

FIRST REPORT OF DICRANUM FULVUM AND LEUCOBRYUM JUNIPEROIDEUM IN NORTHERN IRAN

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Abstract

Dicranum fulvum and *Leucobryum juniperoideum* are new records from Iran, both discovered in a mixed Caspian beech (*Fagus caspica*) and Common yew (*Taxus baccata*) stand at the Gazu site in the central Hyrcanian forests of Savadkuh County (Mazandaran Province, northern Iran). *Dicranum fulvum* is a corticolous moss distinguished by its narrow, fragile leaves that become curly and flexuose when dry, and falcate-secund when moist, with a setaceous acumen and bistratose upper lamina cells. *Leucobryum juniperoideum*, an epixyloous, found on dead wood, is characterized by its greenish-white, distinctive costa and the presence of hyalocysts (leucocysts) and chlorocysts. This is the first report of Leucobryaceae from Iran. Morphological descriptions, along with diagnostic features, photographs, ecological notes, and distributional data, are provided for both species. These findings contribute significantly to understanding moss diversity in the Hyrcanian region and the Iranian moss flora, for which the authors recommend targeted surveys in adjacent Hyrcanian habitats and the inclusion of this species in regional floristic checklists to clarify its distribution and conservation status.

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نخستین گزارش از خزه‌های *Leucobryum juniperoideum* و *Dicranum fulvum* در شمال

ایران

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چکیده: خزه‌های *Dicranum fulvum* و *Leucobryum juniperoideum* گزارش‌های جدیدی از ایران هستند که هر دو در یک توده آمیخته راش خزری (*Fagus caspica*) و سرخدار معمولی (*Taxus baccata*) در منطقه گزو در جنگل‌های هیرکانی مرکزی شهرستان سوادکوه، (استان مازندران، شمال ایران) کشف شده‌اند. *Dicranum fulvum* یک خزه پوست‌نشین است که با برگ‌های باریک و شکننده‌اش در هنگام خشک شدن مجعد و خمیده و در هنگام مرطوب شدن داسی‌شکل با نوک تیز و سلول‌های لایه بالایی دو لایه مشخص می‌گردد. *Leucobryum juniperoideum* یک خزه چوب‌نشین که روی چوب مرده یافت می‌شود و رنگ پریده تا سبز کم‌رنگ مایل به سفید دارای رگبرگ میانی متمایز است و با وجود سلول‌های غیرکلروفیلوز و سلول‌های کلروفیلوز مشخص می‌شود. این نخستین گزارش از *Leucobryaceae* از ایران است. توصیف ریخت‌شناختی دقیق، ویژگی‌های تشخیصی، عکس‌ها، یادداشت‌های بوم‌شناسی و داده‌های پراکندگی برای هر دو گونه ارائه شده است. این یافته‌ها به‌طور قابل توجهی به درک تنوع خزه‌ها در منطقه هیرکانی و فلور خزه‌ای ایران کمک می‌کند. بررسی‌های هدفمند در زیستگاه‌های مجاور هیرکانی و گنجاندن این گونه در چک لیست‌های فلوربستییک منطقه‌ای برای روشن شدن پراکندگی و وضعیت حفاظتی آن توصیه می‌شود.

INTRODUCTION

Dicranum fulvum Hook. (Hooker 1820) (Dicranaceae, Schimper 1856) and *Leucobryum juniperoideum* (Brid.) Müll.Hal. (Bridel 1826) (Leucobryaceae, Schimper 1856) represent two significant additions to the moss flora of Iran, newly recorded from the central Hyrcanian forests of Mazandaran Province (northern Iran). *Dicranum* Hedw. is one of the most morphologically diverse and widely distributed genera within Dicranaceae Schimp., comprising approximately 110 recognized species globally (Brinda & Atwood 2024). Species delimitation within this genus remains challenging due to substantial variation in gametophytic traits influenced by environmental conditions (Hedenäs & Bisang 2004; Huang & al. 2025).

