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LIVERWORTS AND MOSSES FROM ROMANIA WITH MEDICINAL POTENTIAL

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Abstract: Liverworts and mosses are terrestrial plants that contain biologically active substances that give them important medicinal qualities. After reviewing the available literature on the pharmacological activity of the most used liverworts and mosses, we present 34 species found in Romania, used for the treatment of common diseases in folk medicine around the world. Their uses in traditional medicine are sometimes confirmed by pharmacological research, especially external ones (as antimicrobial or cytotoxic remedies). The species of liverworts and mosses are mentioned with their distribution in Romanian flora and the habitats where they live.

Keywords: liverworts, mosses, Romania, medicinal species

Introduction

Liverworts and mosses (bryophyte) are non-vascular plants, separated into a distinct phyla: Anthocerophyta (hornworts), with approximately 200 - 250 species (Villarreal et al., 2010), Marchantiophyta (hepatic), with approximately 7000 - 9000 species (Von Konrat et al., 2010) and Bryophyta (mosses), with approximately 11,000 -13,000 species (Magill, 2010). Some studies mention that out of the approximately 450,000 species of plants, bryophytes with 20,000 – 25,000 species are the second largest group, as species, after angiosperms (Mishra et al., 2014).

They are lesser-known, small-sized plants, with morphological identification characters that are more difficult for most people to notice, but which contribute to a greater or lesser extent to the composition of the terrestrial globe's vegetal carpet, dominated by flowering plants.

Bryophytes have been used as medicinal plants in China and North America as early as 400 years ago (Asakawa et al., 1980; Benek et al., 2022). Phytochemical studies on several bryophyte species have found that they contain biologically active compounds (lipids, proteins, polyphenols, terpenoids, organic acids, fatty acids, etc.) with various bioactivities, including the antibacterial, antitumor, antifungal and insecticidal ones (Glime, 2007). Some researchers have also described their myorelaxant effects on the smooth muscles of the organs in the abdominal cavity, on the bronchioles, as their potential use in the fight against obesity (Saxena and Yadav, 2018;

Bukvički et al., 2012; Purkon et al., 2022; Motti et al., 2023).

Since people still today, in the first phase, turn to medicinal plants for the relief or treatment of various diseases, it is understandable why the research of these species can be considered a priority, both from a medicinal point of view and from the perspective of protecting biodiversity.

In Romania ethnopharmacology the medicinal use of plants was mostly documented by Dihoru and Boruz (2016) without mentioning the bryophyte species, by Butură (1979) and Alexan et al. (1983) which presents data only on *Polytrichum commune*, *Funaria hygrometrica* and *Pogonatum urnigerum* as species of medicinal bryophytes.

In this paper we aim to complete the list of medicinal plants from Romania with species of mosses and liverworts used for medicinal purposes in countries with a tradition both in folk medicine and in pharmacological research of this fascinating group of plants. The selection of medicinal species from the Romanian bryoflora was made from an approximate number of 979 species, of which: 4 hornworts, 217 liverworts and 758 mosses (Ștefănuț and Goia, 2012).

Materials and Methods

Information about bryophytes and their medicinal properties was gathered by searching scientific databases such as: PubMed, Elsevier, Google Scholar, Springer, Scopus and in similar online and offline books. The following keywords were used in the investigations: "ethnobotany", "ethnomedicine", "ethnobryology", "medicinal bryophytes", "ethnopharmacology", phytotherapy", "medicinal", "ailments".

In a first stage, 179 articles were selected, based on their titles and summaries, identified by using the keywords mentioned above. Subsequently, the study focused only on the articles that contained information on medicinally important bryophyte species, including their content in biologically active substances. In the end, the review was narrowed down to 80 articles that corresponded to the purpose of the work, to identify the bryophyte species with medicinal potential that grow in Romania.

The classification of mosses species is according to Goffinet et al. (2009) and of liverworts is according to Crandall-Stotler et al. (2009) and the nomenclature follows the World Flora Online. Their chorology in Romania is according to Mihai et al. (1998).

Results and Discussions

Bryophytes are early and primitive plants, diversified in a hostile environment, during the Upper Ordovician - Silurian phase of the primary radiation of terrestrial biota (Bateman et al., 1998), possessing secondary metabolites with an important role in biology, ecology and evolution them (Peters et al., 2018).

Life on Earth developed through the interaction of plants, animals, and microorganisms, and it is only natural that the secondary metabolites of bryophytes have medicinal qualities, as do those of vascular plants.

