The vulnerability of lichens to the modification of environmental conditions expressed through the ecological valence and spectrum

Adam BEGU[1*]
[1]Institute of Ecology and Geography, Chisinau, Republic of Moldova

*Correspondence to: Adam BEGU. E-mail: adambegu@gmail.com.

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ABSTRACT: Each organism is characterized by a specific potential capacity to react to the influence of environmental factors, according to its genetic constitution and hereditary reaction norm. Some species can withstand large variations, others, on the contrary, very small, i.e. ecological valence is the amplitude of the variations of the conditions of existence between which a species is able to live. The totality of ecological valences constitutes the ecological spectrum of the species. In the context of the increasingly obvious manifestations, both of the climate change scenarios and the maintenance of the high level of pollution, especially with SO_2, whole associations of some species of stenoic lichens may be threatened with extinction. Important is the conservation of ecobioindicator species that ensure non-instrumental ecological monitoring, promoted by the international Conventions. As a result of field expeditions from 2011-2018, 9 forest-petrophyte ecosystems were evaluated in the bordering area of the Dniester River, on the middle course segment, right bank. The altitude of the territory varies from 280-140 m, in the north, to 80-40 m, in the south. The exposure of the studied ecosystems is dominated by the northern orientation, favorable for the development of lichens. In the forest-petrophitic ecosystems the lichens from 9 protected areas belonging to 34 species were recorded. Of these 12 are rare species). It was established that for 10 species the ecological valences to the substrate, illumination and humidity are very narrow, so the ecological spectrum is very narrow. Among the 10 stenoic species 2 are included in the Red Book and 8 are Rare, so these will be the first affected in the case of changes in the environmental components.

KEY WORDS: natural ecosystems, lichens, vulnerability, ecological valence.

1. Introduction

Each organism is characterized by a specific potential capacity to react to the influence of environmental factors, according to its genetic constitution, using the environment for its purpose, or, in the worst cases, resisting their pressure. This potential is determined by the hereditary reaction norm (Johannsen, 1909). So, organisms have the ability to adapt, as much as possible, to changes in the environment. Some species can withstand large variations, others, on the contrary, very small, that is, the species have different ecological valence. So ecological valence is the amplitude of variations in the conditions of existence between which a species is able to live. The totality of ecological valences constitutes the ecological spectrum of the species (Dediu, 2006). Each species has its ecological niche, which corresponds to the rule (law) of ecological individuality (Ramenskii, 1924).

The "ecologically optimal" domain corresponds to the interval in which a species carries out its existence with a minimum of material and energetic "expenses". It is also the interval in which the conditions for the reproduction of the species are ensured. Tolerance limits, as well as areas of favorability, do not have absolute values in relation to a given species. They are influenced by internal factors (state of health, age, phenophase, etc.) and external factors, respectively the intensity of manifestation of the other ecological factors and the way in which they fall into different fields of tolerance. For example, in the conditions of a polluted environment, the species have a lower tolerance to variations in temperature and humidity, etc. In terms of ecological tolerance, the modification of ecological factors by pollution means that, for example, the concentration of sulfur dioxide is located outside the optimal ecological range (the toxic domain), the other limits change, and the difference between the minimum and maximum decreases, by approaching them (Pârvu, 2001).

In the context of the increasingly obvious manifestations of both climate change scenarios (warming, cooling) and the maintenance of a high level of pollution, especially with SO_2, whole associations or populations of some species of stenoic lichens may be threatened with the disappearance of certain natural habitats. This disappearance would be a colossal damage to the conservation of biodiversity, on the one hand, but also, taking into account that these species are the most receptive to minor changes in the environment, we could be deprived of the possibility of performing an effective ecological monitoring, based on lichenoindication, on the other hand. This monitoring is promoted by the Geneva Convention (1979), on the transport of pollutants over long distances, especially SOx, NOx and heavy metals.

2. Study area

The 9 forest-petrophyte ecosystems were evaluated from the area bordering the Dniester River, on the middle course segment, right bank, within the borders of the Republic of Moldova. The studied ecosystems are part of three categories of state-protected areas: 5 - Landscape Reserves (LR), 2 - Natural Geological and Paleontological Monuments (NGPM) and 2 - Natural Forest Reserves (NFR). Almost all the ecosystems are located on the right bank of the Dniester, with the exception of RP Trebujeni, located about 10 km from the Dniester, but on a similar relief near the Răut river. The altitude of the studied territory varies from north to south from the maximum values 280 to 140 m, and the minimum values from 80 to 40m, practically along the entire alignment from north to south it decreases 2 times. The exposure of the studied forest-petrophyte ecosystems is dominated by the northern orientation, favorable for the development of lichens.

