareous montane habitats of northeastern Iran is poorly documented. This study aimed to identify *Pyrenodesmia* specimens from this region and to characterize their basic ecological setting.

Materials & Methods: We collected four specimens from seven thalli from calcareous rock on the southern slopes of Binaloud Mountain at 1600–2000 m above sea level. Identification was based on morphological and anatomical examination and standard spot tests, with confirmation by a Teloschistaceae specialist.

Findings: Three specimens were identified as *Pyrenodesmia transcaspica*, *P. microstepposa*, and *P. micromontana*; the fourth was tentatively identified as *P.* cf. *micromontana* and requires molecular data for confirmation. All specimens had diagnostic features of *Pyrenodesmia* sensu stricto: K−, C−, KC−, CK−, Thallus and Apothecia, and K+ purple (pale to dark) Epithecium, indicating the presence of Sedifolia-gray pigment and the absence of anthraquinones. These records are additional confirmed localities for the three species in Iran.

Conclusion: All specimens grew on calcareous rock; the substrates of *P. transcaspica* and *P. micromontana* agree with earlier reports, whereas *P. microstepposa*, previously also reported on siliceous rock, was recorded here on calcareous rock. Because we sampled few specimens and only one substrate type, these findings are preliminary, and broader sampling and molecular data are needed.

Keywords: Biodiversity; Calcicolous Lichens; Ecological Zones; Taxonomy.

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Introduction

Iran, situated at the crossroads of three major phytogeographical regions, Euro-Siberian, Irano-Turanian, and Saharo-Sindian, harbors a remarkably diverse lichen flora owing to its wide range of climatic conditions and geological substrates, with numerous microclimates (shaped by factors such as rock crevices and overhangs, substrate moisture, light exposure, slope aspect, and vegetation cover and the shade it casts) [1] and ecological niches occurring across the country, particularly along transitional and ecotone zones [2-4]. With a total land area of approximately 1,648,000 km^2, Iran encompasses a wide spectrum of ecological zones, ranging from arid deserts and salt flats to alpine meadows and temperate forests, spanning latitudes of approximately 25° to 40° N [5]. Despite this geographic extent and ecological variety, the lichenological exploration of Iran remains far from complete. A preliminary lichen checklist compiled by Seaward et al. [2] recorded approximately 396 species from across the country; the revised checklist of Seaward et al. [3] recognized a total of approximately 590 lichenized fungal species and 55 lichenicolous fungal species, a figure that has continued to grow with subsequent floristic surveys [6-23].

Razavi Khorasan Province in northeastern Iran covers about 118,854 km^2, accounting for roughly 7.2% of Iran's total land area, and borders Turkmenistan to the north and Afghanistan to the east [5]. Within this province, the Binaloud Mountain exhibits a considerable elevational gradient (about 1300–3220 m above sea level [a.s.l.]) along with a marked diversity of rock types, including calcareous (limestone and dolomite), siliceous (quartzite), conglomerate, and shale rocks [24-26] and soil substrates, which could plausibly play a significant role in shaping regional lichen diversity [25, 27]. A review of the lichenological literature indicates that northeastern Iran, particularly Razavi Khorasan Province, is among the country's relatively well-surveyed regions, with approximately 222 lichen species reported to date [6-14, 16-19, 28, 29]. The region's varied climatic conditions, spanning arid to semi-arid zones, and its extensive presence of calcareous sedimentary substrates provide ideal habitats for crustose saxicolous lichens, which are known to thrive on a wide range of rock types [7, 10, 24, 25].

Saxicolous crustose lichens are stress-tolerant and slow-growing, and elevation, rock chemistry, light availability, and rock microtopography (concave versus convex surfaces) mainly shape their distribution [30, 31]. The diverse rock types and elevational gradient of Binaloud Mountain [24, 25] are therefore expected to create a mosaic of microhabitats that supports a diverse assemblage of saxicolous lichens, including Calcicolous Teloschistaceae [30, 32].