To date, biologically active compounds (lipids, proteins, polyphenols, terpenoids, organic acids, fatty acids, diterpenoids, bibenzyl, bis-bibenzyl, polyketides, etc.) with antibacterial, antitumor, antifungal, insecticidal activity have been reported (Glime, 2007; Novaković et al., 2021).

By consulting the bryological literature, 34 species of medicinal bryophytes for human use were identified from 979 species of Romanian bryoflora. These species are separated into a distinct phyla: Marchantiophyta and Bryophyta (mosses) and grouped into two categories in the

Red List of treated species: Almost Threatened (NT) (*Ditrichum pallidum*) and Least Concern (LC) the other 23 species (Ștefănuț and Goia, 2012).

Marchantiophyta (liverworts)

1. *Conocephalum conicum* (L.) Underw., fam. Conocephalaceae, in traditional medicine, is used to cure cuts, burns, scalds, and fractures, swollen tissue, snake bites, gallstones, jaundice, as antimicrobial, antifungal and antipyretic (Asakawa, 1998, 2007, 2015; Asakawa et al., 2013; Haris, 2008; Alam, 2012). According to Asakawa (1998) the species contains guianolides that showed antitumor activity against P-388 lymphocytic leukemia. The research conducted by Negi et al. (2020) showed good antifungal activity for the acetone extract of *Conocephalum conicum* (collected from Kumaon region of Western Himalaya: altitude 1400 m and 2100 m) against *Aspergillus flavus* and *Aspergillus parasiticus* species (aflatoxigenic species). The authors identified 30 main compounds in the acetone extract (riccardin C, citronellol, geranylgeraniol, phytol, spathulenol, globulol, steroids, fatty acids, etc.).

Methanolic extracts mainly contain monoterpene esters, sesquiterpene lactones and phenethyl glycosides, but do not contain macrocyclic bis-bibenzyls (Ivković et al., 2021). The species is used ethnomedicinally in China, India, Italy (Motti et al., 2023).

In Romania, it is found in the regions of Banat, Bucovina, Maramures, Moldova, Muntenia, Transylvania, Oltenia, distributed in moist places on the ground, on the humus on stones and rocks, on the side of the roads. The thallus emits an aromatic odor when broken. It is included on the Red List of treated species as Least Concern (LC) taxon.

2. *Frullania tamarisci* (L.) Dumort., fam. Frullaniaceae, is used ethnomedicinally in China as an antiseptic (Asakawa, 1998, 2007; Haris, 2008). The dietyl eter extract contains monoterpenes, sesquiterpenes hydrocarbons and lactones and oxygenated sesquiterpenes (Ludwiczuk and Asakawa, 2021).

In Romania it is found in Banat, Bucovina, Moldova, Muntenia, Oltenia, Transylvania.

It grows in the form of cortico-saxicolous mats. It is included on the Red List of treated species as Least Concern (LC) taxon.

3. *Marchantia polymorpha* L., fam. Marchantiaceae, is used ethnomedicinally for liver diseases, as well as for pulmonary tuberculosis, cardiovascular diseases, bladder stones, skin inflammations, insect bites, boils, abscesses and pimple eruptions, fractures, poisonous snake bites, burns, scalds and open wounds (Asakawa, 1998; Glime, 2007; Haris, 2008; Asakawa et al., 2013; Wang et al., 2016). It is used ethnomedicinally in Brazil, China, India, Europe (Estonia) (Glime, 2007; Motti et al., 2023).

Contains the sesquiterpenoids costunolide and tulipinoid (Kanasaki and Ohta, 1976; Glime, 2007); flavonoids (Wang et al., 2016); bis-bibenzyls (marchantin A, B, C, D, E, F, G, J, L, neomarchantin A, riccardin D, etc.) (Asakawa, 2017); and fatty acids (Lu et al., 2019). The following groups of compounds were identified in the methanolic extracts: terpenes, oils, sugars and bis-bibenzyls (marchantin A as one of the most dominant). These extracts showed antimicrobial activity against Gram positive bacteria (Ivković et al., 2021).

Various biological activities are reported for this species in the available literature: antipyretic, antidotal, diuretic (Askawa, 1998; Askawa et al., 2013); antioxidant activity (Wang et al., 2016); antifungal (*Candida*), antiviral, cytotoxic and apoptotic, cardiotonic, muscle relaxant, antioxidant, calcium inhibitor, inhibition of nitric oxide production and antitrypanosomal activity (Asakawa, 2017).

