A COMPREHENSIVE REVIEW ON LICHENS

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Abstract. This review analyses the interactions of lichens with in the *ex vitro* and *in vitro* environment, with an emphasis on structural and functional features, and factors that sustain their favourable evolution in the context of disturbance of certain parameters. An extensive bibliography highlights the lichens' tolerance to desiccation, heavy metals accumulation from polluted environment, cryoprotection mechanisms, by inducing repair mechanism as secondary metabolites production. The *in vitro* conservation of lichens is an efficient alternative reproduction strategy in the context of environmental changes and offers the possibility to understand this type of close symbiosis by promoting new studies of interactions between symbionts

Keywords: lichens, lichen symbiosis, conservation *in vitro*, heavy metal accumulation.

Rezumat. Un review cuprinzător asupra lichenilor. Acest review sintetizează cele mai relevante studii referitoare la biomonitorizarea cu ajutorul lichenilor, analizează interacțiunea lichenilor cu mediul *ex vitro* și *in vitro*, corelată cu o abordare aprofundată a trăsăturilor structurale și funcționale ale acestora precum și a factorilor care susțin evoluția lor favorabilă în contextul perturbării anumitor parametri. Bibliografia vastă consultată subliniază toleranța lichenilor la deshidratare, acumularea de metale grele din mediul poluat, mecanismele de crioprotecție prin inducerea mecanismelor de reparare precum și producerea de metaboliți secundari. Conservarea *in vitro* a lichenilor este o metodă alternativă eficientă de reproducere în contextul schimbărilor climatice și oferă posibilitatea de a întelege acest tip de simbioză strânsă prin încurajarea efectuării de noi studii de interacțiune între simbionți.

Cuvinte cheie: licheni, simbioza lichenică, conservare *in vitro*, acumulare de metale grele.

INTRODUCTION

Lichens: An amazing model of symbiosis. Lichens are enigmatic entities of the vegetal kingdom (HUANG et al. 2019) enclosing microecosystems of bionts (ZACHARIAH & VARGHES, 2018), with a prevalence of the fungal partner, the mycobiont and the algal partner, the photobiont, each of them building a new architecture, a long-living thallus. Lichens are distinguished by their unique chemistry and biotechnological potential (VOICU et al., 2019). The microhabitat and macrohabitat determine lichen abundance in lichens species (VICOL, 2016). Macroclimate and evolutionary events had a decisive role in establishing the symbiosis of lichens (SINGH et al., 2016).

Lichens are used to monitor climatic changes and pollution level (ABAS, 2021), because they are known to be colonizers of a wide range of habitats, from the Antarctica (Spielmann & Pereira 2012) and healthy environmental conditions with rich diversity in lichen species as the Baliem Valley region from Papua, Indonesia (SUHARNO et al 2020) to urban areas and high altitude (ARDELEAN et al 2015) due to the poikilohydric nature and correlation with climatic factors of an area (BAJPAI et al 2018), tolerance to desiccation (KRANNER et al., 2008), heavy metals accumulation (BOONPENG et al., 2020) and highly saline environments (HINOJOSA-VIDAL et al., 2018).

Lichen species include lichen extremophilic species with sensitivity/resistance to freezing; especially lichen algae have cryoprotection estimated as ice nucleation activity; the relatively thick cell wall composed of polysaccharides of the unicellular coccoid lichen phycobionts beside the mucilaginous sheet sustain this property (KVÍDEROVÁ et al., 2013; HÁJEK et al., 2016). The symbiotic lifestyle in lichens gives tolerance to freezing and changes in water relations to the symbionts (FERNÁNDEZ-MARÍN et al. 2020). To counteract with inconvenient factors including desiccation (GASSULA et al., 2021) or snag, lichens are sustained by a range of defence mechanisms, but respond to oxidative stress in different manner, depending on ecotype and species characteristics. Therefore, related to desiccation, lichenised fungi have mechanisms to transit between desiccation and rehydration state. Rehydration process to lichens *Ramalina lacera* determine the reinitiation of metabolic processes, the rapid increase of photosynthetic activity, the production of reactive oxygen species and nitric oxide (WEISSMAN et al., 2005). The capacity of inducing repair mechanisms also differs between lichen symbiosis partners. In this frame, against extreme saline conditions, the photobiont *Trebouxia* isolated from *Ramalina farinacea* developed alternative molecular pathways to avoid this.

Lichen metabolites are involved in thepollution tolerance of lichens and metal homeostasis (BHATTACHARYYA et al., 2016). Fungal hyphae are lined with secondary metabolites as crystals (GOGA et al., 2018). By the composition in metabolites of thallus extracts, as usnic, protocetraric and caperatic acid, many lichen species, including *Usnea florida* and *Flavoparmelia caperata*, have antibacterial activity (DIEU et al., 2020). Therefore, a wide range of lichens are used for synthesis of nanoparticles with antimicrobial potential (MIE et al., 2014; RATTAN et al., 2021) including *Cetraria islandica* (BALÁŽ et al., 2020) *Usnea longissima* (SIDDIQI et al., 2018) *Cladonia rangiferina* (RAI & GUPTA, 2019), *Parmelia perlata* (LEELA & DEVI, 2017).

