RARE LICHENE SPECIES FROM MOLDOVA AND THEIR USE IN ENVIRONMENTAL QUALITY BIOMONITORING

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Abstract. Over the time, researches developed in Moldova highlighted that lichen species currently number 196 species, of which 73 are Rare species for Moldova, and 13 of them are included in the Red Book of Moldova (2015). Rare species can serve as ecobioindicators of separate ecosystems, but their use in biomonitoring, on a large scale, is not recommended. Among the Rare species of lichens, the literature specify that 41 species are sensitive to environmental pollution with SO_2, and 8 species are receptive to NOx pollution. True indicators of environmental acidification are 14 species, of which 9 species prefer acidic environments with pH lower than 5.4. Epilithic species (25) inhabit calcareous (11 species) and siliceous (14 species) rocks, and only 2 species are with toxitolerance I and II, i.e. quite sensitive to pollution, i.e. species with crustose thallus are the most not recommended in ecobioindication. Thus, petrophyte ecosystems cannot be included in the air quality monitoring network based on lichen indication, with the exception of petrophyte-forest ecosystems.

Keywords: Lichens, rare species, bioindicators, pollution, biomonitoring.

Rezumat. Specii rare de licheni în Moldova și utilizarea lor în biomonitoringul ecologic. De-a lungul timpului, conspectul lichenilor Moldovei a evidențiat că actualmente numără 196 de specii, dintre care: 73 sunt specii Rare pentru Moldova, iar 13 dintre acestea sunt incluse în Cartea Roșie a Moldovei (2015). Speciile rare pot servi ca ecobioindicatori ai unor ecosisteme separate, dar utilizarea lor în biomonitoring, pe scară largă, nu este recomandată, Dintre speciile rare de licheni, literatura specifică faptul că sensibili la poluarea mediului cu SO_2 sunt 41 de specii, iar receptive la poluare cu NOx sunt 8 specii. Indicatori veritabili ai acidifierii mediului sunt 14 specii, dintre care 9 specii preferă mediul acid cu pH mai mic de 5,4. Speciile epilitice (25) populează rocile calcaroase (11 specii) și silicoase (14 specii), și doar 2 specii sunt cu toxitoleranţa I și II, adică destul de sensibile la poluare, adică speciile cu tal crustos sunt cele mai nerecomandate în ecobioindicaţie. Astfel, ecosistemele petrofite nu pot fi incluse în reţeaua de monitorizare a calităţii aerului pe baza lichenoindicaţiei, excepţie fiind cele petrofit-forestiere.

Cuvinte cheie: Licheni, specii rare, bioindicatori, poluare, biomonitoring.

INTRODUCTION

Lichens probably existed already at the beginning of the Paleozoic era (about 500 million years ago). Currently, there are over 20,000 species (RAVEN, EVERT, EICHHORN, 1990) included in about 400 genera. They are symbiotic organisms consisting of fungi (mycobiont) and algae (phycobiont). According to the structure of the body, we distinguish species with the following bodies: coriaceous - shells attached to the substrate (e.g. *Graphis scripta*); foliaceous - leaves (e.g. *Xanthoria parietina*) and fruticulous - tericulate or suspended bushes (e.g. *Usnea hirta*) (OXNER (1956), GOLUBKOVA (1966).

Among the ecological groups, we distinguish lichens: epilithic - on rocks; epiphleoid - on bark; epigeic - on soil; epixylic - on xylem.

The first scientific lichenological information from Bessarabia belongs to the agronomist engineer VRABIE (1934), assistant at the National Museum of Natural History in Chisinau, who describes 30 species from 5 habitats around Chisinau: the Durleşti and Căpriana forests, the plum orchards in Valea Dicescu and near Ghidighici, and the *Sophora* trees on the Cricova School road.