In Romania it is widespread in Banat, Bucovina, Dobrogea, Maramures, Moldova, Muntenia, Transylvania, Oltenia, Dobrogea, distributed on clayey, moist and shady soils, sometimes in swamps. It is included on the Red List of treated species as Least Concern (LC) taxon.

4. *Reboulia hemisphaerica* (L.) Raddi, fam. Aytoniaceae, is used ethnomedicinally to stop bleeding, treat wounds and bruises in China (Asakawa, 1998; 2007; Abay, 2011). The ethanol extract contains as the main biologically active substances terpenic and bis-bibenzyl phenolic compounds (riccardin C, marchantin C, M, N, O, marchantiaquinone) with antimicrobial, anticancer, antifungal, antiviral, cytotoxic, antioxidant, anti-inflammatory, analgesic effects, myorelaxant antiobesity and wound healing activities (Tosun et al., 2016; Asakawa, 2017).

In Romania it is spread in Banat, Dobrogea, Maramures, Muntenia, Transylvania, Oltenia, distributed on calcareous rocks. It is included on the Red List of treated species as Least Concern (LC) taxon.

5. *Riccardia multifida* (L.) Gray, fam. Aneuraceae. The methanol extract contains macrocyclic bis-bibenzyl derivatives, riccardin A and B, which inhibited KB cells at a concentration of 10 and 12 μg/ml, respectively (Alam, 2012). It is medicinally active for antileukemic and stomach pain and swelling in cattle (Azuelo et al., 2011; Alam, 2012).

In Romania it is found in Bucovina, Moldova, Muntenia, Transylvania, distributed in open spaces, on rotten logs, wet rocks, wet soil, swamps and peat bogs. It is included on the Red List of treated species as Least Concern (LC) taxon.

6. *Riccia fluitans* L., fam. Ricciaceae, is useful in healing wounds (Tosun et al., 2016) and infections (Lawarence et al., 2023). The methanol extract contains phytosterol mixtures and acetylene fatty acids (Asakawa, 2004) saturated fatty acids, monounsaturated fatty acids, polyunsaturated fatty acids, acetylenic acids (Lu et al., 2019).

In Romania it is widespread in Banat, Dobrogea, Maramures, Moldova, Muntenia, Transylvania. It is a floating plant that grows in moist marshy places, preferring calm waters. It is included on the Red List of treated species as Least Concern (LC) taxon.

7. *Diplophyllum taxifolium* (Wahl.) Dum., fam. Scapaniaceae. The methanol extract contains essential oil with diplophyllin. Diplophyllin shows cytotoxic activity against human epidermoid carcinoma (Bandyopadhyay and Dey, 2022). In Romania it is widespread in Bucovina, Maramures, Muntenia, Transylvania, distributed on stone, siliceous rocks, in the mountain area. It is included on the Red List of treated species as Least Concern (LC) taxon.

Bryophyta (mosses)

1. *Atrichum undulatum* (Hedw.) P. Beauv, fam. Polytrichaceae. The chloroform/methanol extract contains: sterols (major: 24-methylcholesterol and 24-ethyl-22-dehydrocholesterol), carotenoids (-carotene, lutein, violaxanthin, and neoxanthin) (Dembitsky, 1993), fatty acids (major: linoleic acid, -linolenic acid, palmitic acid, oleic acid, and arachidonic acid) (Pejin et al., 2012), coumarin glycosides (Jung et al., 1994). It has an antimicrobial effect against the bacterial species *Escherichia coli, Pseudomonas aeruginosa, Salmonella typhimurium, Enterobacter cloacae, Listeria monocytogenes, Bacillus cereus, Micrococcus flavus* and *Staphylococcus aureus* (Sabovljevic et al., 2010). The anticancer effect is also mentioned in chinese ethnomedicine (Du, 1997).

In Romania it is found in Banat, Bucovina, Dobrogea, Maramures, Moldova, Muntenia, Transylvania, distributed on acidic clayey or

sandy soils, on calcareous soils in forests, from hilly to mountainous areas. It is included on the Red List of treated species as Least Concern (LC) taxon.

2. *Barbula unguiculata* Hedw., fam. Pottiaceae, has been used as an analgesic and decrease fever (Chandra et al., 2017). It is used in traditional medicine in India and the United States (Haris, 2008; Lubaina et al., 2014). There are no chemical or pharmacological studies on this species. (Vollár et al., 2018).