Melanins, a type of lichen secondary metabolites with high - molecular - weight are photoprotective and antioxidants (RASSABINA et al., 2020). The production of secondary metabolites is influenced by temperature and precipitation at different altitude gradients (NEUPANE et al., 2017). Lichens function like biofilters (BAJPAI et al., 2019). Relevant from this point of view are the species *Parmotrema tinctorum* (Despr. Ex Nyl.) Hale, *Usnea longissima*

Ach. (with endangered status in our country) *Rocella montageni* Bel, *Heteroderma diademata*. The procedure to neutralise metal toxicity is laborious. The ability of lichens to function as natural filters is due to the high percentage of secondary chemical compounds rich in electron donor functional groups. This promotes lichens as useful bioresources for eliminating hazardous metal contamination, such as arsenic. As sources of novel bioactive molecules, lichens have a medicinal impact that has not been well studied yet (GAUTAM et al., 2021). The resistance of lichens to abiotic factors is sustained by the association of lichens with more than 800 types of bacteria representing the microbiome; the study of the microbiome on relatively fast growing lichens with ecological significance as *Lobaria pulmonaria* revealed the role on supplying lichens with nutrients, vitamins and trace elements (GRIMM et al., 2021). Traits such as resistance to extreme weather conditions make lichens useful for the genetic transfer of the genes responsible of these characteristics (BACKOR et al., 1998). Car traffic determines heavy metals accumulation in the central part of the thalli (VICOL, 2018). Rainfall can diminish air pollutants by washing and it can both add or remove pollutants in lichen thalli (GALLO et al., 2017). The *in vitro* culture of lichens is an alternative to cope with environmental factors because of the sterile conditions offered by the growth chambers, controlled conditions of temperature, light and humidity, the possibility to improve the input of nutritive factor by the medium culture composition, the possibility to multiplicate in a numerous number the *in vitro* regenerants and to acclimatise them, although lichens are some of the most recalcitrant vegetal organisms to these conditions, because of the different requirements of the symbionts. Also, the slow growth of the lichens in nature determined the scientists to adopt the method of *in vitro* culture.

The relation of lichens with the *ex vitro* and *in vitro* environment. The lichen body with a network architecture and physiological processes developed by symbionts is adjusted to the *ex vitro* and *in vitro* environment (VOICU & GAVRILOAIE, 2017). The reproduction strategy of lichenised fungi in nature is very elaborated (ANSTETT et al., 2014). The structures that contribute to these are assexuate lichen specialised propagules, sexuate spores and assexuate conidia (OTT, 1987; OTT & JAHNS 2002; TRIPP et al., 2018)

Also, the *in vitro* conservation of lichens is a reproductive strategy (VOICU et al 2017; STEINOVA et al., 2019). Fungal isolectins with arginase activity are involved in the mechanism of interaction between the mycobiont and photobiont (MOLINA & VICENTE, 2000). Also, arginase from lichens have a lectin function binding to the cell wall of algal cells, therefore being involved in the recognition and association of symbionts (DÍAZ et al., 2016).

Lichen phenolics are related to the co-development and cooperation between symbionts. Therefore, algal cells release ribitol into the environment only when the mycobiont is present (MOLINA et al., 1997). There are many similarities between the profile of secondary compounds of the *in vitro* thallus cultures established on malt yeast extract (MY 10%) medium and natural lichen thallus SHANMUGAM et al. (2016). These were demonstrated by observations on the i*n vitro* developmental stages of the mycobiont and secondary compound biosynthesis beside the whole thallus cultures of *Buellia subsororioides*along 120 days. Also, mycobiont cultures reach optimum biomass and biosynthesis of nine secondary compounds in MY 10% sucrose concentration.

As a result of symbiotic interrelations, not only does the mycobiont synthesize secondary metabolites, but the photobiont and lichen-associated bacteria also produce a range of potentially valuable molecules (CALCOTT et al., 2018). Also, the mycobiont can produce substances that are absent in symbiotic form in an aposymbiotic culture (FAZIO et al., 2018).

Polyketide (secondary metabolite) synthesis by mycobiont depends on the carbohydrate source from photobiont, as type and concentration. From this point of view, the fumarprotocetraric acid was detected by ELSHOBARY et al. (2016) only in cultures grown with 1 and 5 % ribitol concentration added to the agarised medium. The morphogenetic capacity of the mycobiont *in vitro* is enhanced by concentrations of 2 % malt extract with 0,2 % yeast extract, 1 % malt extract 0,4 % yeast extract and 10% sucrose (FAZIO et al., 2009). A long period of culture (over 5 and 10 months) on Lilly & Barnett medium (LB) stimulates the production of atranorin, corelated with a desiccation treatment. Developed on culture media as potato - carrot, malt extract - yeast extract (MY), Bold' s basal medium with nitrogen (NMBBM), oatmeal and yeast extract with supplements, a number of 25 mycobiont strains covering three classes and five orders of the *Ascomycota* were able to induce ascospore germination, fragmentation and distribution on liquid media for further culture (MCDONALD et al., 2013).