Before this study, several species within the Dicranaceae had been documented in Iran. These include *Cynodontium tenellum* (Schimp.) Limpr., now placed within Rhabdoweisiaceae; *Dicranella howei* Renaud & Cardot, recently reclassified as *Calcidicranella howei* (Renaud & Cardot) Bonfim Santos, Fedosov & Jan Kučera, and assigned to Aongstroemiaceae; and *Dicranella varia* (Hedw.) Schimp., now recognized as *Calcidicranella varia* (Hedw.) Bonfim Santos, Fedosov & Jan Kučera, also within Aongstroemiaceae. Additional records include *Dicranum muehlenbeckii* Bruch & Schimp., *D. scoparium* Hedw., and *Oreas martiana* (Hoppe & Hornsch.) Brid., which has likewise been transferred to Rhabdoweisiaceae (Akhani & Kürschner 2004). These taxonomic placements follow recent revisions published in *Bryologia Gallica & Ultramarina* (2025) and the World Flora Online (2025). *Dicranum viride* (Sull. & Lesq.) Lindb. has also been reported from Iran (Zare & al. 2011). Leucobryaceae Schimp. encompasses 14–17 genera (Bonfim Santos & Stech

2017), notably *Leucobryum* Hampe, which includes 80–100 species distributed across temperate and tropical regions (Frey & Stech 2009; Eddy 1990). Members of *Leucobryum* typically form cushions or hummocks on soil, tree trunks, deadwood, or wet rocks in forested habitats (Feldberg & al. 2023). The genus is taxonomically complex, with significant morphological variation and overlapping traits, contributing to ongoing classification challenges (Vanderpoorten & al. 2003; Ottley & al. 2023). *Leucobryum juniperoideum*, originally described by Bridel (1826) as *D. juniperoideum* and later transferred to *L. juniperoideum* by Müller (1845), was confirmed across Europe, Madagascar, Turkey, the Caucasus, China, and Japan.

Species of *Leucobryum* are distinguished by a multilayered costa composed of large hyalocysts flanking a central strand of chlorocysts, with the lamina restricted to a narrow marginal zone near the leaf base (Feldberg & al. 2023). Leaf morphology varies from lanceolate to falcate-secund, and sporophytes bear oblique, cylindrical capsules with long-beaked opercula. Accurate identification requires examination of well-developed basal leaves and reference to comparative literature. The absence of *Dicranum fulvum* and *Leucobryum juniperoideum* from previous reports of mosses in Iran, including a regional study by Akhani & Kürschner (2004), may be attributed to factors such as genuine rarity or highly localized distribution. The present research contributes to a more comprehensive understanding of the moss flora of northern Iran. This study documents *D. fulvum* and *L. juniperoideum* from a mixed *Fagus caspica* Denk & G.W. Grimm (Denk & al. 2024) and *Taxus baccata* L. stand in the Gazu site, marking the first record of *Leucobryum* and Leucobryaceae in Iran. Morphological descriptions, along with diagnostic

features and ecological notes, are provided, contributing to the expanding checklist of Iranian moss flora and enhancing our understanding of bryophyte diversity in the Hyrcanian region.

MATERIALS AND METHODS

Studied region: The Gazu Reserve, located in Savadkuh County (Mazandaran Province, northern

Iran), comprises a mosaic of mixed temperate forests within the central Hyrcanian region. The site spans approximately 36°14'39"–36°15'47"N and 52°85'58"–52°87'16"E, with elevations ranging 530–1250 m above sea level (Fig. 1). The mean annual temperature is 17.8°C, and the average annual precipitation is approximately 800 mm. According to the De Martonne aridity index, the climate is classified as humid.