In Romania it is found in Banat, Moldova, Transylvania, Oltenia, Dobrogea, distributed in lowlands, hills, less in the mountains, on the ground, on fields, on roadsides, sometimes through forests, on walls, rarely on stones and rocks. It is included on the Red List of treated species as Least Concern (LC) taxon.

3. *Bartramia ithyphylla* Brid., fam. Bartramiaceae. The methanol and acetone extract contains macrocyclic biflavonoid (Marko et al., 2001) and is used in traditional Chinese medicine to suppress fear, calms nerves, irregular heartbeat, epilepsy, apoplexy (Du, 1997).

In Romania it is found in Bucovina, Maramures, Moldova, Muntenia, Oltenia, Transylvania, distributed on sandy soil with humus in forests, through the cracks of siliceous rocks and in the mountainous area. It is included on the Red List of treated species as Least Concern (LC) taxon.

4. *Bryum argenteum* Hedw. Fam. Bryaceae. The ethanolic extract contains flavonoids with antimicrobial activity against various bacterial (*Escherichia coli, Staphilococcus aureus, Bacillus subtilis, Micrococcus luteus*) and fungal strains (*Aspergillus niger, Penicillium ochrochloron, Candida albicans, Trichophyton mentagrophyes*) strains (McCleary et al., 1960; Karpiński and Adamczak, 2017; Markham and Given, 1988). *B. argenteum* showed the highest antimicrobial activity for *E. coli* and *S. aureus* (Vollár et al., 2018).

This species has also been used as an antidotal, antipyretic and antirhinitis treatment (Alam, 2012; Asakawa, 1998, 2015; Asakawa et al., 2013).

It is used in traditional Chinese medicine (Haris E S, 2008). In Romania it is found in Banat, Bucovina, Dobrogea, Moldova, Muntenia, Oltenia, Transilvania from the lowland to the alpine area. It is distributed on cultivated and uncultivated land, on sandy soils, sea dunes, rocks covered with earth, in rock cracks and on roofs. It is included on the Red List of treated species as Least Concern (LC) taxon.

5. *Ptychostomum capillare* (Hedw.) D.T.Holyoak & N.Pedersen., fam. Bryaceae, is used in traditional medicine in the United States for activity against fire sickness, fever, and body aches (Motti et al., 2023). It has antimicrobial, antibiofilm, antioxidant, antigenotoxic and anticancer activities. The ethanolic extract has reduced amounts of ascorbic acid and α-tocopherol (Onbasli and Yuvali, 2021).

In Romania it is found in Banat, Bucovina, Dobrogea, Maramures, Moldova, Muntenia, Oltenia, Transylvania, distributed in forests, in rock cracks, rarely at the base of tree trunks, starting from low to subalpine regions. It is included on the Red List of treated species as Least Concern (LC) taxon.

6. *Climacium dendroides* (Hedw.) F. Weber & D. Mohr, fam. Climaciaceae, is used in traditional Chinese medicine to clear heat, eliminate dampness, relax muscles, rheumatism, and bone and muscle pain (Motti et al., 2023). *Climacium dendroides* contains: fatty acids, monoglycerols, terpenoids, alcohols, sterols, diterpenes, alkanes, wax esters, triterpenes, steroids, polyphenols, amino acids (Klavina et al., 2015). Ethanolic extracts demonstrated pronounced antibacterial activity

against *Bacillus cereus* and *Escherichia coli* species and antiproliferative activity on various animal and human cancer cell lines (Klavina et al., 2015). In Romania it is very widespread in Transylvania, Bucovina, Moldova, Muntenia and to a lesser extent in Banat, Oltenia and Maramureș. It is distributed on the ground in places with high humidity, often near lakes, swamps, in hygrophilous meadows and through forests, rarely at the base of wet trees. It is included on the Red List of treated species as Least Concern (LC) taxon.

7. *Cratoneuron filicinum* (Hedw.) Spruce, fam. Amblystegiaceae, has antibacterial activity evidenced by methanolic extracts obtained from biological material collected from Derventa (Serbia) (Bukvički et al., 2012). It has ethnomedicinal use in China for calming and soothing, heart problems - used for malum cordis (heart disease) in the Western Himalayas (Alam et al., 2015; Asakawa et al., 2013).

In Romania it is found in Banat, Bucovina, Maramures, Moldova, Muntenia, Transylvania, Oltenia. It grows in sparse mats on calcareous substrate, in very wet, floodable places, on the edge of water, in swamps, on stones and at the base of trees near water, in hilly and mountainous regions. It is included on the Red List of treated species as Least Concern (LC) taxon.