The liquid state of the culture media allows a complete contact of symbiotic components, ensuring the agitation of culture vessels and aeration are key points that stimulate with success symbiosis establishing (RAFAT et al., 2015). Resins added to the culture medium can absorb phenols that inhibit the germination spores of *Peltigera.* Elicitors delivered by the symbionts in *in vitro* culture triggers the three-stage gene activation responsive for recognition and the gene implied in protection (ATHUKORALA et al., 2014). Axenic cultures are useful to study the taxonomy, biochemical, molecular or physiological behaviour of symbionts outside the symbiosis (SPRIBILLE, 2019). In this context, the aposymbiotic culture of photobiont allows to compare the binding affinity of lectins. HONEGGER (1996) also studied the signalling process between the bionts. Symbionts reassociation from axenic cultures needed to modulate and tatonate the growth conditions provided *in vitro* by repeated experiments. The similarities between the vegetal tissues in the *in vitro* dedifferentiation process to higher plants in the initiation stage culture with the events conducted inside the lichen thallus inoculated *in vitro* are relevant. The similarities consist in the tendency of the lichen symbionts to dissociate when they are cultured in *vitro* like the initial stage of dedifferentiation to higher plants. A comparative study regarding the interactions between symbionts *in situ* and *ex situ* (*in vitro*) highlighted that these are tighter in natural conditions and weaker in *in vitro*.

Phytohormones have a decisive role in stabilising lichen symbiosis, representing inter-kingdom signalling components (PICHLER et al., 2020). For example, experiments of PICHLER et al. (2020) demonstrated that *in vitro* isolated mycobionts release in the nutritive medium such asa phytohormones as indole - 3 - acetic acid (IAA) that trigger physiological response to compatible corresponding photobionts of *Cladonia grayi, Xanthoria parietina and Tephromela atra*, lichens namely *Asterochloris glomerata, Trebouxia decolorans, Trebouxia sp* increasing water content with 4,4 %.

KONO et al. (2020) achieved a thalloid symbiotic structure with morphologically and biochemically similarities with the natural thallus by culturing together the isolates of the mycobiont of *U. hakonensis* and the photobiont *Trebouxia* sp.

RESULTS

Lichens as bioindicators of heavy metals accumulation. The studies and methodologies on biomonitoring increased significantly in the recent years (ABAS, 2021).The process of bioaccumulation of heavy metals is closely correlated with the degree of pollution of the given biotope (SAWIDIS et al., 1995), although different species presents large variations. The excessive use of coal releases fuel in the air major contaminant in urban area as Ni, V and Cr (YAVUZ &ÇOBANOĞLU, 2019). Heavy metals resulting from industrial activities and vehiclef trafic are absorbed by the aerial organs of plants or the entire body of lichens (SHAHID et al., 2016).

Species used like bioaccumulators encompass a broad spectrum of heavy metals, as Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, and Zn (ŞTEFANUŢ et al., 2017). Also, biomonitoring methods used to plants, specially to trees (ŞTEFANUŢ et al., 2018) can be extrapolated to lichens. A common lichen species, frequently used in biomonitoring studies, is *Xanthoria parietina* (Fig. 1).

The lichen thallus is able to accumulate a maximum concentration of Cd, Cu, Mn, Ni, Zn in certain zones. A common lichen species, frequently used in biomonitoring studies, is *Xanthoria parietina*. Limiting the accumulation of heavy metals as Hg, Cd, Zn, Pb with toxic potential in plants with economic importance is an essential desideratum (BORA & BUNEA, 2019).

Lichens as accumulators of trace elements is a research area of great interest for air pollution monitoring (BRUNIALTI & FRATI, 2014). They represent ideal experimental models for physiological parameters assessment that are affected by this process (OZTETIK & CICEK, 2011). A wide range of foliose and corticolous lichen species are used as biomonitors, as *Flavoparmelia caperata, Leptogium gelatinosum, Collema subnigrescens, Xanthoria calcicola, Xanthoria parietina, Physcia adcendes, Physcia aipolia, Xanthoparmelia conspersa, Ramalina farinacea and Phaeophyscia orbicularis* (KINALIOGLU et al., 2020).

Figure 1 *Robinia pseudacacia* L. trunk covered in abundance with *Xanthoria parietina* L. (original photo, Voicu Diana).

Heavy metal concentrations from the lichen thallus reflects their presence in the environment (CONTI & TUDINO, 2016). The main source of heavy metals uptake is the substrate and the accumulation mechanism implies three stages: trapping of solid particles, extracellular binding with exchange sites to the cell walls of the symbionts and intracellular uptake (ROLA et al 2016). The success of colonization of the substrate by lichens depends on the level of contamination with heavy metals; the accumulation pattern differs between different metals (ROLA et al., 2020).

The lichens have mechanisms of preventing heavy metals accumulation: the secondary metabolites of lichens form chelates with heavy metals; the substance from the lichen cortex, namely parietin, plays an important role in the protection of photobiont cells, photosynthetic pigments and chlorophyll-a fluorescence from the heavy metals deposited in excess, like cadmium (KALINOWSKA et al., 2015); binding cations at the extracellular sites (BAČKOR & LOPPI, 2009); formation of metal complexes by production of metal - binding proteins with suspensions of minerals and rocks, organic and inorganic precipitation, active transport, intracellular compartmentation, constituents of cell walls as chitin and melanin with significant metal-binding affinities; norstictic acid and other lichen substances determine tolerance to excess metal ions enabling colonisation of mineral substrates.