3. Methods

Research in the field: the study of natural forest-petrophyte ecosystems in the main phenophases of vegetation development with the inventory of lichen species and pollution sources; collection of biota samples. Researches in the laboratory: determining the systematic belonging of the collected species (Kondratyuk et al. 1998), the protection status and toxic tolerance to SO_2 based on the Gradations of Air Quality Evaluation (GAQE) (Begu and Brega, 2009) (Tab. 1), the requirements for light, humidity and substrate (Golubkova, 1966; Simonov, Manic, 1987; Begu, 2011) abundance/substrate coverage by lichen species (according to the scale) (Braun-Blanquet, 1964).

Determination of geographical parameters: altitude (according to level curves and altitude quotas); the exposure of the slopes (by indicating the cardinal and intercardinal points, based on the Physical Maps).

Table 1 Gradations of Air Quality Evaluation (GAQE) based on the abundance of lichen species with different degrees of toxitolerance to SO_2 (Begu and Brega, 2009).

Air quality	SO_2 content in the air, mg/m^3	Abundance of species with different degrees of toxic tolerance, % of the surface
Clean	<0,05	I > 10 or I < 10 and II > 75
Lightly polluted	0,05-0,1	I – 0 -10 or II – 50-100
Moderately polluted	0,1-0,2	II - 10-50 or III > 50
Polluted	0,2-0,3	III - 10-50 or IV > 50
Heavily polluted	0,3-0,5	IV - 10-50 or V - 1-100
Critical pollution	>0,5	Complete lack of lichens

4. Results and discussion

Among the ecosystems studied, the richest in species proved to be NFR Cobleni with 21 species, followed by NFR Vîscăuţi, LR Cosăuţi and LR Holoșniţa with 15-12 species and the rest, with 9-6 species (Tab. 2). Epiphloid species predominate, which is characteristic of deciduous forests, with the exception of NGPR Stânca Japca, where epilithic species dominate. A dependence of the specific richness on the geographical location has not been established, because the first 5 ecosystems (according to the table) are specific to the upper course of the Dniester within the borders of the country (further north of the city of Soroca), and the other 4 – on the middle course (within the districts Rezina, Orhei and Dubăsari).

Sometimes the abundance reaches quite high levels - 70-80%, even for species with toxitolerance II (eg. *Cladonia pyxidata, Parmelia sulcata, Physcia aipolia*), not to mention those with increased tolerance to environmental conditions (eg. *Lepraria aeruginosa*). The species *Xanthoria parietina* and *Parmelia sulcata* have the highest frequency (in 8 of the 9 ecosystems), the latter being used as a benchmark in monitoring air pollution with SO_2, in many European countries, including us, for the Republic of Moldova (Begu, 2011).

Depending on the tolerance of lichens to the content of SO_2 in the atmospheric air, out of the 34 species, 2 are very sensitive and are considered to have toxitolerance I, i.e. they will wilt only under the conditions of a concentration of SO_2 below 0.05 mg/m^3 of air, so in habitats with clean air - very narrow ecological valence (Tab. 3); 11 species have toxitolerance II (weak pollution), so they will tolerate SO_2 concentrations up to 0.1 mg/m^3 of air - narrow ecological valence; 12 species have toxitolerance III (moderate pollution), they withstand SO_2 concentrations of up to 0.2 mg/m^3 of air - medium ecological valence; 6 species have toxitolerance IV (strong pollution), supporting concentrations of up to 0.3 mg/m^3 of air - wide ecological valence and 2 species with toxitolerance V, are the most resistant to pollution, developing at concentrations up to 0.5 mg/m^3 of air -– very broad ecological valence.

Table 2 Specific diversity, toxitolerance, abundance and frequency of lichens from forest-petrophite ecosystems bordering the Dniester, 2011-2018.