8. *Dicranum majus* Turner, fam. Dicranaceae, has ethnomedicinal use in China for clearing lungs and stops cough (Motti et al., 2023). Dry 70% ethanol extracts of *Dicranum majus* have anti-inflammatory effect (Marques et al., 2022).

In Romania it is widespread in Bucovina, Maramures, Transylvania, distributed on siliceous rocks, on moist soil, rotten trunks, in mountain forests and in the subalpine layer. It is included on the Red List of treated species as Least Concern (LC) taxon.

9. *Dicranum bonjeanii* De Not., fam. Dicraniaceae, is used ethnomedicinally in Canada and the United States as an absorbent (Motti et al., 2023). There are no chemical or pharmacological studies on this species.

In Romania it is widespread in Banat, Bucovina, Maramures, Muntenia, Transylvania. It prefers to grow in eutrophic swamps and calcareous habitats, while avoiding acidic substrates. It is included on the Red List of treated species as Least Concern (LC) taxon.

10. *Ditrichum pallidum* (Hedw.) Hampe, fam. Ditrichaceae, is used ethnomedicinally in China and India for convulsions, particularly in infants (Asakawa, 1998, 2007; Haris, 2008; Asakawa et al., 2013). There are no chemical or pharmacological studies on this species.

In Romania it is widespread in Banat, Moldova, Oltenia, Transylvania, distributed on the ground among calcareous rocks. It is included on the Red List of treated species as Almost Threatened (NT) taxon.

11. *Funaria hygrometrica* Hedw., fam. Funariaceae, is used ethnomedicinally in China and Germany for pulmonary tuberculosis, hemostasis, bruises, skin infections, athlete's foot dermatophytosis, blood vomiting, light sedative, nose inflammation and sinusitis, alopecia (Asakawa, 2007; Haris, 2008; Asakawa et al., 2013; Chandra et al., 2017). In Romania, it is used ethnomedicinally for its diuretic, sudorific, astringent and expectorant properties (Alexan et al., 1983).

The methanol, chloroform, and acetone extracts obtained from this species contain terpenoids and alkaloids with antimicrobial activity against *Bacillus subtilis* and *Staphylococcus aureus* (Savaroglu et al., 2011).

In Romania it is widespread in Banat, Bucovina, Dobrogea, Maramures, Moldova, Muntenia, Transylvania, Oltenia, distributed on various substrates in mats, on the ground, fields, uncultivated places, in forests, through clearings, on dry sands, sometimes in marshes, on sea dunes, stones and rocks covered with

soil, rarely on rotten wood or at the base of trees. It is common in all areas. It is included on the Red List of treated species as Least Concern (LC) taxon.

12. ***Homalothecium sericeum*** (Hedw.) Schimp., fam. Brachytheciaceae, has medicinal activity as antimicrobial, antioxidant and insecticidal (Ozturk et al., 2018; Çolak et al., 2011).

The acetone extract of *Homalothecium sericeum* has highest antibacterial activity against *Pseudomonas aeruginosa* (Oztopcu-Vatan et al., 2011).

In Romania it is widespread in Banat, Bucovina, Dobrogea, Maramures, Moldova, Muntenia, Transylvania, Oltenia, distributed on sunny rocks, sparse forests on tree trunks. It is included on the Red List of treated species as Least Concern (LC) taxon.

13. ***Hypnum cupressiforme*** Hedw., fam. Hypnaceae. The ethanol, methanol, acetone and chloroform extracts contain biologically active compounds, such as flavonoids, phenolic acids and triterpenoids with complex antimicrobial, antioxidant, antifugic medicinal activity (Lunić et al., 2020; Çolak et al., 2011). Antimicrobial activity is against *Bacillus subtilis* and *Staphylococcus aureus* species (Savaroglu et al., 2011; Ertürk et al., 2015).

In Romania it is spread in Banat, Bucovina, Dobrogea, Maramures, Moldova, Muntenia, Transylvania, Oltenia, distributed on the ground, at the base of tree trunks, rotting wood, on stones and rocks covered with earth, in sess forests, hills, mountains and in the subalpine areas. It is included on the Red List of treated species as Least Concern (LC) taxon.

14. ***Hylocomium splendens*** (Hedw.) Schimp, fam. Hylocomiaceae, is used ethnomedicinally in Canada and Italy as a poultice for treating wounds (sores) (Motti et al., 2023).