Lichens also have adaptations to tolerate metal toxicity. A physiological adaptation of lichens in metalliferous habitats is that they grow very slow. The positive effect of lichen association with metal is that copper lichen complexes and iron compounds function as sun-screening pigments (PURVIS, 2014). Out of the lichen symbionts, the most sensitive to abiotic stress are the photobionts. The photobiont decreases the impact of heavy metals through the sulfhydrate groups. In photobionts subjected to the action of heavy metals the concentrations of cysteine and proline are increased, forming stable complexes with free radicals (BACKOR & FAHSELT, 2008). Photobionts produce phytochelatins when are exposed to different amounts of heavy metals as Cd, Pb and Zn (PAWLIK-SKOWRONSKA et al., 2002); Cd and Cu are strong activators of phytochelatins biosynthesis in the lichen photobiont *Trebouxia erici* (BAČKOR et al., 2007).

Their uptake is positively influenced by a long exposure time (24 h) in 5 mM HEPES in 24 h (BAČKOR et al., 2007). Phytochelatins have not been observed in aposymbiotically grown lichen mycobionts. The cultured *Cladonia cristatella* mycobiont also did not produce phytochelatins (BAČKOR et al., 2006). To some extent, the metabolites produced by the mycobiont are involved in the tolerance of heaby metals.

Plants have detoxification mechanisms as a result of heavy metals accumulation like calcium inhibiting Cr ascension from root to shoot in rice seedlings (BRUNIALTI & FRATI, 2014; MUKTA et al., 2019). The high density of the heavy metals from the atmosphere influences the development of lichens, especially the early stages (SCHUSTER et al., 1985; OTT, 1987). In lichens, heavy metals get inside atoms of the thalli and accumulate by complexes with lichen secondary metabolites (LONGTON, 1997). Heavy metals influence the lichens' physiology. The phenotipic traits of the thallus influence bioaccumulation (OSYCZKA et al., 2018).

Heavy metals like Cu are phytotoxic and inhibitory on photobiont growth, viability and chlorophyll-a fluorescence (BIĽOVÁ et al., 2019). The establishment of lichen symbiosis is influenced by the accumulation of heavy metals. Therefore, the *in vitro* culture experiments proved that the molecules implied in signalling and recognition between symbionts are inhibited by sulphur-based pollutants $ZnSO_4$ x $7H_2O$ (VOICU & GAVRILOAIE, 2007). Sulphur compounds also affect the physiological processes like plasmalemma permeability and enzymatic activity of the symbionts (SUNDSTROM & HALLGREN, 1973). The process of accumulation depends on a range of factors, like pH (decreasing the PH increases the solubility of some metals, from the atmosphere or substrate), temperature, location of lichens (correlated with weather conditions, precipitation allowing solubility), location (lichens from the isolated trees contain a higher quantity of heavy metals than those from a forest), soil stability (WEGRZYN et al., 2016).

Chemical compounds are closely involved in the bioaccumulation of heavy metals. The secondary metabolites of lichens secondary have an increased reactivity to increased concentrations of metal ions. The experimental results revealed that the level of secondary metabolites decreases as thallus accumulates heavy metal ions. Therefore, increased concentrations of copper induce a reduction of the secondary metabolites level in lichen *Stereocaulon japonicum* (NAKAJIMA et al., 2019). Comparative studies regarding air pollution in urban areas and control sites in nearby forests using different species of lichens, as *Parmotrema arnoldii* and *Tillandsia usneoides* (BENITEZ et al., 2019), are required to evaluate heavy metal depositions. For a comparative study related to the different degree of pollution, lichen samples are collected from urban, peri-urban and rural areas. Lichen samples from urban areas are enriched with metals originating from vehicle emissions and road dust (DAIMARI et al., 2020). The absence of sensitive lichen species in the parks of Bucharest beside the morphological changes in the moderately sensitive species reflect the high degree of pollution by intensive traffic (GOMOIU& ȘTEFĂNUȚ, 2008). Bioaccumulation with lichens presents two methodological approaches: bioaccumulation with lichens collected *in situ* and bioaccumulation with lichen transplants (CANSARAN & DUMAS, 2015). Different transplanted sites, as the vicinity of industries, evidence a particular type of metal accumulation (LOGESH et al., 2014). Transplanted lichens are also used to investigate indoor air quality and outdoor air quality in urban and rural areas, mostly in schools; studies indicate that in indoor conditions lichens accumulate Cd, Cu and Pb and maintain their viability (PAOLI et al., 2019). The bioindication parameters of lichens can be improved by calculating various ecological variables and estimation of environment quality.

Lichen abundance as an indicator of metal pollution is a better indicator than the index of atmospheric purity (AGNAN et al., 2017). Soil microbiota sustain plants to neutralize the noxious effect of heavy metals; the use of genetically engineered plants equipped with useful remediation traits according to the requirements of contaminated sites can be a highly effective tool to support this technology for on-site application (KHALID et al.,2016). For the safety of consumers regarding the plants' content of heavy metals, the cultivation of the plants must be realised in the areas without contamination with heavy metals (LAJAYER et al., 2017). Terricolous fruticose lichens absorb heavy metals from the corresponding substrata. They are used to monitor Cu, Zn and As pollution in surface soils (SUEOKA et al., 2016). In *Acarospora smaragdula* and *Lecidea lactea*, norstictic acid form complexes with copper from the cupriferous substrates (PURVIS et al., 1987). Interpretative scales are useful instruments to detect the amplitude of the pollution process in biomonitoring (CECCONI et al., 2019). Chlorophyll fluorescence emission is a parameter measured to highlight health lichens sample status. The lichens' viability influences the bioaccumulation capacity. From this point of view, CECCONI et al. (2019) determined 24 of chemical elements (Al, As, Ba, Bi, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Sb, Sr, Ti, Zn) to samples of *Pseudevernia furfuracea* devitalised by spectrophotometric method. The desiccation/rehydration state of the lichens influences the effect of some heavy metals on lichens ROS induced especially by the photobiont photosynthetic pigments; therefore, the concentration of ROS decreases (ÁLVAREZ et al., 2015). Differences are seen between species in terms of bioaccumulation level. In this context, FORTUNA & TRETIACH (2018) demonstrate that *P. furfuracea* accumulates three times more Hg than both *X. parietina* and *R. pseudoacacia*.