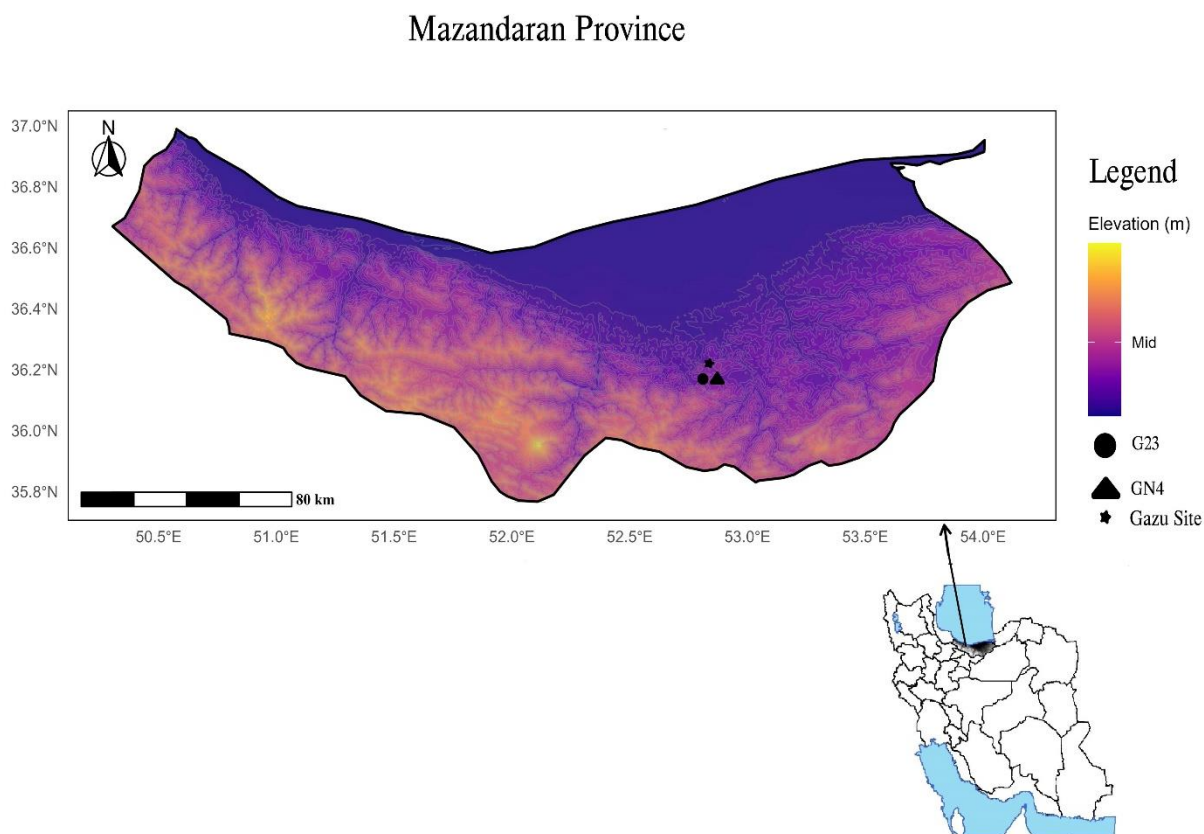


Fig. 1. Distribution map of moss records in the Gazu site, Mazandaran Province, Iran, showing the G23 locality for *Leucobryum juniperoideum* and the GN4 locality for *Dicranum fulvum*.

Morphological-anatomical analysis: Specimens were examined using a stereomicroscope (OPTIKA, Italy) and a biological microscope (HP320, China) at magnifications of 4×, 10×, and 40×. Image and map analyses were performed using ImageJ (Schneider & al. 2012) and R version 4.5.1 (R Core Team 2025). Voucher specimens of *Dicranum fulvum* (voucher No. 2520 NBGH) and *Leucobryum juniperoideum* (voucher No. 2519 NBGH) are deposited in the Herbarium of Nowshahr Botanical Garden (NBGH), Mazandaran Province (Iran). Leaf, stem, and costa sections were examined in cross-section and surface view to assess cell structure, including adaxial and abaxial surfaces,

cell shape, presence or absence of papillae, leaf margin configuration, and costa anatomy. Identification was guided by authoritative floras and diagnostic keys, including: Moss Flora of Middle European Russia (Ignatov & Ignatova 2003), Liverworts, Mosses and Hornworts of Southwest Asia (Kürschner & Frey 2011), The National Key to Sweden's Flora and Fauna (Hallingbäck & al. 2006), The National Checklist of Iranian Moss Flora (Akhani & Kürschner 2004), World Flora Online (WFO 2025), and Bryologia Gallica & Ultramarina (Bryologia Gallica 2025). Consultation with expert bryologists further supported species confirmation.