Indicators				Ecological group			Forest-petrophyte ecosystems and abundance, %									
№	Toxitolerance	Ecosystem / Species	Protection status	By habitat	By light	By humidity	LR La 33 de vaduri	NGPM Falia tectonică s. Naslavcea	LR Rudi Arioneşti	LR Cosăuţi	LR Holoşniţa	NGPM Stânca Japca	NFR Cobleni	NFR Vişcăuţi	LR Trebujeni	Frequency
		GAQE, SO_2 mg/m^3					I	II	III	III	III	I	I	I	III	
		Altitude, m	Rare-R; Red Book-RB	Epiphloid,Epilithic, Epigeic, Epixilic	Heliophyllous Sciophyllous	Xerophyte; Mesophyte	80-280	80-280	60-230	50-180	50-170	45-150	40-140	40-140	70-150	-
		Exhibition					NW	NW	NE	NV	N	NE	NE	N	N;E	-
1		*Usneea hirta*	R	Ef	it	mz		5								1
2	I	*Catapyrenium squamulosum*	RB	El	hf	mz						30				1
3		*Peltigera canina*	RB	Eg,Ef	it	mz	10	5						15		3
4		*Graphis scripta*	R	Ef	sc	mz	7	5		7	8					4
5		*Anaptychia ciliaris*	R	Ef, El	hf	xr	7						1			2
6		*Aspicilia gibbosa*	RB	El	hf	xr						7				1
7		*Evernia prunastri*		Ef	hf	xr	7	12	10	2	5					5
8		*Evernia furfuracea*	R	Ef,El,Ex	sc	mz				3	3				5	3
9	II	*Placolecanora muralis*		El	hf	xr						30	40	35		3
10		*Physcia aipolia*		Ef	hf	xr							70	20		2
11		*Cladonia pyxidata*	R	Eg, Ex	it	mz		3					80	60		2
12		*Caloplaca aurantiaca*	R	Ef,Ex,El	hf	xr						5				1
13		*Parmelia sulcata*		Ef,Ex,El	hf	xr,mz	70	15	15	30	30		5	5	17	8
14		*Parmelia caperata*		Ef	sc	mz				5	5		10	5		5
15		*Hypogymnia physodes*		Ef,Ex,El	it	xr,mz			40	5	5		7	5	5	6
16		*Parmelia olivacea*	R	Ef	sc	mz		5		15			5			3
17		*Lecanora allophana*		Ef	hf,sc	xr,mz				10						1
18	III	*Lecanora carpinea*		Ef	hf	xr,mz							5			1
19		*Physcia grisea*		Ef,Ex,El	hf,sc	xr,mz				3			12	7		3
20		*Physcia stellaris*		Ef, El	hf	xr			30				5	5	7	4
21		*Physcia caesia**		Ef,Ex,El	hf,sc	xr,mz							1			1

22		*Parmelia acetabulum*		Ef, Ex	hf	mz				3	3		20	20		4
23		*Xanthoria elegans*		El	hf	xr						7			7	1
24		*Verrucaria nigrescens*		Ef, El	hf	xr							1			1
25		*Ramalina Roesleri*	R	Ef,Ex,El	it	mz							5			1
26		*Lecidea glomerulosa**		Ef, Ex	hf,sc	xr,mz				5	3					3
27		*Candelariella vitelina*		Ex, El	hf	xr	7			7	5	3	20	15	5	7
28		*Physcia ascendens**		Ef, El	hf,sc	xr,mz							5	7		2
29	**IV**	*Caloplaca decipiens**	R	Ex, El	hf,sc	xr,mz							1			1
30		*Physcia orbicularis*		Ef,Ex,El	hf,sc	xr,mz	5									1
31		*Physcia hispida**		Ef, Ex	hf,sc	xr,mz			40	3	3				5	4
32		*Physcia nigricans**		Ef, El	hf,sc	xr,mz				3	1		20	5		4
33	**V**	*Lepraria aeruginosa*		Ef, El	sc	mz								7	70	2
34		*Xanthoria parietina*		Ef,Ex,El	hf,sc	xr,mz	5	15	20	30	25		7	10	30	8
		TOTAL SPECIES	**12**				**8**	**8**	**6**	**15**	**12**	**6**	**21**	**15**	**9**	

**species for which the ecological group according to light and humidity is proposed by the author, because it is missing in the consulted specialized literature.*

A narrow and very narrow ecological valence to the content of SO_2 in the air is specific for 9 of the 12 rare species identified, but the impact of SO_2 is the most aggressive, compared to habitat, light and humidity, which further threatens these already rare (R) species, some even included in the 3rd edition of the Red Book (RB-3) of the Republic of Moldova (2015). For example, *Catapyrenium squamulosum* and *Aspicilia gibosa* are critically endangered, previously being recorded in only 2 and one location, respectively, and *Peltigera canina* is endangered, previously being recorded in 5 locations.