In Moldova, scientific investigations on lichens are gaining momentum thanks to the research of the collaborator of the Botanical Garden, who confirms the existence of 124 species of lichens on the territory of the Republic of Moldova (SIMONOV et al. 1994; SIMONOV 2000; 2004). Contributions to the study of lichens were also made by: MÎRZA & OBUH (2004) in 1961, 1988, 1995, 1999 – studying the lichens of the OS Călineşti and Balatina and of the Scientific Reserve "Pădurea Domnească", indicating 58 species (28 – previously undescribed for the Republic of Moldova); OBUH & COLUN (2001), studied the saxicolous lichens from the middle sector of the Prut, indicating 22 species, of which 9 previously undescribed for the Republic of Moldova; The doctoral thesis of the professor Kondratyk (Kiev Institute of Botany) VASILENKO (2005) indicates 21 species of lichens in the forest near the village of Merenești (Tighina), of which 4 are new species for Moldova. The contribution of the above-mentioned researchers, etc., has contributed to the completion of the list of lichens of Moldova, which currently numbers 196 species (BEGU, 2010), of which: 73 are Rare species for Moldova, and 13 of them are included in the Red Book of Moldova, 3rd edition (2015). Rare species (73) can serve as ecobioindicators of separate ecosystems, but their use in large-scale ecobioindication is not recommended, especially in research that depends on the collection of samples for subsequent laboratory analysis. They deserve to be studied, in particular, for their conservation in preferable habitats, by creating state-protected areas.

The undersigned Begu A. initiated research in the field of ecobioindication, using lichens in 2001 within the National Institute of Ecology (INECO) where the Ecobioindication laboratory was founded, the research theme being oriented towards lichenindication. Later, together with Dr. Gh. Simonov (2002-2005), the lichen register of the Republic

of Moldova was completed with another 22 species new to the country (BEGU, 2009). Unfortunately, until our study, presented in various publications, practically, rare species of lichens were not included, as the scientific value of a naturally protected area (as well as other groups of organisms – mosses, algae, fungi, insects, mollusks, etc.).

A number of states, including the most developed ones, widely use the bioindication method in monitoring environmental quality. Bioindication is based on the study of species and communities of organisms, sensitive to changing external environmental conditions, or with cumulative characteristics, especially of chemical pollutants, i.e. ecobiological monitoring or ecobiomonitoring is applied, expressed by the ecobioindication method. This method makes it possible to obtain information about fluctuations in time and space, the accumulation or synergism effect between certain abiotic factors and the response of living organisms to environmental changes (BLANDIN, 1986).

Taking into account the primary importance of forest ecosystems in biodiversity conservation, as well as urban ones, in strengthening population health, the application of bioindication in environmental monitoring, both separately and integrated with instrumental methods, would allow for a more truthful monitoring of the state of biota elements under technogenic impact. Thus, monitoring the state of the environment through the biological monitoring method, based on the principle of ecobioindication, a direction promoted at European level and by the CONVENTION ON LONG-RANGE TRANSBOUNDARY AIR POLLUTION (GENEVA, 1979), is becoming quite current.

Taking a broad retrospective of phyto- and zooindication, the biomonitoring method is proposed for use in monitoring the state of forest ecosystems as an important alternative to the instrumental method (MĂCIUCĂ, 2003).

The best-known bioindicators of air quality are lichens, successfully used in ecological monitoring in many countries of the world, because they allow testing, at the same time, both air pollution with gaseous compounds (especially SO_2) and with heavy metals. The content of heavy metals in lichens correlates quite well with their level in the atmosphere, decreasing with distance from the pollution source (BURTON, 1986). Lichens are more widely distributed and large scales of environmental quality monitoring have already been developed for them at national and international levels.

MATERIAL AND METHODS

Lichen species were collected from various natural ecosystems (over 100) during field expeditions (2002-2025) and were determined in the laboratory with special determinants: OXNER (1974), SIMONOV (2004), KONDRATYUK et al. (1998), GOLUBKOVA (1966).

The degree of rarity is established according to information published by the above mentioned authors and some RED LISTS/BOOKS OF MOLDOVA (2015), UKRAINE (2009).

The assessment of the resilience of ecosystems to anthropogenic impact (especially SO_2 in the air) is carried out by non-instrumental methods, as recommended by the Geneva Convention (1979), expressed by the bioindication method, and lichens are used as indicator species, which give us the opportunity to assess the degree of atmospheric air pollution with SO2 and heavy metals. Collection of samples for species determination and samples (10 g d.u.) for laboratory analysis – traditionally, in polyethylene bags, from tree trunks (up to about 1.8-2.0 m high) or from other substrates (rocks, soil, roof, wood, etc.)

The lichen indication method is a non-instrumental method most indicated by the literature (HAWKSWORTH & ROSE, 1970; TRASS, 1984; BARTOK, 1985). For Moldova, the Lichen Toxicolerance Scale is used, with 6 steps (BEGU, 2009), of which 5 steps are characterized by certain indicator species of lichens, and the 6th step is completely devoid of lichens.

