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NEW RECORDS OF MOSS SPECIES FROM HYRCANIAN BOX TREE (BUXUS HYRCANA POJARK.) FOREST, NORTHERN IRAN

Soraya Yousefvand[1], Omid Esmailzadeh[1]*, Habib Zare[2]

[1]*Department of Forest Science and Engineering, Faculty of Natural Resources and Marine Sciences, Tarbiat Modares University, Tehran, Iran*.
[2]*Associate Prof., Research Institute of Forests and Rangelands, Agricultural Research, Education and Extension Organization (AREEO), Tehran, Iran*.
[*]*Corresponding author*: *Omid Esmailzadeh, oesmailzadeh@modares.ac.ir*

Abstract
During bryological studies in parts of the Hyrcanian forests, four moss species—*Dicranum brevifolium* (Lindb.) Lindb. (Dicranaceae) on the soil substrate, *Loeskeobryum brevirostre* (Brid.) M. Fleisch (Leucobryaceae), *Tortella dolomitica* Köckinger & Hedenäs (Pottiaceae) on the substrate of stones and soil, and *Zygodon rupestris* Schimp.ex Lorentz (Orthotrichaceae) on *Zelkova carpinifolia*, *Celtis caucasica*, *Quercus castaneifolia*, *Buxus hyrcana*, *Carpinus betulus*, and *Acer velutinum*, —are recorded from Hyrcanian box tree stands. Detailed morphological descriptions and diagnostic features of each species are provided along with corresponding illustrations.

Keywords: Bryophytes; *Dicranum*; epiphytes; saxicolous; terricolous; *Zygodon*

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گزارش‌های جدید گونه‌های خزه از جنگل‌های شمشاد هیرکانی، شمال ایران

ثریا یوسفوند: دانشجوی دکتری، گروه علوم و مهندسی جنگل، دانشکده منابع طبیعی و علوم دریایی، دانشگاه تربیت‌مدرس، نور، ایران.

امید اسماعیل‌زاده: دانشیار، گروه علوم و مهندسی جنگل، دانشکده منابع طبیعی و علوم دریایی، دانشگاه تربیت‌مدرس، نور، ایران.

حبیب زارع: دانشیار، موسسه تحقیقات جنگلها و مراتع، باغ گیاه‌شناسی نوشهر، سازمان تحقیقات آموزش و ترویج کشاورزی، تهران، ایران.

چکیده: در طی مطالعات خزه‌شناسی در بخش‌هایی از جنگل‌های هیرکانی، چهار گونه خزه *Dicranum brevifolium* (Lindb.) Lindb. از خانواده (Dicranaceae) روی بستر خاک و *Loeskeobryum brevirostre* (Brid.) M. Fleisch از خانواده (Leucobryaceae)، *Tortella dolomitica* Köckinger & Hedenäs از خانواده (Pottiaceae) روی بستر سنگ و خاک و *Zygodon rupestris* Schimp.ex Lorentz از خانواده (Orthotrichaceae) روی تنه درختان آزاد، داغداغان، بلوط، شمشاد، ممرز و پلت، در توده‌های شمشاد هیرکانی، گزارش می‌شوند. شرح دقیق ویژگی‌های ریخت‌شناسی و خصوصیات تشخیصی هر گونه به‌همراه تصاویر مربوطه ارائه شده است.

INTRODUCTION

Bryophytes undoubtedly represent one of the earliest and most diverse lineages of terrestrial plants, forming an essential component of vegetation diversity. Despite their ecological significance, bryophytes are often excluded from biodiversity surveys due to the complexity of their identification and the scarcity of comprehensive taxonomic resources (Ah-Peng & al. 2007; Song & al. 2015). These plants play vital roles in ecosystem processes, particularly in regulating hydrological cycles and contributing to nutrient retention and accumulation (Ódor & al. 2013). Globally, more than 20,000 bryophyte species have been recorded, of which over 12,000 are mosses (Hoa & Chu, 2021).

Mosses are fundamental components of forest ecosystems and serve as a critical component of forest biodiversity (Longton, 1992; Kriebitzsch & al. 2013). They contribute to carbon and nutrient cycling, water retention, and erosion control (Oechel & Van Cleve, 1986; Turetsky, 2003). As pioneer species, mosses facilitate soil formation and development (Zhao & al., 2009), and they are instrumental in hydrological regulation (Hölscher & al. 2004), vegetation restoration, and ecological succession processes (Jeschke & al. 2008).