More than sixty species of this family have been reported from Iran alone [2, 3, 6, 7, 10-13, 15, 18, 20, 33], including the genus *Pyrenodesmia* A. Massal. [12, 13]. Arup et al. [34] resurrected this genus, and Frolov et al. [32, 35] refined it; it comprises saxicolous, predominantly calcicolous taxa that lack anthraquinone pigments and instead possess Sedifolia-gray (K+ purple) [32]. Within this genus, *P. microstepposa* differs from the closely related *P. micromontana* and *P. transcaspica* by extracellular oil drops in the hymenium [35].

Ecologically, *Pyrenodesmia* sensu stricto has a Holarctic distribution, with three recognized centers of diversity in the

Mediterranean basin, Central Asia, and arid western North America, reflecting a strong association with sun-exposed, xerothermic calcareous outcrops rather than mere geographic proximity [32]. This pattern is based primarily on the concentration of published records and taxonomic studies from these regions rather than on formal quantitative diversity indices, as illustrated by the comprehensive Altai-Sayan monograph of Vondrák et al. [36] and the studies of Frolov et al. [32, 35], which together reflect, at least in part, the intensity of regional taxonomic sampling effort. In such habitats, species turnover is closely tied to substrate chemistry and climatic gradients, allowing morphologically similar congeners to partition the same mountain system, such as Binaloud Mountain [30, 35]. Records of *Pyrenodesmia* from Iran have accumulated gradually, with *P. microstepposa* [6] and *P. micromontana* [7] each previously reported only once from Razavi Khorasan Province, and *P. transcaspica* from four localities in the province [13]. The present study reports four *Pyrenodesmia* specimens from two additional localities on the Binaloud Mountain, providing new locality records for these species in the province.

Materials & Methods

Study Area

The Binaloud Mountain range is a principal orographic feature of the province, extending northwest-southeast between Neyshabour and Mashhad, with an elevational span of about 1300–3220 m (reaching its highest point at Binaloud Mountain) and a semi-arid climate (mean annual precipitation ~185 mm; mean annual temperature ~13°C) (Figure 1) [26]. The range comprises thick successions of sedimentary, metamorphic, and igneous rocks, dominated by Triassic-Jurassic metamorphic lithologies, whose exposed substrates provide diverse, stable microhabitats suitable for saxicolous and terricolous lichen communities [24].

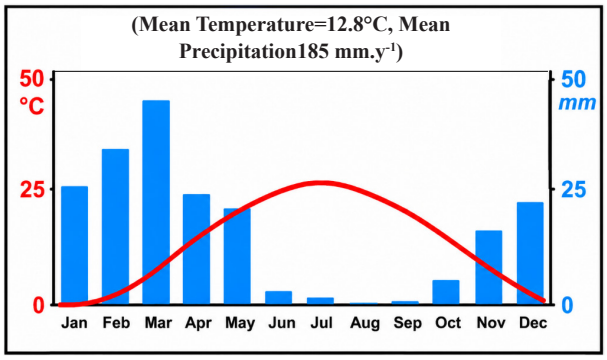


Figure 1) Climate diagram for Neyshabour station [26].

Sampling

Specimens were collected from calcareous rock substrates on the southern slopes of the Binaloud Mountain, Razavi Khorasan Province, northeastern Iran, from two localities: Eish-Abad (Central District, Neyshabour County; 36°30′ N, 58°58′ E) and Dizabad-e Olya (Zebarkhan District, Neyshabour County; 36°09′ N, 59°28′ E) (Figure 2).

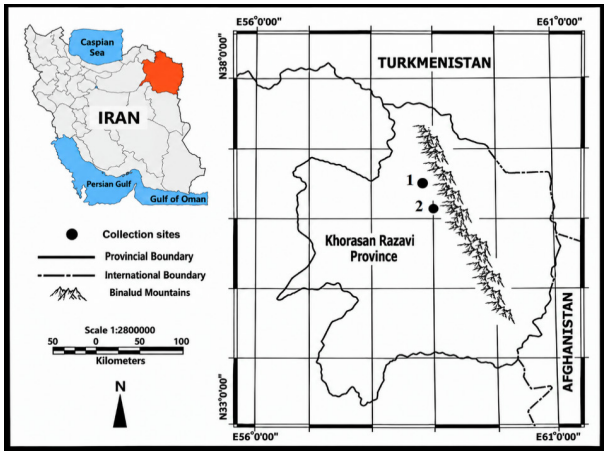


Figure 2) Map of the two collection localities on the southern slopes of Binaloud Mountain, Razavi Khorasan Province, NE Iran: 1) Eish-Abad (Central District, Neyshabour County) and 2) Dizabad-e Olya (Zebarkhan District, Neyshabour County).