RESULTS

Leucobryum juniperoideum (Brid.) Müll.Hal., *Linnaea* 18: 689. 1844[1845] (Leucobryaceae). (Fig. 2)

Specimens examined: IRAN: Mazandaran Province, Savadkuh, Pol-e Sefid, Gazu Reserve region, Imamzadeh Gazo, Common yew forests, 29.09.2024, on Deadwood, 1053 m a.s.l, Esmailzadeh, Yousefvand, Sekhavat, and Maghsoudi, 2519 NBGH.

Description: Plants dioicous, epixyloous, forming loose cushions, greenish-white to glaucous green due to hyaline cells, 5–8 mm tall. Stems erect, slender, unbranched or sparsely branched. Leaves thick, whitish, slightly curved, spirally arranged, lanceolate to linear-lanceolate, 2.5–4.2 mm long, with basal portion shorter than the parallel-sided upper part; apex gradually tapering to a long, mucronate, sub-secund acumen. Leaf margins entire, bordered by a narrow band of unistratose cells. Costa massive, occupying most of the leaf lamina, composed of two layers of hyaline cells; in cross-section, a single row of chlorocysts is flanked above and below by hyalocysts, 14–30 µm wide. Lamina reduced to marginal zones, one cell layer thick. Alar cells not differentiated. Coloration varies from pale green to whitish, depending on moisture and exposure to light. Sporophytes not observed in Iranian material.

Habitat and ecology: Specimens of *Leucobryum juniperoideum* were collected in an epixyloous humid microhabitat within a mixed stand of *Taxus baccata* and *Fagus caspica*. The collection site was located at 36°08'43"N, 52°51'21"E, a slope of 33°, and a northern aspect (see G23 in Figure 1). The species was found on a shaded, fallen tree trunk, and associated vegetation and environmental variables were recorded to characterize the microhabitat. The percentage of total nitrogen of soil was determined using the Kjeldahl method (Kjeldahl 1883). Associated mosses include *Abietinella abietina* (Hedw.) Fleisch., *Dicranella heteromalla* (Hedw.) Schimp., *Hypnum cupressiforme* Hedw., *Isoetecium alopecuroides* (Lam. ex Dubois) Isov., *Isoetecium myosuroides* Brid., *Leucobryum juniperoideum*, *Palamocladium euchloron* (Müll. Hal.) Wijk & Margad., *Rhynchostegiella tenella* (Dicks.) Limpr., *Sciuro-hypnum flotowianum* (Sendtn.) Ignatov & Huttunen, and *Sciuro-hypnum oedipodium* (Mitt.) Ignatov & Huttunen.

Distribution: Western and central Europe, Asia, Turkey, Caucasus, China, Taiwan, Japan, Macaronesia, North America, Mauritius, Réunion, Madagascar, and Northern Iran.

Dicranum fulvum Hook., *Musci Exot.* 2: 149. 1819 (Dicranaceae). (Fig. 3)

Specimens examined: IRAN: Mazandaran Province, Savadkuh, Pol-e Sefid, Gazu Reserve region, Imamzadeh Gazo, Caspian beech forests, 30.09.2024, on Tree Trunk, 988 m a.s.l, Esmailzadeh, Yousefvand, Sekhavat, and Maghsoudi, 2520 NBGH.