Studies on the moss flora of Iran are still limited. Researchers such as Ghahraman & al. (2007), Frey & Kürschner (2010), and Zare & al. (2011) have reported eighteen new moss species from the Hyrcanian Forest region, and Shirzadian & al. (2011), Mousavi & al. (2024) have added additional records to the bryophyte flora of Iran. According to Kürschner & Frey (2011), a total of 426 moss species were documented in Iran up to the year 2010. This number was later raised to 470 species based on verified sources, as reported by Shirzadian & al. (2022).

In the present study, conducted in the Mazandaran and Golestan provinces, four moss species *Zygodon rupestris*, *Loeskeobryum brevirostre*, *Dicranum brevifolium*, and *Tortella dolomitica*, are reported for the first time for the bryophyte flora of Iran. Additionally, the genus *Zygodon* is reported here for the first time, representing a novel generic record for the country.

MATERIAL AND METHODS

Moss specimens were collected in August 2023 from box tree *(Buxus hyrcana* Pojark) stands located in three distinct habitats within the Hyrcanian Forest region. The first site, Sisangan (Nowshahr), is situated at 51°47′59″ E, 36°34′45″ N, with an elevation of 12 m above sea level and an average annual rainfall of 1301.5 mm. The second site, Sangdeh (Sari), is located at 53°18′35″ E, 36°05′02″ N, at an elevation of 1650 m a.s.l., receiving approximately 800 mm of rainfall annually. The third site, Cheshme Bolbol (Bandargaz), located at 53°52′09″ E, 36°42′17″ N, with an elevation of 130 m a.s.l. These locations represent diverse ecological conditions within the Hyrcanian box tree habitats (Fig. 1).

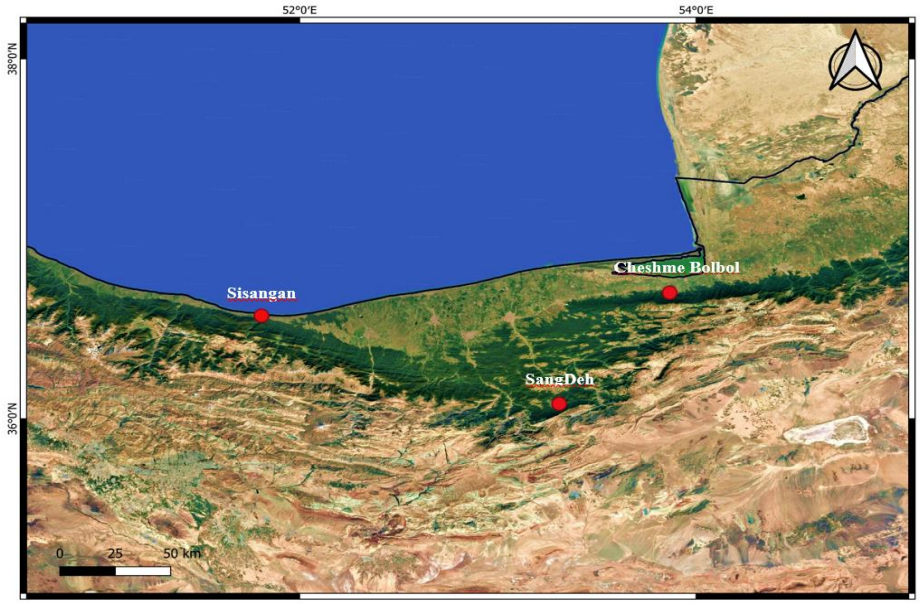

Fig. 1. Geographic distribution of sampling sites documenting new moss records in Mazandaran and Golestan provinces, northern Iran

Following field collection, the specimens were then prepared for initial identification and deposited in the Nowshahr Botanical Garden Herbarium. For taxonomic identification, a portion of the stem and a single leaf were selected from each specimen and rehydrated in water for a species-specific duration. Microscopic examination was conducted using a stereo microscope, with a focus on key morphological features of the stem, exostome, and peristome. For certain taxa requiring more detailed analysis, cross-sections of the leaf and stem were prepared. Detailed microscopic observation of leaf cells—including their shape, marginal characteristics, and the arrangement of lateral appendages—was conducted using authoritative floristic references and identification keys specific to the Scandinavian region (Nyholm, 1975), Central Europe and Russia (Ignatov & Ignatova, 2003), the British Isles (Smith, 2004), and broader European moss flora (Frey & al. 2006; Kürschner & Frey, 2011). Specimens were subsequently verified through comparison with herbarium collections and sent to the Herbarium of the Swedish Museum of Natural History in Stockholm for final taxonomic confirmation.