All specimens were collected by the first author during summer and autumn 2023. We collected seven *Pyrenodesmia* thalli (four from Eish-Abad and three from Dizabad-e Olya):two thalli for each of the three confirmed species and one for the tentatively identified specimen. Of the seven, we selected the four specimens with well-developed vegetative and reproductive structures for detailed study and treated them in the present study. Specimens TARI 13015 (*Pyrenodesmia transcaspica*) and TARI 13017 (*Pyrenodesmia micromontana*) were collected from Eish-Abad at elevations of 1600 and 1700 m a.s.l., respectively, and specimens TARI 13012 (*Pyrenodesmia* cf. *micromontana*) and TARI 13013 (*Pyrenodesmia microstepposa*) from Dizabad-e Olya at elevations of 1800 and 2000 m a.s.l., respectively; voucher specimens are deposited in the Herbarium of the Research Institute of Forests and Rangelands (TARI), Tehran, Iran, under the accession numbers indicated above.

Laboratory Analyses and Species Identification

The calcareous nature of the rocks was confirmed in the laboratory by applying a few drops of 10% hydrochloric acid (HCl), via micropipette, to lichen-free rock surfaces; effervescence indicated the presence of calcium carbonate [37].

Morphological examinations were carried out using a stereomicroscope and a light microscope. Hand-cut sections of the thallus and apothecia were mounted in water for anatomical analysis. Standard spot tests were performed with Potassium Hydroxide (K), Sodium Hypochlorite (C), Potassium Hydroxide followed by Sodium Hypochlorite (KC), the reverse order (Sodium Hypochlorite followed by Potassium Hydroxide; CK), and Lugol's iodine solution (I), following the protocols of Orange et al. [37]. We identified species using more than 40 macro- and microscopic diagnostic characters, following Vondrák et al. [38], and recorded 10–15 measurements per character per specimen [38]. Molecular analyses were not performed in this study; this limitation is discussed further in the Study Limitations section.

We compiled distributional data for similar specimens in the province from published literature, including Haji Moniri et al. [13] and Baradaran et al. [6, 7]. We initially identified all four specimens based on available taxonomic literature, primarily Frolov et al. [35]. Thin sections were prepared for each specimen, and detailed descriptions were compiled based on the authors' observations and comparison with relevant literature. We emailed all measurements, observations, and preliminary identifications, along with macro- and microphotographs, to Dr. Ivan Frolov, a specialist in the family Teloschistaceae, who confirmed three specimens with definitive species-level identifications and designated the fourth as *P.* cf. *micromontana*, which requires molecular investigation for confirmation.

Findings

Voucher TARI 13015: *Pyrenodesmia transcaspica* (Nyl.) S.Y. Kondr.

Synonym: *Caloplaca transcaspica* (Nyl.) Zahlbr.

Thallus: crustose, areolate, dark gray to blackish. **Apothecia:** lecanorine, black with gray margin, 1–2 per areole; **disc** flat to convex, 0.35–1.2 mm diameter. **Epithecium:** gray to dark brown, 11.4–17.1 µm thick. **Hymenium:** light gray, 71–92 µm tall, without oil drops. **Subhymenium:** 46–57.5 µm tall. **Paraphyses:** moniliform, unbranched, terminal cell 2.85–3.42 µm

wide. **Asci:** 8-spored, clavate, 42.75–57 × 14.25–17.1 µm. **Ascospores:** polarilocular, hyaline, 10.83–14.25 × 5.7–6.27 µm, septum 0.8–1.14 µm wide. **Chemistry:** thallus and apothecia K–, C–, KC–, CK–; Epithecium K+ purple (Sedifolia-gray); hymenium I+ blue. **Photobiont**: chlorococcoid, globose cells (Figure 3 A, B).

Ecology: 1600 m a.s.l.; on calcareous rock, associated with *Pyrenodesmia molariformis* and *Verrucaria viridula*. **Locality**: Eish-Abad.