The volatile oil extracted from *Hylocomium splendens* showed antimicrobial activity against *Escherichia coli, Yersinia pseudotuberculosis, Staphylococcus aureus, Enterococcus faecalis, Bacillus cereus, Mycobacterium smegmatis* and *Candida albicans* species (Cansu et al., 2013; Klavina et al., 2015) identified the following groups of substances from *Hylocomium splendens* extracts (collected from Latvia): fatty acids, monoglycerols, terpenoids, alcohols, sterols, diterpenes, alkanes, wax esters, triterpenes, steroids, polyphenols. amino acids. According to the cited authors, the ethanolic extracts demonstrated antibacterial activity against *Bacillus cereus* and *Pseudomonas aeruginosa* species.

In Romania it is widespread in Banat, Bucovina, Maramures, Moldova, Muntenia, Transylvania, Oltenia. It grows on acid soil, rocks, rotting trunks, in more or less lighted places, in mountain forests, in junipers and the alpine layer, rarely in the region of high hills. It is included on the Red List of treated species as Least Concern (LC) taxon..

15. ***Philonotis fontana*** (Hedwig) Brid., fam. Bartramiaceae, is used ethnomedicinally in China as antipyretic, drawing out toxins, sore throat, diuretic, urinary obstructions (Chandra et al., 2017). The ethanol extract obtained from *Philonotis sp*. contains flavonoids and carotenoids (Marko et al., 2001). Asakawa (1998) and Asakawa et al. (2013) mentions the species with antipyretic, antidotal activity, for andenopharyngitis.

In Romania it is widespread in Banat, Bucovina, Maramures, Moldova, Muntenia, Transylvania, Oltenia. It always grows in a wet place (in springs, spring streams), rocks with drainage in the mountain area. It is included on the Red List of treated species as Least Concern (LC) taxon.

16. ***Plagiomnium cuspidatum*** (Hedw.) T.J. Kop., fam. Mniaceae. The methanol extract contains sesquiterpenoids (Suire et al., 2000). This species demonstrated antimicrobial

activity (against *Bacillus cereus, Staphylococcus aureus, Staphylococcus epidermidis*) (Yildirim Akatin et al., 2022) and antiproliferative activity (against cancer cell lines) (Vollár et al., 2018).

In Romania it is widespread in Banat, Bucovina, Dobrogea, Moldova, Muntenia, Transylvania, Oltenia, distributed on the ground, at the base of tree trunks, on exposed roots, in forests, sometimes in meadows, on humus on moist and shaded rocks, in hill and mountain regions. It is included on the Red List of treated species as Least Concern (LC) taxon.

17. ***Plagiopus oederianus*** (Sw.) H. A. Crum et L. E. Anderson, fam. Bartramiaceae, is used ethnomedicinally in China as a sedative, in epilepsy, apoplexy, cardiovascular diseases (Asakawa et al., 2013). It is not studied chemically and pharmacologically. In Romania it is widespread in Transylvania, Moldova and sporadically in Maramures, Muntenia, Oltenia. It grows on moist calcareous, sometimes siliceous rocks in mountain and alpine regions. It is included on the Red List of treated species as Least Concern (LC) taxon.

18. ***Pogonatum urnigerum*** (Hedw.) P. Beauv. Fam. Polytrichaceae, is cited as antifungal agent (Asakawa, 1998). In Romania, it is mentioned ethnomedicinally as a useful species against rheumatism (Alexan, 1983; Butură, 1979). It is little studied chemically and pharmacologically. Lu et al. (2023) studied the long-chain polyunsaturated fatty acid profile of *Pogonatum urnigerum* collected from Iceland.

In Romania it is spread in Banat, Bucovina, Maramures, Moldova, Muntenia, Oltenia, Transylvania. It grows on acid, dry or moist, light soils, in forests in hilly and mountainous areas. It is included on the Red List of treated species as Least Concern (LC) taxon.

19. ***Polytrichum commune*** Hedw., fam. Polytrichaceae, is used ethnomedicinally in Canada, China, Germany, Ecuador, India, Guatemala, United Kingdom as anti-inflammatory and antidotal, hemostatic, gallbladder and kidney, stones, to speed up the birth of a baby during childbirth, to strengthen hair (Glime, 2007, Asakawa, 2015; Bandyopadhyay and Dey, 2022). Alexan et al. (1983) mentions the use of this species in traditional Romanian medicine for its diuretic, sudorific, astringent and expectorant properties.