RESULTS

Of the 73 rare lichen species, 53 species exhibit more pronounced ecological peculiarities and, of course, they are better known to scientific researchers in the field of biology (being rare), but also serve as indicators of the state of the environment (Table 1). The presence of rare species with toxitolerance I (17 species) and II (10 species) demonstrates that the atmospheric air is clean (>0.05 mg/m3 of air) or, respectively, slightly polluted (0.05-0.1 mg/m3 of air) with SO_2. Thus, 6 species with toxitolerance I are included in the RED BOOK OF THE REPUBLIC OF MOLDOVA, edition III (2015), 3 of them are critically endangered (CR) and 2 were recorded only in one location: *Cladonia glauca* – TP Briceni, mixed, epixylic forest, *Peltigera rufescens* – MNGP Stânca Mare, on moss), and one - *Dermatocarpon miniatum* – in 2 locations (Photo 1, 2, 3); another 3 species are endangered (EN): *Cetrelia cetraroides* – 4 locations, *Peltigera canina* - 5 locations and *Peltigera polydactyla* - 3 locations (Photo 4, 5, 6). The other 5 species included in the Red Book are critically endangered (CR), but for which the toxitolerance is II - *Ramalina fastigiata*, or toxitolerance, at the moment, is unknown - *Cladonia rangiformis*, *Aspicilia gibbosa*, *Catapyrenium squamulossum* and *Catapyrenium rufescens*, but all the last four species are very rare for Moldova (Photo 7, 8, 9, 10, 11). It is worth mentioning one more species for which some indicative particularities are not established - *Xanthoparmelia vagans* - CR; with a single location - Ciucur-Mingir (Cimișlia), but it is included in the RED BOOK OF UKRAINE (Vulnerable) and is specific to the areas of SE Ukraine and southern Bessarabia (Photo 12).

Table 1. List of rare lichens from Moldova and their chorological and ecological particularities (according to The Ainsworth & Bisby's Dictionary of the fungi (HAWKSWORTH et al., 1995) and with the nomenclature proposed by KONDRATYUK et al., 1998).

Nr.	Taxon	Chorology, Terra /RM	Red Book, 2015; locations/ threat	Sensitivity to certain factors and the author of the species record					
				SO_2	NOx	Ca	Si	pH	Author
1	2	3	4	5	6	7	8	9	10
1.	*Opegrapha varia* Pers. *(O. diaphora* Ach.; *O. lichenoides* Pers.; *O. pulicaris* Hoffm. Schrad.)	F/R		II		+			S
2	*Squamarina lamarkii* (DC.) Poelt.	-/R				+			S
3	C*andelariella xanthostigma* (Ach.) Lettau	F/R		III	3			<5,4	S
4	*Cladonia fimbriata* (L.) Fr. f. *fimbriata*	F/R		III					S
5	*Cladonia pyxidata* (L.) Hoffm.	F/R		II					S
6	*Cladonia rangiformis* Hoffm.	F/FR	2/CR			+			S
7	*Cladonia glauca* Florke	F/FR	1/CR	I					B
8	*Aspicilia gibbosa* (Arch.) Korber	-/FR	1/CR				+		SB
9	*Pseudevernia furfuracea* (L.) Zopf. (*Evernia furfuracea* Mann.)	C/R		II	1			<5,4	S SB
10	*Cetrelia cetraroides* (Del. ex Duby)W.L. Culb & C.Culb	R/R	4/EN	I					S
11	*Hypogymnia tubulosa* (Schaer.) Hav.	F/R		III					S
12	*Parmelia olivacea* (L.) Ach.	F/R		III					SB
13	*Parmelia subaurifera* Nyl.	-/R		II					B
14	*Parmelia quercina* (Willd.) Vain.	C/FR		II					V
15	*Parmelia verruculifera* Nyl.	R/R		III				<5,4	S
16	*Parmeliopsis ambigua* (Wulfen) Nyl. (*Parmelia ambigua* Ach.)	C/R		III					OC
17	*Platismatia glauca* (L.) C.Culb.et.W.Culb.	-/R		III	2				S
18	*Usnea dasypoga* (Ach.) Hornem. emend. Mot. var. *dasypoga*	F/FR		I					OBN
19	*Usnea hirta* (L.) F.C.Weber ex F.H.Wigg..	F/FR		I	1				S
20	*Usnea sublaxa* Vaino ap. Norrlin & Nyl.	F/FR		I					OBN
21	*Usnea barbata RNS Sadova*	-/FR		I					B
22	*Anaptychia ciliaris* (L.) Koerb. Ex A. Massal	C/R		II				~7	OBN
23	*Physcia ciliata* (Hoffm.) Du Rietz.	F/R		II					SB
24	*Phaeophyscia nigricans* (Florke) Moberg (*Physcia nigricans* (Flk.) Stizb.)	C/FR		IV					SB
25	*Ramalina farinacea* (L.) Ach.	F/R		III	2				V
26	*Ramalina fastigiata* (Pers.) Ach.	F/FR	1/CR	II					S
27	*Ramalina fraxinea* (L.) Ach. var.*fraxinea*	F/R		I				~ 7	V
28	*Ramalina pollinaria* (Westr.) Ach. var. *pollinaria*	F/R		II	2			~ 7	VSBC
29	*Ramalina roesleri* (Hochst. Ex Schaer.Hue	C/FR		III					S
30	*Rhizocarpon geographicum* (L.) DC. ap. Lam. & DC.	F/R					+		OC
31	*Umbilicaria pustulata* Hoffm	-/R					+		OC
32	*Graphis scripta* (L.) Ach.	F/R		III					S
33	*Diploschistes ocellatus* (Vill.) Norman	-/R				+	+		OC
34	*Lobaria pulmonaria* (L.) Hoffm. f. *pulmonaria*	R/FR		I	1			+	OC