RESULTS AND DISCUSSION

Dicranum brevifolium (Lindb.) Lindb. (Dicranaceae)

Plants medium-sized to large, dioicous, forming dense tufts; coloration ranges from light to dark green, dark brown, or nearly black, exhibiting a dull appearance. Stems 2–8 cm long, densely tomentose with brown to orange rhizoids extending nearly to the apex. Leaves (3–) 5. 5–6.5(–8.5) mm long × 0.4–0.8 mm wide, falcate-secund to erect-spreading, often positioned at wide angles from the stems, strongly crisped when dry, sometimes they show slight undulations in the distal half. Leaves concave beneath, keeled above, lanceolate, and acute; Margins entire below and serrulate above, incurved near the leaf's middle; lamina primarily 1-stratose but may be 2-stratose in the distal half, especially along the margins, with occasional complete 2-stratose laminae and rarely 3-stratose margins. Costa percurrent or shortly excurrent, comprising about 1/6 to 1/4 of the leaf base width, very prominent and rounded on the abaxial surface, smooth or slightly rough on the upper side, lacking abaxial ridges, and shaped like a pair of tongs with a single row of guide cells and 2 well-developed thick stereid bands extending to the apex, adaxial epidermal layer is not differentiated, while the abaxial layer distinct. Cell walls between lamina cells are strongly bulging; leaf cells smooth to papillose on the abaxial surface; alar cells differentiated and 2-stratose, occasionally extending to the costa; proximal laminal cells elongate-rectangular, pitted or not, (15–) 31–46 (–75) × (5–) 7–9 (–12) µm; distal laminal cells short, irregularly quadrate-rectangular, non-pitted, (5–) 7–14 (–37) × (4–) 8–9 (–13) µm. Sexual condition pseudomonoicous; with dwarf males found on the stem rhizoids of female plants; interior perichaetial leaves abruptly short-acuminate and convolute-sheathing.

Only vegetative parts were present; no capsules were detected. This species occurs on humus or soil over rock, rarely on decayed wood, typically exposed on protected or open bluffs and cliffs.

Examined specimen: Mazandaran Province, Sangdeh Sari, Esmailzadeh & Yousefvand (2611 NBGH).

Habitat: On the soil bed in Sangdeh Sari at an altitude of 1100-1200 m a.s.l.

Geographic distribution: Europe, Asia, North America, Caucasus, China, Russia, Canada, Iceland

Dicranum brevifolium primarily differs from the three commonly confused species—*D. muehlenbeckii*, *D. acutifolium*, and *D. fuscescens*—by key anatomical and morphological traits. Most distinctively, *D. brevifolium* possesses leaves with a "tongue-shaped" cross-section in the distal half, features strongly bulging cell walls between lamina cells, and has crisped leaves standing out at wide angles when dry, alongside a prominent and conspicuously rounded costa. This contrasts with *D. muehlenbeckii* and *D. fuscescens*, which both have less prominent costae and V-shaped cross-sections (or tubular in *D. muehlenbeckii*); moreover, *D. acutifolium* has leaves that are merely erect-spreading or slightly curled when dry.

Loeskeobryum brevirostre (Brid.) M. Fleisch. (Hylocomiaceae)

Plants medium-sized to robust, dioicous, often forming loose or dense tufts. Stems procumbent, reddish, irregular or 1– (2)-pinnate branching. Annual branches typically arcuate or stoloniferous; Paraphyllia numerous, small, thin, irregularly branched, diverging at the base, and composed of a single row of elongate cells; Pseudoparaphyllia present. Lower stem leaves sheathing at the base, weakly longitudinally plicate, oblong-ovate, wide at base, abruptly tapering into a long acumen, thin, non-decurrent, flexuose, squarrose to recurved, and strongly dentate; the rest of stem leaves narrower, with the base of the acumen rugose, at margins strongly dentate in the upper half of the leaf, denticulate at base. Laminal cells smooth; median cells linear, while basal cells oblong, thick-walled, porose, yellowish; alar cells not differentiated. Costa double, extending one-third to one-half the length of the leaf. Branch leaves smaller than stem leaves.

The material examined did not include any fertile individuals. This species grows on soil, humus, decaying wood, and rocks in moist forests (Fig. 3).