The methanol extract from *Polytrichum commune* contains luteolin, quercetin, astragalin, rutin (Nam et al., 2008) sterols, terpenoids, fatty acids, polyphenolics, carbohydrates, amino acids (Klavina et al., 2015). Ethanol extracts have high antibacterial activity against *Bacillus cereus* and *Staphylococcus aureus* and antiproliferative activity on different animal and human cancer cell lines (Klavina et al., 2015).

In Romania it is widespread in Banat, Bucovina, Maramures, Moldova, Muntenia, Transylvania, Oltenia, distributed on acid soils, in peat bogs, in mountain forests and on the alpine area. It is included on the Red List of treated species as Least Concern (LC) taxon.

20. ***Polytrichum juniperinum*** Hedw., fam. Polytrichaceae, is used ethnomedicinally in Canada, China, India, United Kingdom for prostate diseases, urinary difficulties, sores, boils, and swelling (Glime, 2007; Motti et al., 2023).

The methanol extract obtained from this species contains anthraquinone derivatives, terpenoids, flavonoids, alkaloids and have demonstrated antimicrobial activity (against *Bacillus subtilis, Pseudomonas aeruginosa* and *Staphylococcus aureus*) (Savaroglu et al., 2011).

Polytrichum juniperinum (collected from Latvia) contains fatty acids, monoglycerols, terpenoids, alcohols, sterols, diterpenes, alkanes, wax esters, triterpenes, steroids, polyphenols, aminoacids and the ethanolic extracts have demonstrated antiproliferative

activity on different animal and human cancer cell lines (Klavina et al., 2015).

In Romania it is widespread in Banat, Bucovina, Dobrogea, Maramures, Moldova, Muntenia, Transylvania, Oltenia, distributed in more or less lighted forests, in dry or wet resorts, sometimes on old decaying trunks, starting from the low regions to the alpine ones. It is included on the Red List of treated species as Least Concern (LC) taxon.

21. *Rhizomnium punctatum* (Hedw.) T.J. Kop., fam. Mniaceae, is used in the United States as a treatment for leg swelling (Abay, 2011; Motti et al., 2023). *R. punctatum* shows antimicrobial activity against the species *Bacillus cereus, Staphylococcus aureus, Staphylococcus epidermidis* (Yildirim Akatin et al., 2022). Lu et al. (2023) studied the long-chain polyunsaturated fatty acids profile of *R. punctatum* collected from Iceland.

In Romania it is widespread in Banat, Bucovina, Maramures, Moldova, Muntenia, Transylvania, Oltenia, distributed on moist soil, often with gravel, near streams, springs in forests in the hills and mountains. It is included on the Red List of treated species as Least Concern (LC) taxon.

22. *Rhodobryum roseum* (Hedw.) Limpr., fam. Bryaceae. The ethanol extract contains piperine and methyl piperate that exert significant protective effects on cardiac myocytes (Hu et al., 2009). It is used ethnomedicinally as remedy for cardiovascular diseases, high cholesterol, being also cited for its sedative properties in China and India (Asakawa, 2007; Glime, 2007).

In Romania it is widespread in Bucovina, Moldova, Muntenia, Transylvania, Oltenia, distributed on the ground, sometimes on gravel or wet rocks covered with earth, in shady forests, in hilly and mountainous regions. It is included on the Red List of treated species as Least Concern (LC) taxon.

23. *Sphagnum girgensohnii* Russow, fam. Sphagnaceae is used ethnomedicinally in China as a surgical dressing (Haris, 2008; Motti et al., 2023). The ethanol extract obtained from *Sphagnum girgensohnii* contains p-coumaric acid and rutin (Zych et al., 2023).

In Romania it is widespread in Banat, Bucovina, Maramures, Moldova, Muntenia, Transylvania, Oltenia, distributed in very humid depressed places in mountain forests up to the alpine area. It is included on the Red List of treated species as Least Concern (LC) taxon.

24. *Sphagnum magellanicum* Brid., fam. Sphagnaceae, is used ethnomedicinally in China and Canada for surgical dressings, diapers (Motti et al., 2023). The ethanol extract contains sterols, triterpenoids- ursolic acid, fatty acids, fatty alcohols, n-alkanes, wax ester, phenolics (Baas et al., 2000; Alam, 2021). According to Klavina et al. (2015) *Sphagnum magellanicum* contains fatty acids, monoglycerols, terpenoids, alcohols, sterols, diterpenes, alkanes, wax esters, triterpenes, steriods, polyphenols, aminoacids and the ethanolic extracts have demonstrated antibacterial activity (against species *Bacillus cereus* and *Escherichia coli*) and antiproliferative activity (on different animal and human cancer cell lines). Zyck et al. (2023) identified in *Sphagnum magellanicum* extracts: p-coumaric acid, rutin and quercetin; the extracts show strong antioxidant activity.