Their results are discussed in the context of the actual European Union directives concerning air pollution monitoring and assessment, revealing that both active and passive biomonitors are efficient tools to provide a reliable estimation of the spatial changes of Hg concentrations in the environment.

One of the longest biomonitoring studies of Hg air pollution ever carried out at a local scale concern five biomonitors performed in the proximity of a waste incinerator over a 16-year period according to both active (biomonitor transplants) and passive (sampling native biomonitor populations) techniques Our study demonstrate the high capacity of lichens to biomonitor pollution level with heavy metals.

Lichen nutrients and their implications in health benefit, beside secondary metabolites, promote lichens in future studies (ZHAO et al 2021).

CONCLUSIONS

The partners of the symbiosis ensure the morphological, physiological, biochemical unity of lichens system. The study lichen symbiosis implies deciphering numerous important aspects of development and reproduction strategies of this system in nature and *in vitro*. The *in vitro* conservation of lichens is an efficient alternative reproduction strategy in the context of environmental changes and offer the possibility to understand this type of close symbiosis by promoting new studies of interactions between symbionts.

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REFERENCES

ABAS A. 2021. A systematic review on biomonitoring using lichen as the biological indicator: A decade of practices, progress and challenges. *Ecological indicators*. Elsevier. Paris. **121**: 107-197.

ÁLVAREZ R., DEL HOYO A., DÍAZ-RODRÍGUEZ C., COELLO A. J., DEL CAMPO E. M., BARRENO E., CATALÁ M., CASANO L. M. 2015. Lichen rehydration in heavy metal-polluted environments: Pb modulates the oxidative response of both *Ramalina farinacea* thalli and its isolated microalgae. *Microbial Ecology*. Springer. Berlin. **69**(3): 698 -709.

ANSTETT D. N., SALCEDO A., LARSEN E. W. 2014. Growing foliose lichens cover on slips: A method for asexual propagation and observing development. *Bryologist*. BioOne Publisher. London. **117**: 179-186.

ARDELEAN I. V., KELLER C., SCHEIDEGGER C. 2015. Effects of Management on Lichen Species Richness, Ecological Traits and Community Structure in the Rodnei Mountains National Park (Romania). *Folia Cryptogamica Estonica*. Plos One Publisher. Varshava: 30.

ATHUKORALA S. N. P., PIERCEY - NORMORE M. D. 2014. Recognition and defense - related gene expression at 3 resynthesis stages in lichen symbionts. *Canadian Journal of Microbiology*. University Press. Toronto. **61**(1): 1-12.

AGNAN Y., PROBST A., SÉJALON-DELMAS N. 2017. Evaluation of lichen species resistance to atmospheric metal pollution by coupling diversity and bioaccumulation approaches: A new bioindication scale for French forested areas. *Ecological Indicators*. Elsevier. Paris. **72**: 99-110.

BAJPAI R., SEMWAL M., SINGH C. P. 2018. Suitability of lichens to monitor climate change Suitability of lichens to monitor climate change, *Cryptogam Biodiversity and Assessment*. Indian Lichenological Society Publisher. New Delhi: 182-189.

BAJPAI R., SHUKLA V., PANDEY U., UPRETI D. K. 2019. Do lichens have the ability to remove arsenic from water. *International Journal of Plant and Environment*. ISEB Publisher. London. **5**(1): 47-49.

BALÁŽ M., GOGA M., HEGEDÜS M., DANEU N., KOVÁČOVÁ M., TKÁČIKOVÁ L. 2020. Biomechanochemical Solid-State Synthesis of Silver Nanoparticles with Antibacterial Activity Using Lichens. *ACS Sustain. Chem. Engine.* ACS Publisher. London. **8**: 13945-13955.

BHATTACHARYYA S., RANI DEEP P., SINGH S., NAYAK B. 2016. Lichen secondary metabolites and its biological activity. *American Journal PharmTech Research*. EPIXPUB Publisher. New York. **6**(6): 23-50.

BAČKOR M., PAWLIK – SKOWRONSKA B., TOMKO J., BUDOVA J., SANITA᾽ DI TOPPI L. 2006. Response to copper stress in aposymbiotically grown lichen mycobiont *Cladonia cristatella*: uptake, viability, ergosterol and production of non-protein thiols. *Mycological research*. University Press. Toronto. **110**: 994 -999.

BAČKOR M., VACZI P., BARTAK M., BUDOVA J., DZUBAJ A. 2007. Uptake, photosynthetic characteristics and membrane lipid peroxidation levels in the lichen photobiont Trebouxia erici exposed to copper and cadmium. *The Bryologist*. BioOne Publisher. London. **110**(1): 100-107.

BAČKOR M. & FAHSELT D. 2008. Lichen photobionts and metal toxicity. *Symbiosis*. BioOne Publisher. London. **46**: 1-10.