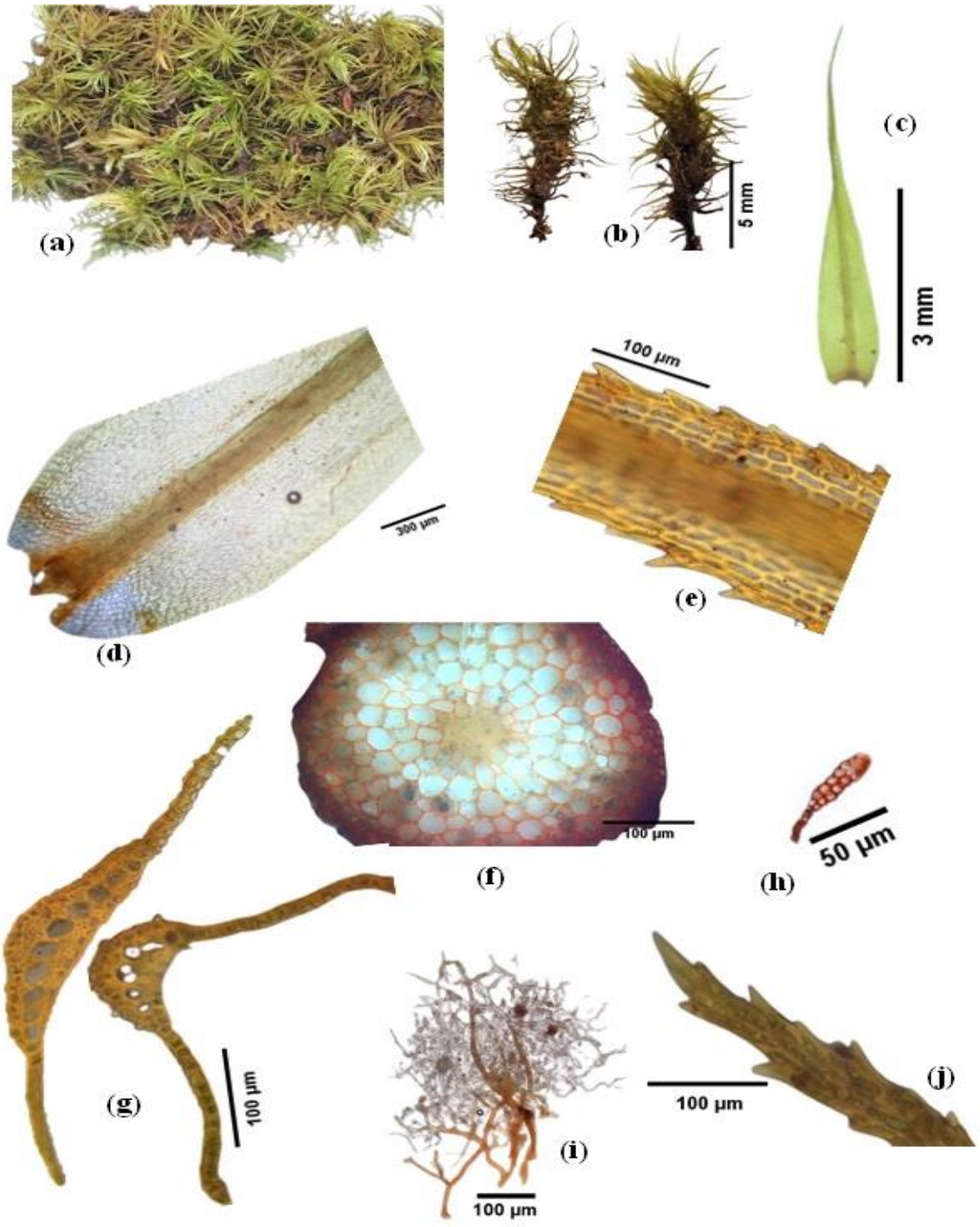

Fig. 2. *Dicranum brevifolium*. a, habit; b, shoot dry and moist; c, leaves; d, cellular arrangement of leaf base; e, the middle structure of the leaf; f, cross-section of the stem; g, tongue-shaped transverse sections in the upper leaf; h, alar cells 2-stratose; i, paraphyllium; j, leaf apex.