Description: Plants small, slender, tuft-forming, corticolous, acrocarpous, 0.5–1 cm tall, dioicous. Fresh plants green, turning dark green when dry. Leaves fragile, arranged in multiple rows, 3–3.8 mm long, ~262 µm wide at base; flexuose and curly when dry, falcate-secund, twisted, and wavy when moist, green to yellowish-green. Leaf shape narrowly lanceolate, abruptly narrowing from oblong base to long, setaceous acumen; apex serrulate. Margins plane and entire below, involute above, minutely toothed near tip; acumen slightly fragile. Basal lamina cells quadrate to elongate-rectangular, 25 µm long. Middle cells mostly quadrate, occasionally short-rectangular. Upper lamina cells quadrate, bistratose near apex. Costa broad, excurrent, occupying ~1/3 of leaf base width, expanding distally; basal width ~99 µm. Alar cells quadrate, light brown to hyaline, prominently differentiated, extending toward the costa; unistratose in cross-section, 20–25 µm long. The specimen was corticolous, growing directly on beech bark. The pH of the bark from the host tree was measured using a flat-surface electrode pH meter (EXTECH ExStik® PH100) with 0.5 ml of 0.1 M potassium chloride as the electrolyte solution (Schmidt & al. 2001; Jüriado & Paal 2019).

Habitat and ecology: Specimens of *Dicranum fulvum* were collected from a *Fagus caspica* stand at 36°09'10"N, 52°51'03"E, a north-facing slope of 30° (see GN4 in Figure 1), growing directly on bark at 130 cm diameter at breast height in mixed *Fagus-Taxus* stands at the Gazu site, central Hyrcanian, in moist microhabitats with high atmospheric humidity. Bark pH of *Fagus* ranged from 5.0 to 5.3, suggesting subtle microchemical influences on colonization. Occurs in moist microhabitats with high atmospheric humidity. Associated mosses include *Pseudanomodon attenuatus* (Hedw.) Ignatov & Fedosov, *Hypnum cupressiforme*, *Isoetecium alopecuroides* (Lam. ex Dubois) Isov., *Alleniella complanata* (Hedw.) S.Olsson, *Palamocladium euchloron*, *Sciuro-hypnum flotowianum*, and *S. oedipodium*.

Distribution: Europe, North America, Asia, Turkey, and Northern Iran.