35	*Lobaria verrucosa* (Huds.) Hoffm.	R/FR		I				+	OC
36	*Nephroma laevigatum* Ach.	R/FR		I					OC
37	*Peltigera aphthosa* (L.) Willd.	R/R		I				3-4	OC
38	*Peltigera canina* (L.) Wild. var. *canina*	F/R	5/EN	I				3-4	S
39	*Peltigera polydactyla* (Neck.)Hoffm. f. *polydactila*	F/R	3/EN	I				3-4	S
40	*Peltigera rufescens* (Weis.) Humb f. *rufescens*	F/R	1/CR	I				3-4	S
41	*Peltigera didactyla* (With.) J.R. Laundon (*P. spuria* (Ach.) DC *P. erumpens* (Tayl.) Vainio.	F/R		I				3-4	VS
42	*Ochrolechia androgyna* (Hoffm.) Arnold.	-/R		I					OBN
43	*Pertusaria discoidea* (Pers.) Malme. (*P. albescens* (Huds.) Choisy & Werner, *P. globulifera*)	F/R		II					S
44	*Caloplaca decipiens* (Arnold.) Blomb & Forssell.) (*Gasparinia decipiens* (Arn.)Sydow)	F/R		IV		+	+		S
45	*Caloplaca* (*Gasparinia*) *murorum* (Hoffm.) Tornab.	F/R				+	+		S
46	*Verrucaria fuscella* (Turner) Winch.	-/R				+			BS
47	*Catapyrenium squamulossum* (Ach.) Breuss *(Dermatocarpon hepaticum*(Ach.)Th.Fr)	R/FR	2/CR			+			S
48	*Dermatocarpon miniatum* (L.) Mann.	R/FR	2/CR	I		+	+		S
49	*Placocarpus schaereri* (Fr.) Breuss *(Dermatocarpon monstrosum* (Schaer.) Vainio)	R/FR				+			OC
50	*Placopyrenium trachyticum* (Hazsl.) breuss in Nimis & Poelt *(Dermatocarpon trachyticum* (Hazsl.) Vainio).	R/FR					+		OC
51	*Catapyrenium rufescens* (Ach.) Breuss *(Dermatocarpon rufescens* (Ach.) Koerb.)	R/FR	2/CR			+			S
52	*Phlyctis agelaea* (Ach.) Flot.	F/R		III	2				S
53	*Phlyctis argena* (Spreng.) Flot.	C/R		III				<5,4	S
	Total	FR-19	11	41	8	11	14	14	

Legend: F – very widespread, C – common, R – rare, FR – very rare; Threat: EN – endangered, CR – critically endangered; Nitrophilia: 1–nitrophobic, 2–weakly sensitive, 3–moderately sensitive, 4–very sensitive; S – Simonov; OC – Obuh, Colun; C – Colun; V – Vrabie; Vs – Vasilenco; SB – Simonov, Begu; OBN – Obuh, Begu, Nigel; BC – Begu, Coşleţ; B – Begu.