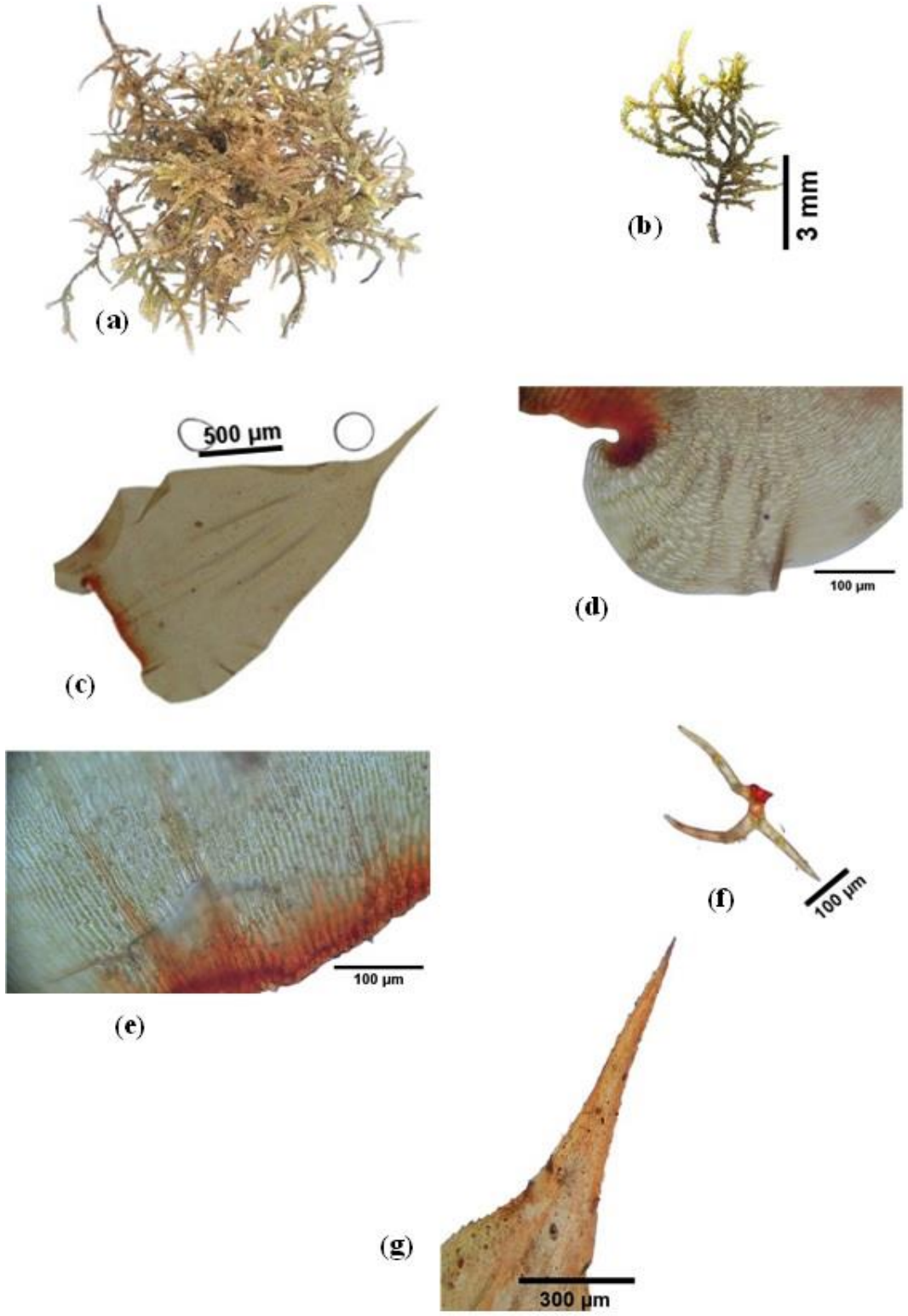

Fig. 3. *Loeskeobryum brevirostre*. a, habit; b, shoot moist; c, leaves; d, cellular arrangement of leaf base; e, costa; f, paraphyllium; g, leaf apex.

Examined specimen: Mazandaran Province, Sangdeh Sari, Esmailzadeh & Yousefvand (2610 NBGH).
Habitat: On the substrate of stones and soil in the Sangdeh Sari habitat at an altitude of 1100 to 1200 m a.s.l**.**
Geographic distribution: North, West, East, and Central Europe, Southeast, East, and North Asia, Japan, India, North America, Faroe, Tunisia, North Africa, Algeria, Greenland, Russia, Iceland, and Canada.

Loeskeobryum brevirostre is similar to *Rhytidiadelphus loreus* in general appearance, but they are reliably distinguished based on their paraphyllia: *L. brevirostre* possesses multiform and often branched paraphyllia (small, multi-shaped, and often branched structures on the stem). In contrast, *R. loreus* is characterized by having simple, non-branched, subulate paraphyllia (simple, unbranched, awl-shaped paraphyllia) or may sometimes lack them entirely.