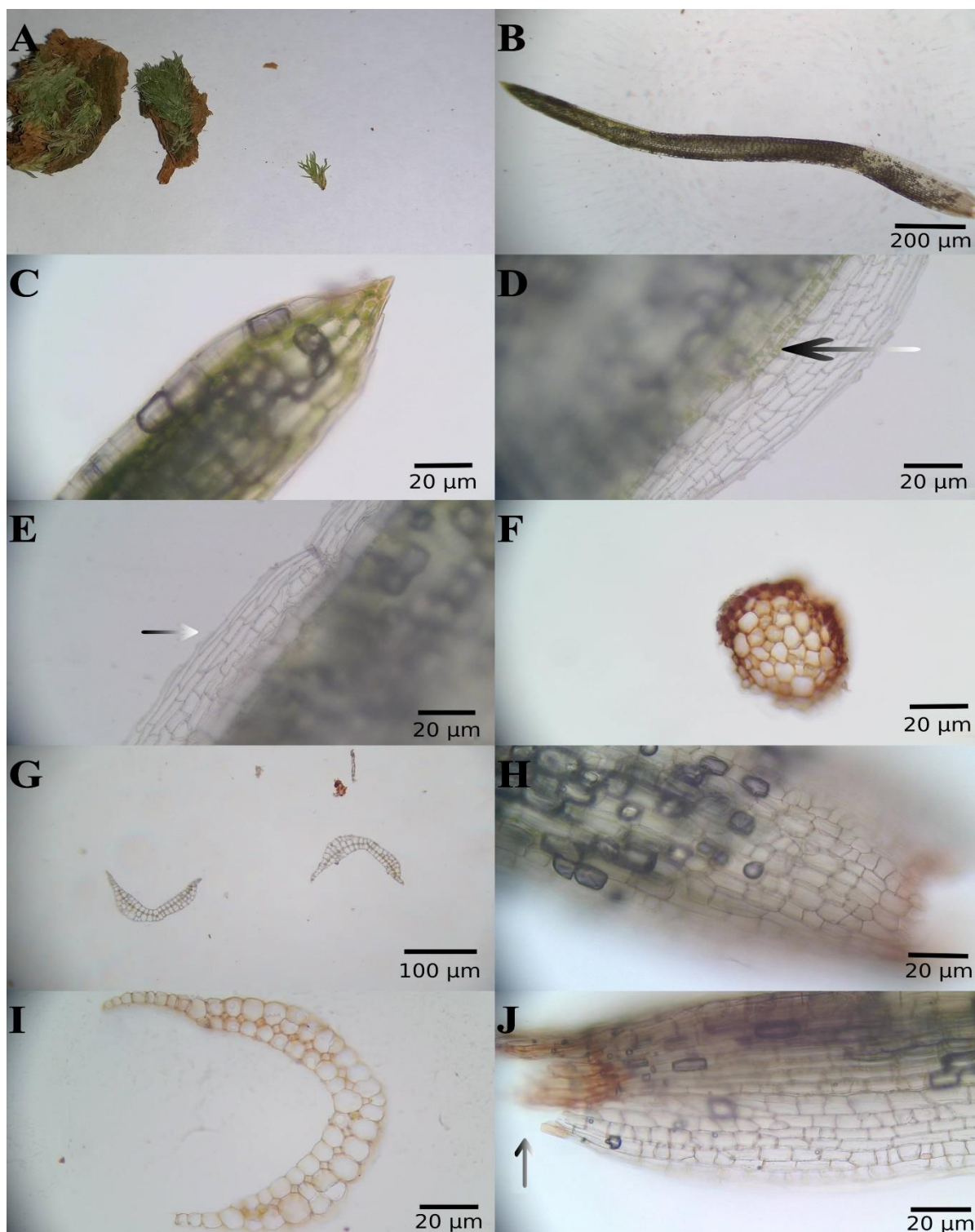


Fig. 2. *Leucobryum juniperoideum*: A, Plant under stereomicroscope; B, Leaf (4×); C, Tip of leaf (40×); D, Chlorocysts (40×); E, Hyalocysts (40×); F, Cross-section of stem (40×); G, Cross-section of costa (10×); H, Base cells of leaf (40×); I, Cross-section in the basal part of the leaf (40×); J, Alar cells (40×).