BAČKOR M. & LOPPI S. 2009. Interactions of lichens with heavy metals. *Biologia plantarum*. Springer. Berlin. **53**(2): 214-222.

BENITEZ A., MEDINA J., VASQUEZ C., LOAIZA T., LUZURIAGA Y., CALVA J. 2019. Lichens and Bromeliads as Bioindicators of Heavy Metal Deposition in Ecuador. *Diversity*. Webster Publsher. London. **11**: 28.

BIĽOVÁ I., GOGA M., BAČKOR M. 2019. Physiological responses of *Xanthoria parietina* to longterm copper excess: role of the extracellular secondary metabolite parietin. *Botanica Serbica*. Faculty of Biology Publisher. Belgrad. **43**(2): 133-142.

BORA F. D. & BUNEA C. 2019. *Bioacumularea metalelor în vița-de-vie*. Edit. Bioflu., Cluj – Napoca. 300 pp.

BOONPENG C., SANGIAMDEE D., NOIKRAD S., WATTHANA S., BOONPRAGOB K. 2020. Metal accumulation in Lichens as a tool for assessing atmospheric contamination in a Natural Park. *Environment and Natural Resources Journal*. ISEB Publisher. London. **18(**2): 166-176.

BRUNIALTI G. & FRATI L. 2014. Bioaccumulation with lichens: the Italian experience *International Journal of Environmental Studies*. ISEB Publisher. London: 1-12.

CALCOTT M. J., ACKERLEY D. F., KNIGHT A., KEYZERS R. A. OWEN J. G. 2018. Secondary metabolism in the lichen symbiosis. *Chemical Society Review.* Bulletin of the Chemical Society of Japan Publisher. Tokyo. **47**(5): 1730-760.

CANSARAN-DUMAN D. & ARAS S. 2015. Lichens as an Alternative Lichens as an Alternative Biosorbent. *A Review in Ansari A A, Singh S, Gill R, Lanza GR, Newman L (eds.).* University Press. London: 233-238.

CECCONI E., FORTUNA L., BENESPERI R., BIANCHI E., BRUNIALTI G., CONTARDO T., DI NUZZO L., FRATI L., MONACI F., MUNZI S., NASCIMBENE J., PAOLI L., RAVERA S., VANNINI A., GIORDANI P., LOPPI S., TRETIACH M. 2019. New Interpretative Scales for Lichen Bioaccumulation Data: The Italian Proposal. *Atmosphere*. Springer. Berlin. **10**: 136.

CONTI M. E. & TUDINO M. B. 2016. Lichens as Biomonitors of Heavy-Metal Pollution. *In Comprehensive Analytical Chemistry*. Eds. Guardia M. and Armenta S. Elsevier. Paris. **73**(6): 117-149.

DAIMARI R., BHUYAN P., HUSSAIN S. 2020. Biomonitoring by epiphytic lichen species-*Pyxine cocoes* (Sw.) Nyl.: understanding characteristics of trace metal in ambient air of different landuses in mid-Brahmaputra Valley. *Environmental Monitoring and Assessment.* Springer. Berlin. **192**: 37.

DÍAZ E. M., SÁNCHEZ-ELORDI E., SANTIAGO R., VICENTE C., LEGAZ M. E. 2016. Algal-Fungal Mutualism: Cell Recognition and Maintenance of the Symbiotic Status of Lichens. *Journal Veterinary and Medicine Research*. Dove Press. London. **3**(3): 1052.

DIEU A., MAMBU L., CHAMPAVIER Y., CHALEIX V., SOL V., GLOAGUEN V., MILLOT M. 2020. Antibacterial activity of the lichens *Usnea florida* and *Flavoparmelia caperata (Parmeliaceae Natura)*. Product Research. *Formerly Natural Product Letters*. London. **34**(23): 3358-3362.

ELSHOBARY M. E., OSMAN M. E., ABO-SHADY A. M., KOMATSU E., PERREAULT H., SORENSEN J., PIERCEY- NORMORE M. D. 2016. Algal carbohydrates affect polyketide synthesis of the lichen-forming fungus *Cladonia rangiferina*. *Mycologia*. Taylor & Francis Publisher. New York. **108**(4): 646-656.

FAZIO A. T., ADLER M. T., PARNMEN S., LÜCKING R., MAIER M. S. 2018. Production of the bioactive pigment elsinochrome A by a cultured mycobiont strain of the lichen *Graphis elongata. Mycological Progress*. Springer. Berlin. **17**: 479-487.

FAZIO A. T., BERTONI M. D., ADLER M. T., RUIZ L. B., ROSSO M. L., MUGGIA L., HAGER A., STOCKER-WÖRGÖTTER E., MAIER M. S. 2009. Culture studies on the mycobiont isolated from *Parmotrema reticulatum* (Taylor) Choisy: Metabolite production under different conditions. *Mycological Progress*. Springer. Berlin. **8**: 359-365.

FAZIO A. T., ADLER M. T., MAIER M. S. 2014. Usnic acid and triacylglycerides production by the cultured lichen mycobiont of *Ramalina celastri*. *Natural Product Communications*. Sage Press. London. **9**(2):213-214.

FERNÁNDEZ-MARÍN B., LÓPEZ-POZO M., PERERA-CASTRO A., ARZACM, SÁENZ-CENICEROS A., COLESIE C., DE LOS RÍOS A., SANCHO L. G., PINTADO A., LAZA M., PÉREZ-ORTEGA S., GARCÍA-PLAZAOLA J. I. 2019. Symbiosis at its limits: ecophysiological consequences of lichenization in the genus Prasiola in Antarctica. *Annals of Botany*. Oxford Academic Press. London. **124**(7): 1211-1226.