Tortella dolomitica Köckinger & Hedenäs, (Pottiaceae)

Plants medium-sized to large, dioicous, forming loose to dense turfs, light greyish glaucous, sometimes yellowish to light brown (in sun); interior of cushions pale greyish. Shoots reach up to 2–3 cm, loosely foliated, irregularly branched, without narrow branch innovations. Stems circular in cross-section, up to 350 µm wide, with a distinct hyalodermis and cortex, thin-walled cylinder cells, and a central strand always present (up to 70 µm wide, less than 1/5 of stem width). Leaves 5–10 × 0.5–0.8 mm, linear (-lanceolate), with a length/width ratio of 15:1, when dry incurved and loosely to strongly curled, erect to spreading when moist, straight to slightly secund or sigmoid from above, not noticeably fragile; apex ending in a weakly toothed, non-colored to yellowish mucro, 100–200 µm long; costa strong, dorsally spinose in shade morphs, strongly papillose mid-leaf, gradually tapering, about 1/3–1/5 of leaf width mid-leaf. Leaf cross-section lunate to horseshoe-shaped in mid-limb, with a concave adaxial side and the abaxial side merging into the lamina. Leaf margins flat and crenulate. Lamina unistratose, weakly undulate mid-leaf, with a V- to U-shaped transition from sheath to limb. Mid-limb cells isodiametric, 8–10 µm wide, with knobby papillae, while sheath cells are thin-walled and rectangular. Male plants smaller, rarely observed.

Capsules were not found in any of the examined specimens. (Fig. 4). *Tortella dolomitica* is primarily a pioneer species, growing on moist, stabilized dolomitic gravel or sand, usually in moderate shade, and found both in natural habitats and along roadsides. Occasionally, it also occurs on moist dolomitic rock (Köckinger & Hedenäs, 2023).

Examined specimen: Mazandaran Province, Sangdeh Sari, Esmailzadeh & Yousefvand (2612 NBGH).
Habitat: On the substrate of stones and soil in the Sangdeh Sari habitat at an altitude of 1100-1200 m a.s.l.
Geographic distribution: This species has so far been recorded only from the middle montane to subalpine zones of the Austrian Eastern Alps, where it is scattered and typically present in low abundance.

Tortella dolomitica is similar to *T. robusta* but can be reliably distinguished based on the anatomy of its leaves. *T. dolomitica* is defined by a distinctly lunate or horseshoe-shaped cross-section at the leaf mid-limb, where the costa is only slightly protuberant on the dorsal side and mostly concave ventrally. In contrast, *T. robusta* exhibits a costal cross-section that is dorsally protuberant and ventrally ± flat.

Zygodon rupestris Schimp. ex Lorentz (Orthotrichaceae)

Plant small, dioicous, typically forms compact tufts reaching up to 1.7 cm tall. Stems erect, simple or branched. Rhizoids reddish-brown or yellowish-brown, roughened or papillose, at the base of stem. Leaves radially arranged, lanceolate to narrowly lanceolate in shape, gradually taper into a fine point. In a hydrated state, leaves erect-spreading with recurved tips, whereas in dry conditions, they become contorted and often exhibit a characteristic spiral twist; leaf margins finely crenulate, contributing to the species' distinctive foliar texture; costa typically terminates just below the leaf apex, although in some instances it may extend slightly beyond, forming a short, sharp tip; laminal cells in the upper region approximately 10 µm wide, thick-walled, and densely papillose, contributing to a roughened leaf surface. In contrast, basal cells elongate, thin-walled, and lack papillae, presenting a smooth texture that distinguishes them from the upper laminal cells.

Notably, no capsules were observed in the collected specimens. Vegetative reproduction is frequent, with ovoid gemmae commonly observed. Gemmae typically consist of 4–5 cells lacking transverse walls, mostly 20–30 µm in width. Rhizoids reddish to yellowish-brown. This species typically forms soft, slender tufts ranging from yellowish green to occasionally dark green. It primarily grows on tree trunks and, less frequently, on calcareous rocks, reflecting its corticolous and lithophytic tendencies (Fig. 5).

Examined specimen: Mazandaran Province, Bandar Gaz, Cheshme-Bolbol (2521 NBGH) and Nowshahr, SiSangan, Esmailzadeh & Yousefvand (2522 NBGH).