Notes: These features are consistent with *P. transcaspica* within *Pyrenodesmia* sensu stricto [32, 33, 35]. It differs from *P. variabilis* s. lato by its thinner septa and *P. micromontana* and *P. microstepposa* by its usually larger, more raised apothecia and thallus [35].

Voucher TARI 13012: *Pyrenodesmia* cf. *micromontana* (I.V. Frolov, Wilk & Vondrák) Hafellner & Türk

Synonym: *Caloplaca micromontana* Frolov, Wilk & Vondrák

Thallus: Crustose, areolate, light brown to cream, 0.5–2 mm wide. **Apothecia:** Lecanorine, black, 1–5 per areole, raised to sessile; **disc** concave to rarely flat, 0.33–0.50 mm diameter (Figure 3 E). **Epithecium:** Dark gray to blackish, 8.55–22.8 µm thick. **Hymenium:** colorless, without oil drops, 42.75–114 µm tall; **Subhymenium** 94.5–162.5 µm tall. **Paraphyses:** Moniliform, apical cell 2.85 µm wide. **Asci:** 8-spored, clavate, 54.15–59.85 × 19.95–22.8 µm. **Ascospores:** Polarilocular, hyaline, 12.5–16.8 × 5.5–7.5 µm, septum 1.0–3.2 µm wide (Figure 3 C, D). **Chemistry:** Thallus and apothecia K–, C–, KC–, CK–; Epithecium K+ purple (Sedifolia-gray); hymenium I+ blue. **Photobiont:** Chlorococcoid, globose cells. **Ecology:** 1800 m a.s.l.; on calcareous rock, associated with *Xanthoria elegans*. **Locality:** Dizabad-e Olya.

Notes: The hymenium lacks extracellular oil drops; Frolov et al. [35] treat this character as fully diagnostic for separating *P. micromontana* from the otherwise similar *P. microstepposa*. In many characters and measurements, this specimen falls within the range observed in *P. micromontana*; however, owing to differences in certain characters, notably the number of apothecia per areole (up to five versus one to two) and the raised, sessile apothecial position (versus immersed to adnate), it is provisionally identified as *P.* cf. *micromontana* on the advice of Dr. Ivan Frolov, a specialist in the genus. Definitive identification requires molecular investigation.

Voucher TARI 13013: *Pyrenodesmia microstepposa*: (I.V. Frolov, Nadyeina, Khodos. & Vondrák) Hafellner & Türk

Synonym: *Caloplaca microstepposa* Frolov, Nadyeina, Khodos. & Vondrák

Thallus: Crustose, light brown to cream-gray, areoles 0.5–1.5 mm wide. **Apothecia**: Zeorine, black to brown, one per areole; **disc:** Cracked when mature, 0.4–1.2 mm diameter (Figure 3 F). **Epithecium:** Olive-green to dark brown, 28.5–48.5 µm thick. **Hymenium:** Colorless to light yellow-green, inspers (numerous oil drops), 82.5–91.5 µm tall; **Subhymenium:** 68.5–94 µm tall. **Paraphyses:** Simple, apical cell 2.85 µm wide. **Asci:** 8-spored, clavate, 57–68.5 × 12.8–21.5 µm. **Ascospores:** Polarilocular, hyaline, 13.5–17.5 × 5.7–8.5 µm, septum 1.14–2.85 µm wide. **Chemistry:** Thallus and apothecia K–, C–, KC–, CK–; Epithecium K+ dark purple (Sedifolia-gray with brown pigment); hymenium I+ blue. **Photobiont:** Chlorococcoid, globose cells.

Ecology: 2000 m a.s.l.; on calcareous rock. **Locality:** Dizabad-e Olya.

Notes: These characters correspond to

the diagnostic profile of *P. microstepposa* established by Frolov et al. [35]. The inspers hymenium is the single fully diagnostic character separating *P. microstepposa* from *P. micromontana* and *P. transcaspica*, both of which lack extracellular oil drops [35]. Ascospore measurements (13.5–17.5 × 5.7–8.5 µm) and septum width (1.14–2.85 µm) agree closely with those reported by Baradaran et al. [6] (ascospores 14.2–17.1 × 5.7 µm, septum up to 2.6 µm). *Pyrenodesmia microstepposa* is known from inland arid and semi-arid regions of Asia and dry inland localities throughout Europe [35].