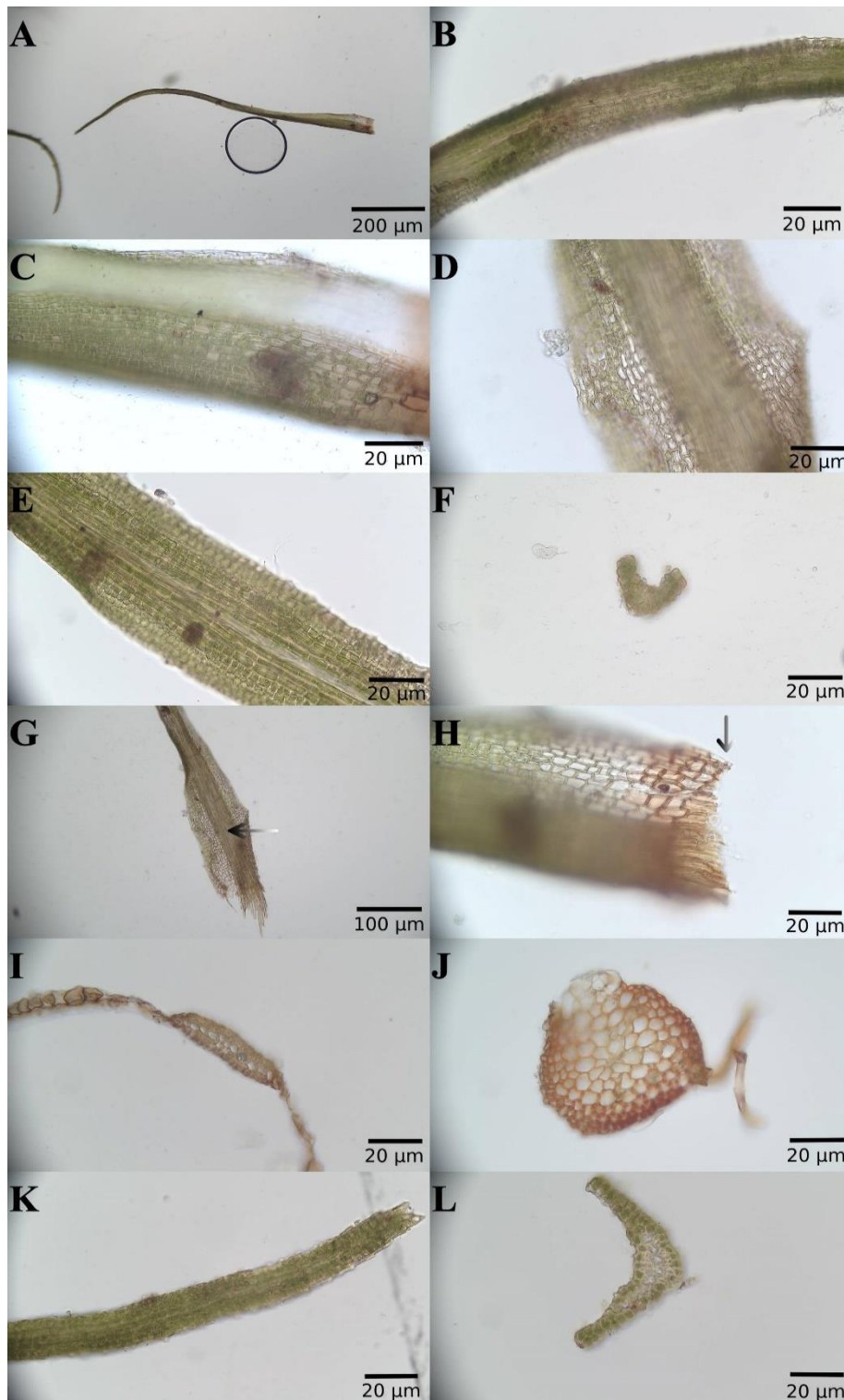


Fig. 3. *Dicranum fulvum*: A, Leaf (4×); B, Leaf margin (40×); C, Basal laminal cells; D, Middle laminal cells (40×); E, Upper laminal cells (40×); F, Cross-section of upper lamina, bistratose cells (40×); G, Costa (10×); H, Alar cells (40×); I, Cross-section of alar cells (40×); J, Cross-section of stem (40×); K, Tip of leaf (40×); L, Cross-section of the middle region of leaf and costa (40×).

DISCUSSION

The discovery of *Leucobryum juniperoideum* and *Dicranum fulvum* in northern Iran expands the known bryophyte diversity of the Hyrcanian forests and represents significant additions to the national moss flora. *Leucobryum juniperoideum* is widely distributed across temperate and tropical regions, including Europe, Asia, Africa, and the Americas, with records from Britain, Ireland, Turkey, China, and Japan (Crundwell 1972; Ignatov & Ignatova 2003; Smith 2004; Hallingbäck & al. 2006; Kürschner & Frey 2011; Frahm 2011; Wang & al. 2012, 2014, 2015). Our study provides the first record of both the species and the family Leucobryaceae in Iran. Ecologically, *L. juniperoideum* occupies a broad range of habitats, from humid forests to xeric sites, but shows a preference for moist, oceanic conditions. In Iran, it was found epixyloous on deadwood within *Taxus baccata* stands, reflecting its preference for shaded, humid microhabitats.