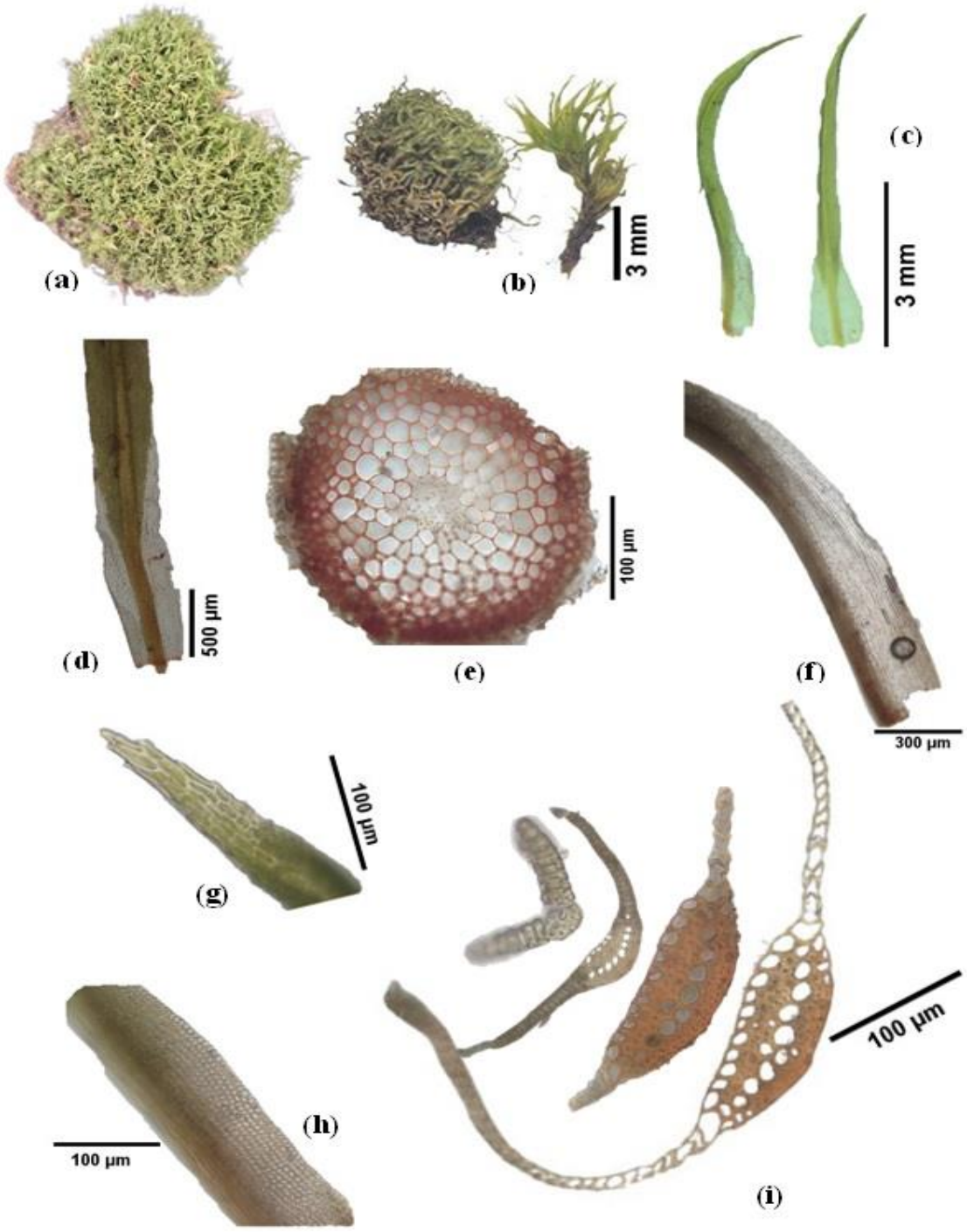

Fig. 4. *Tortella dolomitica*. a, habit; b, shoot dry and moist; c, leaves; d, v-shaped transition from sheath to limb; e, cross-section of the stem; f, limb-sheath transition zone; g, mucro; h, papillosity of the lamina cells; i, leaf transverse sections.