Voucher TARI 13017: *Pyrenodesmia micromontana* (I.V. Frolov, Wilk & Vondrák) Hafellner & Türk

Synonym: *Caloplaca micromontana* Frolov, Wilk & Vondrák

Thallus: Crustose, green-gray, very small (0.4–0.7 mm wide), sometimes present only below the apothecia. **Apothecia:** Lecanorine, dark brown, immersed to adnate, 1–2 per areole; **disc:** concave to flat, 0.3–0.5 mm diameter (Figure 3 G). **Epithecium:** gray, 11.5–15.5 µm thick. **Hymenium:** Colorless, I+ blue, 63–85 µm tall, without oil drops. **Subhymenium:** Colorless, underlain by an algal layer, with a central conical downward extension. **Paraphyses:** Moniliform. **Asci:** 8-spored, clavate, 50–65 × 14–18 µm. **Ascospores:** Polarilocular, hyaline, 11.5–16.0 × 5.5–8.0 µm, septum 1.2–2.1 µm wide. **Chemistry:** Thallus and apothecia K–, C–, KC–, CK–; Epithecium K+ pale purple; hymenium I+ blue. **Photobiont:** Chlorococcoid globose cells.

Ecology: 1700 m a.s.l.; on calcareous rock. **Locality:** Eish-Abad.

Notes: The diagnostic character placing this specimen in *P. micromontana* rather than *P. microstepposa* is the complete absence of extracellular oil drops in the hymenium [35]. This specimen is assigned to *P. micromontana* based on its montane, non-coastal habitat and its ascospore septum width (1.2–2.1 µm) [35]. The ascospore dimensions and septum width are broadly comparable with the range reported for *P. micromontana* by Baradaran et al. [7] (ascospores 14.2–17.1 × 5.7–8.5 µm, septum up to 2.6 µm).

Table 1 compares the diagnostic characters of the four *Pyrenodesmia* specimens collected in NE Iran.

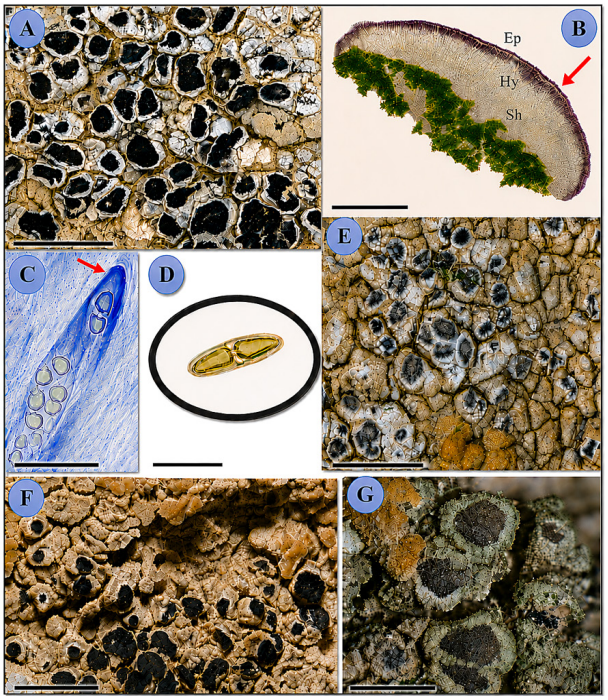


Figure 3) Morphological and anatomical features of *Pyrenodesmia* species. (A) Areolate thallus and raised, lecanorine apothecia. (B) Apothecial cross-section showing the Epithecium (Ep), hymenium (Hy), and Subhymenium (Sh); the Epithecium is K+ purple (arrow) in *P. transcaspica*. (C) *Teloschistes*-type ascus (arrow). (D) Polarilocular, bicellular ascospore. (E) Light-brown thallus with raised to sessile apothecia in *P.* cf. *micromontana*. (F) Thallus with immersed to adnate apothecia in *P. microstepposa*. (G) Green-gray thallus with immersed to adnate apothecia in *P. micromontana*. Scales, A, E and F= 1mm., G=0.5mm., B= 100 µm., C= 20 µm. D= 10 µm.