The ecological valence of the lichen species in relation to the particularities of the habitat is almost equally shared by the 34 species: eurytopes - 9 species that can live on three types of substrate - epiphleoid, epixilic and epilithic (Ef, Ex, El); intermediate – 13 species that live only on two types of substrate – 6 species are epiphleoid and epilithic (6 - Ef, El); 2 species are epiphleoid and epixilic (2 – Ef, Ex); 2 species are epilithic and epixilic (2 – El, Ex); one species each are epigeic and epixilic (1 – Eg, Ex) and epigeic and epiphleoid (1 – Eg, Ef); stenotopes – 12 species that live only on one type of substrate – 8 species are epiphleoid and 4 species are epilithic (8 – Ef; 4 - El).

Ecological valence of lichen species in relation to the degree of illumination shows an obvious dominance of stenophotic species - 19 species (14 - hf; 5 - sc), followed by euriphotic ones - 10 species (hf, sc) and intermediate ones - 5 (it).

Ecological valence of lichen species in relation to the degree of humidity places most of the species as stenohydric - 10 species (xr), followed by eurihydric - 13 species (xr, mz); intermediate – 11 species (mz).

It is curious that the 14 species very sensitive to SO_2 pollution, therefore with very narrow and narrow ecological valences, are totally stenohydric and, with the exception of one species, stenophotic. The consequence of these narrow and very narrow ecological values is also confirmed by the fact that among them are 9 of the 12 rare species.

Table 3 Specific diversity, toxitolerance, valence and ecological spectrum of lichens in the studied ecosystems, 2011-2018.

Indicators				Ecological valence in relation to:				Ecological spectrum of species (5 levels)
№	Toxitolerance	Species	Protection status	SO_2 content in the air (5 levels)	Habitat peculiarities (3 levels)	Degree of illumination (3 levels)	Air humidity (3 levels)	
1	I	*Usneea hirta*	R	very narrow	narrow	medium	medium	very narrow
2		*Catapyrenium squamulosum*	RB	very narrow	narrow	narrow	medium	very narrow
3		*Peltigera canina*	RB	very narrow	medium	medium	medium	narrow
4	II	*Graphis scripta*	R	narrow	narrow	narrow	medium	very narrow
5		*Anaptychia ciliaris*	R	narrow	medium	narrow	narrow	narrow
6		*Aspicilia gibbosa*	RB	narrow	narrow	narrow	narrow	very narrow
7		*Evernia prunastri*		narrow	narrow	narrow	narrow	very narrow
8		*Evernia furfuracea*	R	narrow	wide	narrow	medium	narrow
9		*Placolecanora muralis*		narrow	narrow	narrow	narrow	very narrow
10		*Physcia aipolia*		narrow	narrow	narrow	narrow	very narrow
11		*Cladonia pyxidata*	R	narrow	medium	medium	medium	narrow
12		*Caloplaca aurantiaca*	R	narrow	wide	narrow	narrow	narrow
13		*Parmelia sulcata*		narrow	wide	narrow	wide	wide
14		*Parmelia caperata*		narrow	narrow	narrow	medium	very narrow
15	III	*Hypogymnia physodes*		medium	wide	medium	wide	wide
16		*Parmelia olivacea*	R	medium	narrow	narrow	medium	very narrow
17		*Lecanora allophana*		medium	narrow	wide	wide	medium
18		*Lecanora carpinea*		medium	narrow	narrow	wide	medium
19		*Physcia grisea*		medium	wide	wide	wide	very wide
20		*Physcia stellaris*		medium	medium	narrow	narrow	narrow
21		*Physcia caesia**		medium	wide	wide	wide	very wide
22		*Parmelia acetabulum*		medium	medium	narrow	medium	narrow
23		*Xanthoria elegans*		medium	narrow	narrow	narrow	very narrow
24		*Verrucaria nigrescens*		medium	medium	narrow	narrow	narrow
25		*Ramalina Roesleri*	R	medium	wide	medium	medium	narrow
26		*Lecidea glomerulosa**		medium	medium	wide	wide	very wide
27	IV	*Candelariella vitelina*		wide	medium	narrow	narrow	narrow
28		*Physcia ascendens**		wide	medium	wide	wide	very wide
29		*Caloplaca decipiens**	R	wide	medium	wide	wide	very wide
30		*Physcia orbicularis*		wide	wide	wide	wide	very wide
31		*Physcia hispida**		wide	medium	wide	wide	very wide
32		*Physcia nigricans**		wide	medium	wide	wide	very wide
33	V	*Lepraria aeruginosa*		very wide	medium	narrow	medium	narrow
34		*Xanthoria parietina*		very wide	wide	wide	wide	very wide

Generalizing the information about the ecological values of the species studied, we can say that the ecological spectrum of lichens is as follows: very wide - 9 species; wide – 2 species; medium – 2 species; narrow – 11 species; very narrow – 10 species. Thus, in relation to the 4 environmental factors (SO_2, habitat, light and humidity) most species have a very narrow and narrow ecological spectrum (21 species), which makes them quite vulnerable to changes in the environmental components (air, water, soil, biota, climate).