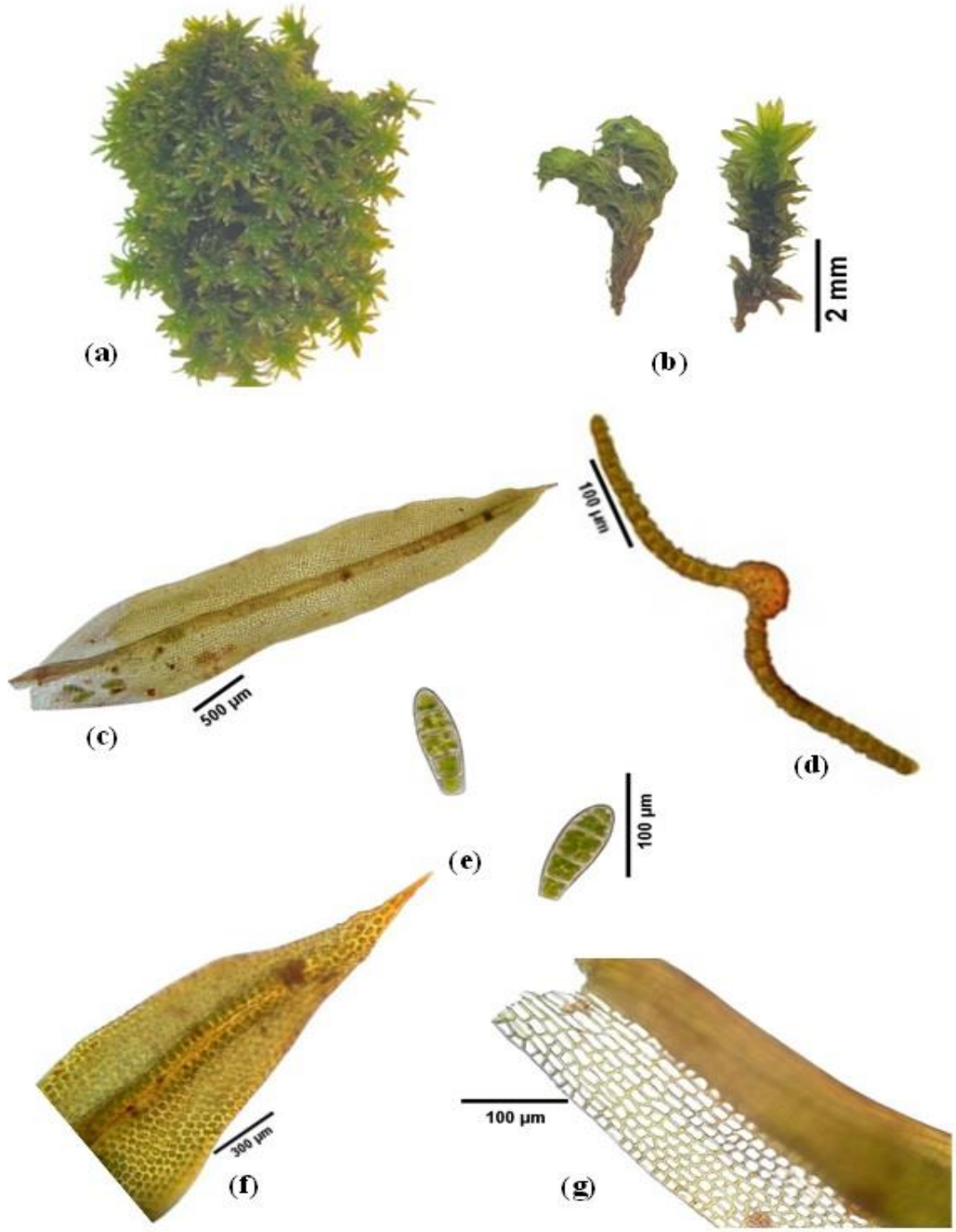

Fig. 5. *Zygodon rupestris*. a, habit; b, shoot dry and moist; c, leaves; d, leaf transverse sections; e, gemmae; f, leaf apex; g, cellular arrangement of leaf base

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Habitat: Lower sections of tree bases—specifically from protruding roots up to 50 cm above ground level—on *Zelkova carpinifolia*, *Celtis caucasica*, *Quercus castaneifolia*, and *Buxus hyrcana* within the *Zelkova–Buxus* forest type of the Cheshme-Bolbol habitat (130 m a.s.l.), representing the easternmost known distribution range of the Hyrcanian box tree. Additional samples were obtained from the basal (0–0.5 m) and middle (0.5–2 m) portions of trunks of *Buxus hyrcana*, *Carpinus betulus*, and *Acer velutinum* in the SiSangan habitat (12 m a.s.l.), located within the central Hyrcanian box tree stands.

Geographical distribution: Europe, Caucasus, Turkey, Central Asia, Japan, Macaronesia, North America, Northern Taiga, Russia, Mexico, Southeast Asia, Canada, and Northwest Africa.

Zygodon rupestris is very similar in appearance to *Z. viridissimus*, yet their primary distinction lies in the morphology of their propagule (asexual gemmae). Specifically, *Z. rupestris* develops fusiform-clavate or fusiform propagules, which are characterized by having only transverse septa, with the occurrence of any longitudinal or oblique septa being rare or exceptional. Conversely, *Z. viridissimus* produces clavate to ovoid propagules that are distinguished by the presence of numerous transverse and longitudinal septa (which may be straight, curved, vertical, or oblique).

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