Discussion

This study adds new locality records of *Pyrenodesmia* from Razavi Khorasan

Province, documenting three confirmed species (*P. transcaspica*, *P. microstepposa*, and *P. micromontana*) and one tentatively identified taxon (*P.* cf. *micromontana*) from two localities on the southern slopes of the Binaloud Mountain, NE Iran. Four specimens were collected on calcareous rock substrate (1600–2000 m a.s.l.) and share the diagnostic features of *Pyrenodesmia* sensu stricto (Teloschistaceae):thallus and apothecia K–, C–, KC–, CK–, with K+ purple (pale to dark) Epithecium caused by Sedifolia-gray pigment, which is consistent with the absence of anthraquinone pigments and supports their placement within *Pyrenodesmia* s.str. (Lineage P of Frolov et al. [32]). Although the identifications of the three species were confirmed by Dr. Ivan Frolov (see Materials and Methods), the identification of *P.* cf. *micromontana* remains tentative due to morphological overlap with closely related taxa.

The most important diagnostic character separating *P. microstepposa* from the other three taxa is the presence or absence of extracellular oil drops in the hymenium: *P.*

Table 1) Key diagnostic characters of the four *Pyrenodesmia* specimens from the Binaloud Mountain, NE Iran.

Character	*P. transcaspica*	*P.* cf. *micromontana**	*P. microstepposa*	*P. micromontana*
Thallus Form	Crustose, Areolate	Crustose, Areolate	Crustose, Areolate	Crustose, Reduced
Thallus Color	Dark Gray to Blackish	Light Brown to Cream	Light Brown to cream-Gray	Green-Gray
Apothecia Type	Lecanorine	Lecanorine	Zeorine	Lecanorine
Apothecium Diam. (mm) (n=10)	0.35–1.2	0.33–0.50	0.40–1.2	0.30–0.50
Apothecium Position	Raised	Raised to Sessile	Immersed to Adnate	Immersed to Adnate
Apothecia Per Areole	1–2	1–5	1	1–2
Apothecia/ Thallus (K Reaction)	Negative	Negative	Negative	Negative
Epithecium (K Reaction)	K+ Purple	K+ Purple	K+ Dark Purple	K+ Pale Purple
Hymenium Oil Drops	Absent	Absent	Present (Inspers)	Absent
Ascospore Size (µm) (n=15)	10.83–14.25 × 5.7–6.27	12.5–16.8 × 5.5–7.5	13.5–17.5 × 5.7–8.5	11.5–16.0 × 5.5–8.0
Septum Width (µm) (n=15)	0.8–1.14	1.0–3.2	1.14–2.85	1.2–2.1

Note: All character states and measurements presented in this table refer to the specimens examined in this study and do not necessarily represent the full range of variation known for each species. Morphometric ranges for apothecium diameter, ascospore size, and septum width are based on 10–15 measurements per character per specimen. *The identification of *P.* cf. *micromontana* remains tentative. It requires molecular data for confirmation and should not be treated as equivalent to the confirmed record of *P. micromontana* in broader conclusions.

microstepposa is consistently distinguished by an inspers hymenium, whereas *P. micromontana*, *P.* cf. *micromontana*, and *P. transcaspica* all lack this feature [35]. Some anomalous characters of *P.* cf. *micromontana*, notably the high number of apothecia per areole (up to five) and the broadly raised, sessile apothecial position, deviate from the original description of *P. micromontana* and warrant further investigation; molecular analyses will be necessary for definitive resolution.

Pyrenodesmia microstepposa [6] and *P. micromontana* [7] had each been recorded only once from Razavi Khorasan Province, and *P. transcaspica* from four localities [13]. Records from two additional localities, Eish-Abad and Dizabad-e Olya, extend these species' known distribution in the province and suggest they may be more common than earlier records indicate [6, 7, 13]. However, because the specimens were collected during a single sampling period (summer and autumn 2023) at only two sites, these findings do not allow inferences about the long-term persistence of these populations. Broader, systematic sampling is needed before we can consider these species regular components of the region's lichen flora.