Even if the ecological spectrum, which represents the totality of the ecological valences, is an integral index of the valences, the valences of different factors play different roles in ensuring a certain degree of tolerance of the species towards negative impact factors. Thus, for lichens an important role is played by the presence of the habitat (for example - bark or wood, for epiphloid and, respectively, epixilic species), otherwise, the species will be absent from the given territory.

Among the other factors analyzed (SO_2, light, humidity), the primary role belongs to the content of SO_2 in the air, because exceeding the concentration for species with different degrees of toxitolerance will lead to the destruction of chlorophyll and, as a consequence, the species will perish. So, the ecological valence of lichen species in relation to the SO_2 content in the air has a much greater weight in determining the ecological spectrum of the species, compared to the ecological valences in relation to light and humidity. Among other things, lichens are very resistant to the lack of humidity and light, maintaining their viability for decades and even hundreds of years (such are those in herbarium collections).

So, the role and share of ecological valences in establishing the ecological spectrum of lichen species, depending on the degree of influence, form the following series, in descending order: the biotope (40%), the SO_2 content in the air (40%), the degree of lighting (10%) and air humidity (10%).

5. Conclusion

1. The diversity of lichens in the studied ecosystems includes 34 species recommended for biological monitoring of air pollution with SO_2, of which 12 are rare species for the Republic of Moldova.

2. No laws have been established regarding the specific wealth, the abundance on the habitat surface or the frequency of species depending on the ecosystem, the exposure of the different species or the altitude, while 4 ecosystems are located in clean air conditions (toxic tolerance I), 1 - slightly polluted air (toxic tolerance II) and others 6 – air moderately polluted with SO_2 (toxic tolerance III).

3. A narrow and very narrow ecological valence to the content of SO_2 in the air is specific for 9 of the 12 rare species identified, but the impact of SO_2 is the most aggressive, compared to the habitat, light and humidity, a fact that continues to threaten these species already have become rare, some even included in the Red Book of the Republic of Moldova: *Catapyrenium squamulosum* and *Aspicilia gibosa* are critically endangered (CR), previously being recorded in only 2 and one location, respectively, and *Peltigera canina* is endangered (EN), having previously been recorded in 5 locations.

4. In relation to the 4 environmental factors (SO_2, habitat, light and humidity) most species (21 species) have a very narrow and narrow ecological spectrum, which makes them quite vulnerable to changes in the environmental components.

References

Begu A., 2011. Ecobioindicaţia. Premise şi aplicare. Editura Digital Hardware, Chişinău.

Begu A., Brega V., 2009. The assessment of air quality through lichen indication in forest ecosystems. Studia universitaris Babeş–Bolyai, series Geographia, V. 54, Nr. 3. p. 95-102. Cluj Napoca, România.

Braun-Blanquet J., 1964. Pflanzensoziologie, Grundzüge der Vegetationskunde. (3. Auflage). Springer Verlag, Wien.

Dediu I., 2006. Introducere în ecologie. Ed. Phoenix, Ed. Linadi. Chișinău.

Golubkova N. S., 1966. Opredeliteli lișainikov srednei polosî Evropeiskoi ciasti SSSR, tom I-V. Iz. Nauka, Moskva-Leningrad (in Russian).

Johannsen W. L., 1909. Elemente der exacten Erblicheistlehre. Jena.

Kondratyuk S., Khodosovtsev A., Zelenko S., 1998. The second checklist of lichen forming, lichenicolous and allied fungi of Ukraine. M.H. Kholodny Institute of Botany. Kiev.

Pârvu C., 2001. Ecologie generală. Editura Tehnică, Bucureşti.

Ramenskii L. G., 1924. Osnovnîie zaconomernosti rastitelinogo pocrova i metodî ih izucenia. Vestn. opîtn. dela. Voronej (in Russian).

Simonov G., Manic S., 1987. Lesnîe rastenia. Gribî-macromițetî. Lișainiki. Mohoobraznîe. Știința. Kișinev (in Russian).

****Cartea Roșie a Republicii Moldova/The Red Book of the Republic of Moldova. 2015. Î:E.P. Știința, Chișinău.*

****Convenţia de la Geneva privind poluarea atmosferică transfrontalieră pe distanţe lungi (1979). https://treaties.un.org/doc/Treaties/1979/11/19791113%2004-16%20PM/Ch_XXVII_01p.pdf* (accessed 06.07.2023).