The distribution of *L. juniperoideum* appears to be closely linked to nutrient availability, particularly nitrogen and phosphorus concentrations across substrates. Epilithic populations typically occupy nutrient-poor habitats, whereas epigeic and epixyloous populations occur in sites with higher nutrient levels (Wang & al. 2014). Elevated soil nitrogen may restrict establishment in terrestrial habitats, favoring colonization of deadwood and other nutrient-poor substrates. This pattern was corroborated in our study, where Iranian material was found in epixyloous microhabitats with a measured nitrogen content of 0.25%. These findings suggest that nitrogen deposition may limit the distribution of *L. juniperoideum* in soil-based environments, reinforcing its preference for epiphytic or epixyloous niches. Morphological variability, such as slightly wavy or secondarily curved leaves, was observed in the Iranian specimen, consistent with intraspecific variation reported elsewhere (Crundwell 1972; Frahm 2011). Taxonomic delimitation of *L. juniperoideum* remains problematic, with treatments considering it synonymous with *L. albidum* or closely resembling *L. glaucum* (Kürschner & Frey 2011). Accurate identification requires careful examination of hyalocyst dimensions and costa anatomy (Vanderpoorten & al. 2003; Ottley & al. 2023). Conservation assessments categorize the species as Least Concern (González Mancebo 2019; IUCN 2025), yet its rarity in Iran underscores the need for continued monitoring.

Dicranum fulvum is similarly widespread across temperate regions, with records from Europe, Asia, and North America, but absent from far northern Europe

(Birse & al. 1957; Dunham 1915; Kellough 1960; Seltzer & Wistendahl 1971; Hedenäs & Bisang 2004; Kubešová & al. 2009, 2015; Glime 2017; Schnyder 2020; Huang & al. 2024, 2025). It typically colonizes shaded siliceous rocks, sandstone outcrops, and occasionally tree trunks, favoring deciduous forests but also occurring in coastal dune systems. Iranian specimens were found on the bark of *Fagus capsica* (pH=5.0–5.3), paralleling observations by Billings & Drew (1938), who reported its occurrence solely on *Tsuga* bark. Despite differences in bark pH between *Fagus* (5.4–6.3) and *Tsuga* (4.2–4.9), *D. fulvum* appears capable of tolerating a broad range of acidic conditions. This supports the hypothesis that *D. fulvum* exhibits ecological plasticity, enabling colonization of bark, soil, rock, and deadwood (Stokland & al. 2012). Rasmussen (1975) further noted that vertical zonation of mosses on *Fagus* trunks was influenced by moisture availability, though no consistent pattern was observed, suggesting relatively uniform moisture distribution along the trunk. Collectively, these findings imply that bark acidity may play a more decisive role than moisture in determining the presence of *D. fulvum* in the Hyrcanian forests.

Morphologically, *Dicranum fulvum* is difficult to delimit because of its similarity to related taxa such as *D. viride*, *D. scottianum*, and *D. fuscescens*. However, the Iranian specimens can be distinguished by a combination of diagnostic characters. In contrast, related species generally possess entire or weakly denticulate leaf margins and narrower costae (Hedenäs & Bisang 2004; Huang & al. 2024). Additionally, the taxonomy of this species has historically been complicated by its treatment under the synonyms *Paraleucobryum fulvum* and *Orthodicranum fulvum* (Goffinet & Shaw 2009; Rosa & al. 2013). Recent molecular studies have improved the delimitation of fragile-leaved *Dicranum* species (Ignatova & Fedosov 2008; Lang & Stech 2014; Tubanova & Dugarova 2022), although Iranian material remains poorly represented in phylogenetic analyses. Conservation assessments currently categorize *Dicranum fulvum* as Least Concern in Europe (Schnyder & al. 2019; IUCN 2025), whereas its conservation status in Iran remains unclear and requires additional field investigations.

However, *D. fulvum* and *L. juniperoideum* are currently categorized as Least Concern on the IUCN Red List; their conservation status in Iran is under review due to their recent documentation. Targeted surveys in adjacent Hyrcanian habitats and inclusion of these species in regional floristic checklists are suggested to clarify their distribution and national conservation status. Finally, this study's results

emphasize that targeted sampling of underexplored and local microhabitats can reveal overlooked moss records and contribute to a more complete understanding of regional biodiversity.

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