Elevation is widely recognized as a principal gradient structuring lichen richness and turnover in mountain ecosystems; it integrates co-varying temperature, moisture, radiation and microhabitat availability, with most studies reporting hump-shaped or otherwise non-linear richness patterns and pronounced species turnover [1, 31]. Although the present dataset is too limited to resolve a formal elevational pattern for *Pyrenodesmia* in the Binaloud Mountain, the four congeneric taxa were recorded across an elevational span of only 400 m (1600–2000 m a.s.l.), which suggests that this genus may occur over a considerable part of the elevational range of calcareous outcrops in the area. Whether this reflects a general pattern requires broader, systematic sampling along the entire elevational gradient [1, 31].

Ecological Comparison with Previously Documented Populations

To further contextualize the ecological setting of the specimens reported here, Table 2 compares their elevation, substrate, and habitat characteristics with previously documented populations of the same taxa from Iran and other regions worldwide.

The ecological characteristics of the four *Pyrenodesmia* taxa recorded in the present study provide an informative comparison with previously documented populations from Iran, Pakistan, the Altai-Sayan region, and Europe. Because temperature, precipitation, moisture, and exposure were not quantified during the present sampling, these variables should not be treated as measured environmental drivers.

***Pyrenodesmia transcaspica*:** Recorded at 1600 m in the Binaloud Mountain, falls within its previously documented elevational and substrate range in Iran and the Altai-Sayan region (Table 2) [13, 36], consistent with a broad elevational amplitude and a recurring association with lime-rich substrates.

***Pyrenodesmia microstepposa*:** Shows the broadest ecological variation among the four taxa, having been recorded on both calcareous and siliceous substrates across a wide elevational range in Iran, the Altai-Sayan region, and Pakistan (Table 2) [6, 36, 39], indicating that it is not restricted to one substrate type or a narrow elevation range.

Pyrenodesmia micromontana collected at 1700 m on Binaloud Mountain, occurred at a lower elevation than previous Iranian and Altai-Sayan records, but well within

Table 2) Comparison of the ecological characteristics of *Pyrenodesmia* taxa from the Binaloud Mountain with previously reported populations from Iran and other regions worldwide.

Taxon/Source	Region/Locality	Elevation (m)	Substrate	Habitat/Climate	Ecological Significance
***P. transcaspica*-** present study	Binaloud Mountain, NE Iran	1600	Calcareous	Mountainous; semi-arid regional climate [26]	Within the previously documented Iranian elevation range and calcareous-substrate context.
***P. microstepposa*-** present study	Binaloud Mountain, NE Iran	2000	Calcareous	Mountainous; semi-arid regional climate [26]	Calcareous occurrence here contrasts with the siliceous Torghabeh record, possibly indicating the species' tolerance of diverse substrates.
***P. micromontana*-** present study	Binaloud Mountain, NE Iran	1700	Calcareous	Mountainous; semi-arid regional climate [26]	Lower than the Iranian 2120-m record and the Altai-Sayan 2170–2900m records.
***P.* cf. *micromontana*-** present study	Binaloud Mountain, NE Iran	1800	Calcareous	Mountainous; semi-arid regional climate [26]	Provisionally related to *P. micromontana*; requires molecular confirmation
***P. transcaspica* -** NE Iran [13]	Sarvelaiat, Chenaran, Tandoureh National Park (2 sites), NE Iran	1165–2200	Calcareous rock	Mountainous Grassland with limestone outcrops	Consistent with the present 1600m record.
***P. transcaspica*-** Altai–Sayan [36]	Central Asia	600–2900	Lime-rich silicate; limestone	Arid Alpine and arid non-alpine	Broad elevational and habitat amplitude; repeated association with lime-rich substrates.
***P. microstepposa*-** Torghabeh [6]	Razavi Khorasan, Iran	≤1900	Siliceous rock	Often sunny; inland arid/semi-arid distribution	Demonstrates that the species is not restricted to calcareous rock.
***P. microstepposa*-** Altai-Sayan [36]	Central Asia	410–2350	Calcareous sandstone; concrete; lime-enriched silicate; limestone	Mostly arid non-alpine; one arid alpine record	Broad substrate use and predominantly dryland occurrence.
***P. microstepposa*-** Pakistan [39]	Garam Chashma, Chitral	2554	Calcareous rock	Semi-arid; 21 to −4 °C; ~603 mm annual precipitation	High-elevation calcareous occurrence.
***P. micromontana*-** Bakharz [7]	Razavi Khorasan, Iran	2120	Calcareous	Semi-dry-cold	Similar substrate, but higher elevation than the Binaloud record.
***P. micromontana*-** Altai–Sayan [36]	Central Asia	2170–2900	Limestone; schist	Arid and humid alpine	Strong alpine component; associated with carbonate-rich rocks.
***P. micromontana*-** Europe/Asia [35]	Alps; Poland; Slovakia; Russia; Pakistan	~150–4100	Limestone and other lime-rich rocks	Mountain habitats; geographically variable	Very broad geographical and elevational amplitude.