FORTUNA L. & TRETIACH M. 2018 Effects of site-specific climatic conditions on the radial growth of the lichen biomonitor *Xanthoria parietina*. *Environmental Science Pollution Research*. Scimago Press. London. **25**: 34017-34026.

GAUTAM A. K., YADAV D., SAINI K. C., SINGH P. K., JIN J-O. 2021. Lichen: A comprehensive review on Lichens as a natural sources exploring nutritional and biopharmaceutical benefit. *Progress in Nutrition.* Mattioli Press. New York. **23**(3): 13-25.

GASSULA F., DEL CAMPO E., CASANO M., GUERA A. 2021 Advances in understanding of desiccation tolerance of lichens and lichen - forming algae. *Plants*. MDPI Press. London. **10**: 807.

GALLO L., CORAPI A., APOLLARO C., VESPASIANO G., LUCADAMO L. 2017. Effect of the interaction between transplants of the epiphytic lichen *Pseudoevernia furfuracea* L. (Zopf) and rainfall on the variation of element concentrations associated with the water – soluble part of atmospheric depositions. *Atmospheric Pollution Research*. Elsevier. Paris. **8**(5): 912-920.

GOGA M., ELEČKO J., MARCINČINOVÁ M., RUČOVÁ D., BAČKOROVÁ M., BAČKOR M. 2018. Lichen metabolites: An overview of some secondary metabolites and their biological potential. *In*: Merillon JM; Ramawat K. (eds) Co - evolution of secondary metabolites. *Reference series in phytochemistry*. Springer. Berlin: 1-36.

GRIMM M., GRUBE M., SCHIEFELBEIN U., ZUHLKE D., BERNHARDT J., RIEDEL K. 2021. The Lichen' s microbiota, still a mistery? *Frontiers in Microbiology*. Springer. Berlin. **12**: 623-839.

GOMOIU I. & ȘTEFĂNUȚ S. 2008. *Lichen and bryophytes as bioindicators of air pollution in Species monitoring in the Central parks of Buchares*. Edit. Ars Docendi. București. 135 pp.

HÁJEK J., BARTÁK M., HAZDROVÁ J., FORBELSKÁ M. 2016. Sensitivity of photosynthetic processes to freezing temperature in extremophilic lichens evaluated by linear cooling and chlorophyll fluorescence. *Cryobiology*. Elsevier. Paris. **73**(3): 329-334.

HINOJOSA - VIDAL E., MARCO F., MARTINEZ - ALBEROLA F., ESCARAY F. J., GARCIA -BREIJO F., REIG-ARMINANA J., CARRASO P., BARRENO E. 2018. Characterization of the responses to saline stress in the symbiotic green microalga *Trebouxia* sp. TR9 *Planta*. Serveis Press. London. **248**(6): 1473-1486.

HONEGGER R. 1996. Experimental studies of growth and regenerative capacity in the foliose lichen *Xanthoria parietina*. *New phytologist*. Willey Press. London. **133**(4): 573-581.

HUANG J., KRAICHAK E., LEAVITT S. D., NELSEN M., LUMBSCH H. 2019. Accelerated diversification in three diverse families of morphologically complex lichen - forming fungi link to major historical events. *Scientific Reports.* Nature Research Publisher. London. **9**: 8518.

KHALID S., SHAHID M., NIAZI N. K., MURTAZA B., BIBI I., DUMAT C. 2016. A comparison of technologies for remediation of heavy metal contaminated soils. *Journal of Geochemical Exploration*. Elsevier. Paris. **182**: 247-268.

KALINOWSKA R., BAČKOR M., PAWLIK-SKOWROŃSKA B. 2015. Parietin in the tolerant lichen *Xanthoria parietina* (L.) Th. Fr. increases protection of *Trebouxia* photobionts from cadmium excess. *Ecological Indicators*. Elsevier. Paris. **58**: 132-138.

KINALIOGLU K., KUTBAY H. G., SURMEN B., YILMAZ H. 2020. Heavy metal accumulation in some lichen species occurred from west to east black sea regions of Turkey. *FEB*. Barcelona: 6258-6264.

KRANNER I, BECKETT R, HOCHMAN A, NASH III T 2008. Desiccation-tolerance in lichens: a review. *The Briologist*. BioOne Press. London. **111**: 576-593.

KONO M., KON Y., OHMURA Y., SATTA Y., TERAI Y. 2020. *In vitro* resynthesis of lichenization reveals the genetic background of symbiosisspecific fungal-algal interaction in *Usnea hakonensis*. *BMC Genomics*. BioMed Publisher. London. **21**: 671.

KVÍDEROVÁ J., HÁJEK J., WORLAND M. 2013. The ice nucleation activity of extremophilic algae. *CryolLetters*. Conect Publication. London. **34**(2): 137-148.

LAJAYER B. .A, GHORBANPOUR M., NIKABADI S. 2017. Heavy metals in contaminated environment: destiny of secondary metabolite biosynthesis, oxidative status and phytoextraction in medicinal plants in contaminated environment: Destiny of secondary metabolite biosynthesis, oxidative status and phytoextraction in medicinal plants, *Ecotoxicology and Environmental Safety*. Elsevier. Paris. **145**: 377-390.