The lichen diversity of Moldova is well provided with species of true indicators of environmental pollution, especially of atmospheric air with various chemical pollutants – SO_2, NOx, etc. Thus, among the Rare species of lichens, sensitive to environmental pollution with SO_2 are 41 species, of which very sensitive – 17 and sensitive -10 species, respectively. Receptive to NOx pollution are 8 species. It is good to know the nitrophilous species in order to exclude them when assessing the impact based on the criteria of specific diversity and abundance per unit area, because they can have an excellent development in the environment rich in NOx, creating the impression of unpolluted air. For example, species of the genera *Xanthoria* and *Physcia*, frequent and abundant on tree trunks on the edges of car routes benefit from NOx pollution, etc. emissions from fuel combustion. True indicators of environmental acidification are 14 species, of which 9 species prefer acidic environments with a pH lower than 5.4. Their presence in certain habitats or ecosystems indicates the quality of the substrate or the degree of air pollution with acid ions. Epilithic species (25) inhabit calcareous rocks – 11 species and – 14 species are siliceous. It is known that epilithic species, predominantly with crustose thallus, are the most not recommended in ecobioindication, because they remain practically indifferent to the action of pollutants in moderate and high concentrations (NILSON, 1986). Thus, petrophyte ecosystems cannot be included in the air quality monitoring network based on lichenindication, with the exception of petrophyte-forest ones, provided with epiphleoid indicator species.

Therefore, the species richness and their morphological, ecological and chorological particularities of Moldova's lichen diversity provide optimal premises for monitoring environmental factors in different types of ecosystems, especially forest, forest-petrophyte, petrophyte, urban and, to a lesser extent, steppe, marsh and agricultural ones.

Photo 1. *Cladonia glauca* – CR; Trebisăuți (Briceni).

Photo 2. *Peltigera rufescens* – CR; Corjeuți (Briceni).

Photo 3. *Dermatocarpon miniatum* – CR; Fetești (Edineț), Japca (Florești).

Photo 4. *Cetrelia cetraroides* – EN; Caracușenii-Vechi (Briceni), Zloți (Cimișlia), Ciobalaccia (Cantemir), Rezervația Științifică Codrii.

Photo 5. *Peltigera canina* – EN; Scoreni (Str.), Goian (m. Chișinău), Arionești (Dondușeni), Bahmut (Călărași), Cornești (Ungheni).

Photo 6. *Peltigera polydactyla* – EN; Cotiujeni (Briceni), Butești and Cobani (Glodeni)

Photo 7. *Ramalina fastigiata* – CR; Ciuciuleni (Hîncești).

Photo 8. *Cladonia rangiformis* – CR; Ciucur-Mingir (Cimișlia), Ciumai (Taraclia).

Photo 9. *Aspicilia gibbosa* – CR; TP la NV s. Lopatna (Orhei).

Photo 10. *Catapyrenium squamulosum*. – CR; Ciucur-Mingir (Cimișlia), Ciumai (Taraclia).

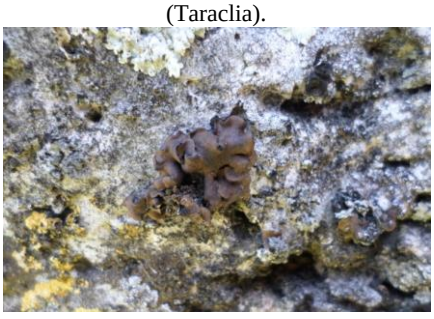

Photo 11. *Catapyrenium rufescens* – CR; Japca (Florești), Trebujeni (Orhei).

Photo 12. *Xanthoparmelia vagans* – CR; **(CR UA – V,** SE, SBas) Ciucur-Mingir (Cimișlia).

CONCLUSIONS

1. The lichen diversity of Moldova includes 196 species (Begu, 2010), of which: 73 are Rare species for Moldova, and 13 of them are included in the Red Book of the Republic of Moldova, 3rd edition (2015).

2. Most of the species in the Red Book are critically endangered (CR) – 9 species, the other 4 species are endangered (EN) and are found quite rarely, populating from 1 to 5 locations.

3. Rare species can serve as ecobioindicators of the environmental status of separate ecosystems, but their use in large-scale ecobioindication is not recommended, especially in research that depends on the collection of samples for laboratory analysis.

4. Of the 73 rare species of lichens, 53 species exhibit more pronounced ecological peculiarities and, of course, they can serve as indicators of environmental pollution, 41 species are particularly sensitive to atmospheric air pollution with SO2, of which 17 are very sensitive and 10 are sensitive.

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