In Romania it is widespread in Banat, Bucovina, Maramures, Moldova, Muntenia, Transylvania, Oltenia. It grows in peat bog. It is included on the Red List of treated species as Least Concern (LC) taxon.

25. *Sphagnum palustre* L., fam. Sphagnaceae, is used ethnomedicinally in China for surgical dressing, eye diseases (Motti et al., 2023) and in Korea for several diseases such as heart pain and stroke (Nam et al., 2011). The ethanol extract contains sterols, ursolic acid, fatty acids, fatty alcohols, n-

alkanes, wax ester (Baas et al., 2000). Coumarin, caffeic acid, quercetin, astragalin, chlorogenic acid, rutin were identified in the ethanolic extract (Nam et al., 2011; Zych et al., 2023). Eom et al. (2016) reported that ethanolic extracts of *S. palustre* (collected from Korea) showed inhibitory effect on aromatase activity.

In Romania it is spread in Banat, Bucovina, Maramures, Moldova, Muntenia, Transylvania, Oltenia. It grows in moist coniferous forests and marshy meadows. It is included on the Red List of treated species as Least Concern (LC) taxon.

26. *Sphagnum squarrosum* Crome, fam. Sphagnaceae, is used ethnomedicinally in China as a surgical dressing (Motti et al., 2023; Haris, 2008). The ethanol extract from *Sphagnum squarrosum* contain p-coumaric acid, rutin and apigenin (Zych et al., 2023) .

In Romania it is widespread in Banat, Bucovina, Maramures, Moldova, Muntenia, Transylvania, Oltenia. It grows in bogs, wet places, depressed places with increased humidity, in mountain forests, in the subalpine area. It is included on the Red List of treated species as Least Concern (LC) taxon.

27. *Weisia controversa* Hedw., fam. Pottiaceae, is used ethnomedicinally in China to clear heat and relieves toxicity, nose inflammation and sinuses (Motti et al., 2023). It has also been used to treat the liver disorder (Bandyopadhyay and Dey, 2022). It is not analyzed chemically and pharmacologically.

In Romania it is widespread in Banat, Bucovina, Moldova, Muntenia, Transylvania, Oltenia, distributed on the ground, in fields, uncultivated places, wet rocks, in lowland, hilly and mountainous regions. It is included on the Red List of treated species as Least Concern (LC) taxon.

We find that of the 34 bryophyte species existing in Romania and registered as medicinal plants globally, 22 are used in China, where traditional medicine is over 4000 years old (Tan and Vanitha, 2004). Chemical and pharmacological investigation of the gametophyte extract of the species mentioned in this article and the age of use of the 22 species from China constitute serious evidence that Romanian bryophytes represent an important natural source for obtaining new drugs for the treatment of human diseases.

Conclusions

The data in the article contains 34 species of bryophytes, with ethnomedicinal use in different parts of the world: China, India, Italy, Brazil, Estonia, United States of America, Canada, Romania, Germany, Ecuador, Guatemala, Great Britain, Korea.

2. Many species of bryophytes have antimicrobian action: *Rhizomnium punctatum, Polytrichum juniperinum, Polytrichum commune, Plagiomnium cuspidatum, Hylocomium splendens, Hypnum cupressiforme, Homalothecium sericeum, Funaria hygrometrica, Climacium dendroides, Ptychostomum capillare, Bryum argenteum, Marchantia polymorpha, Conocephalum conicum.*

3. Bryophytes contain secondary metabolites with therapeutic potential in the treatment of serious ailments, common today: *Diplophyllum taxifolium* has anticancer activity against human epidermoid carcinoma, *Polytrichum juniperinum* is used in prostate diseases, and *Riccardia multifida* has antileukemic activity.

4. The ethno-medicinal properties of *Sphagnum* species recommend their use as a dressing with good and fast absorption.

5. All species with medicinal potential have a degree of vulnerability, but *Ditrichum pallidum* requires more careful protection.

Chemical and pharmacological studies can focus on species with medicinal potential that

have been less studied and are mentioned in this paper.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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