Note: Climatic variables were not measured at the sampling sites; the regional climate given for the Binaloud samples is from the Neyshabour Station [26] and is not inferred for individual specimens.

the much broader elevational and substrate range reported across Europe and Asia (Table 2) [7, 35, 36].

The occurrence of ***P.* cf. *micromontana*:** at 1800 m on calcareous substrate is ecologically close to the confirmed *P. micromontana* record from the same mountain system; however, because this identification remains provisional, it should be treated separately from confirmed *P. micromontana* records in distributional interpretations until resolved. Overall, the combined evidence suggests that calcareous and other lime-rich rocky substrates represent an important ecological setting for several *Pyrenodesmia* taxa in mountainous regions. However, the data do not support treating all taxa as strictly calcicolous. The broad substrate spectrum of *P. microstepposa*, including siliceous rock, concrete, lime-enriched silicate, calcareous sandstone, and limestone, demonstrates that substrate use differs among taxa. Likewise, the wide elevational ranges of *P. micromontana* and *P. transcaspica* indicate that elevation alone is unlikely to explain their distributions.

All four taxa were collected from calcareous rock, which was the only substrate type sampled in this study. Their occurrence on calcareous substrate agrees with earlier reports for *P. transcaspica* and *P. micromontana*, whereas *P. microstepposa* has also been recorded on siliceous rock [6] (Table 2); thus, our records alone cannot indicate a substrate preference. Broader sampling across calcareous and siliceous substrates and along elevation, moisture, and exposure gradients would be necessary to test whether these taxa are associated with calcareous substrates in the Binaloud Mountain.

Study Limitations

Species identifications in the present study were based on morphological, anatomical, and chemical (spot test) characters, supported by confirmation from a specialist in the family Teloschistaceae. Although this approach proved sufficient to differentiate the taxa treated here reliably, it may be less conclusive for closely related or cryptic species within *Pyrenodesmia*, and molecular data are needed to resolve the tentatively identified specimen (*P.* cf. *micromontana*). The most important limitation of this study is the very small sample size: we collected only seven thalli from two localities, of which four were studied. Molecular analyses were beyond the scope of the present study, given the current lack of sequencing facilities in the country and the considerable cost of outsourcing samples abroad.

Future studies should therefore begin with an extensive species collection of *Pyrenodesmia*, covering a wider elevational range and a larger area of the Binaloud Mountain. The aim should be to build a genus-level reference collection that can later be used to resolve phylogenetic relationships among its species. Such large-scale sampling requires considerable personnel, time, equipment, and funding. Nevertheless, once available, this collection would provide a suitable basis for molecular studies, including resolving the identity of *P.* cf. *micromontana* and verifying the morphology-based identifications of the other taxa.

Conclusion

This study reports four *Pyrenodesmia* specimens from two localities on the Binaloud Mountain, three identified to species level (*P. transcaspica*, *P. microstepposa*, and *P. micromontana*) and one provisionally identified (*P.* cf. *micromontana*), all collected on calcareous rock at 1600–2000 m a.s.l. Comparison with published records (Table 2)

shows that the occurrences of *P. transcaspica* and *P. micromontana* on calcareous rock agree with the lime-rich substrates reported for these species, whereas *P. microstepposa*, previously also recorded on siliceous rock, was found here on calcareous rock. *Pyrenodesmia micromontana* occurred at a lower elevation than earlier Iranian and Altai-Sayan records. Because only four specimens (selected from seven thalli) from a single substrate type were studied at two localities, these findings are preliminary and do not allow conclusions about substrate preference. Broader sampling across substrates and elevations, together with molecular data, is needed, particularly to resolve the identity of *P.* cf. *micromontana*.

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