LOGESH A. R., UPADHYAY A. K., JOSHI S., KALAISELVAM M., UPRETI D. K., SHUKLA A. C. 2014. Lichen as indicator of metal pollution in the vicinity of SIPCOT industries in Cuddalore, southeast coast of India. *Mycosphere*. Scimago Press. London. **5**(5): 681-687.

LONGTON L. 1997. The role of Bryophytes and lichens in polar ecosystems. *BES*. Barcelona. **13**: 69-96.

LEELA K. & ANCHANA DEVI C. 2017. A study on the applications of silver nanoparticle synthesized using the aqueous extract and the purified secondary metabolites of lichen. *Parmeliaperlata*. *Int. J. Pharm. Sci. Invent*. Scimago Press. London. **6**: 42-59.

MCDONALD T. R., GAYA E., LUTZONI L. 2013. Ttwenty - five cultures of lichenizing fungi available for experimental studies on symbiotic systems. *Symbiosis*. Springer. Berlin. **59**(3): 165-171.

MIE R., SAMSUDIN M. W., DIN L. B., AHMAD A., IBRAHIM N., AND ADNAN S. N. A. 2014. Synthesis of silver nanoparticles with antibacterial activity using the lichen *Parmotrema praesorediosum*. *International Journal Nanomed.* Dove Press. London. **9**, 121-127.

MOLINA M. C., STOCKER - WÖRGÖTTER E., ZORER R., TÜRK R., VICENTE C. 1997. Comparison between recent – isolated and cultured populations of phycobionts from *Xanthoria parietina* (L.) In: Schenk HEA, Hermann RG, Jeon KW, Müller NE, Schwemmler W (eds). *Eukaryotism and Symbiosis*. Springer. Berlin Heidelberg: 484-490.

MOLINA MC, STOCKER - WÖRGÖTTER E, TÜRK R, VICENTE C 1997. Axenic culture of the mycobiont of *Xanthoria parietina* in different nutritive media: effect of carbon source in spore germination. *Endocytobiosis & Cell Res*. Springer. Berlin Heidelberg. **12**: 103-109.

MOLINA M. C. & VICENTE C. 2000. Purification and characterization of two isolectins with arginase activity from the lichen *Xanthoria parietina*. *Journal of Biochemistry and Molecular Biology*. Elsevier. Paris. **33(**4): 300-307.

MUKTA R. H., KHATUN M. R., HUDA A. K. 2019. Calcium induces phytochelatin accumulation to cope with chromium toxicity in rice (*Oryza sativa* L.). *Journal of Plant Interactions*. Wiley Press. London. **14(**1): 295-302.

NAKAJIMA H., FUJIMOTO N., YAMAMOTO Y., AMEMIYA T., ITOH K. 2019. Response of secondary metabolites to Cu in the Cu-hyperaccumulator lichen *Stereocaulon japonicum*. *Environ Sci Pollut Res*. EcoMed Publisher. London. **26**: 905-912.

NEUPANE B. P., MALLA K. P., GAUTAM A., CHAUDHARY D., PAUDEL S., TIMSINA S., JAMARKATTEL N. 2017. Elevation trends in usnic acid concentration of lichen Parmelia flexilis in relation to temperature and precipitation. *Climate*. IPCC Press. London. **5**: 40.

OTT S. 1987a. The juvenile development of lichen thalli from vegetative diaspores. *Symbiosis*. BBA Press. London. **3**: 57-74.

OTT S. 1987b. Sexual reproduction and developmental adaptations in *Xanthoria parietina*. Nord. Journal Botanical. **7**: 219-228.

OTT S. & JAHNS H. M. 2002. Differentiation processes in lichens - *in vivo* cultivation and transplantation methods. *In: Kranner IC, Beckett RP, Varma AK (eds.) Protocols in Lichenology. Springer Lab Manuals*. Springer. Berlin, Heidelberg: 23-45.

OZTETIK E. & CICEK A. 2011. Effects of urban air pollutants on elemental accumulation and identification of oxidative stress biomarkers in the transplanted lichen *Pseudovernia furfuracea*. *Environmental Toxicology and Chemistry*. Wiley Press. London. **30**(7): 1629-1636.

OSYCZKA P., BOROŃ P., LENART-BOROŃ A., ROLA K. 2018. Modifications in the structure of the lichen *Cladonia thallus* in the aftermath of habitat contamination and implications for its heavy-metal accumulation capacity. *Environmental Science Pollutation Research*. PubMed Press. London. **25**: 1950-1961.

PAOLI L., FACKOVCOVÁ Z., GUTTOVÁ A., MACCELLI C., KRESÁNOVÁ K., LOPPI S. 2019. *Evernia* Goes to School: Bioaccumulation of Heavy Metals and Photosynthetic Performance. *In LichenTransplants Exposed Indoors and Outdoors in Public and Private Environments*. Plants. MDPI Press. London. **8**: 125.

PAWLIK-SKOWROŃSKA B., SANITÀ DI TOPPI L., FAVALI M. A., FOSSATI F., PIRSZEL J., SKOWRONSKI T. 2002. Lichens respond to heavy metals by phytochelatin. Synthesis. *New Phytologist*. Wiley Press. London. **156**: 95-102.

PURVIS O. W., ELIX J. A., BROOMHEAD J. A., JONES G. C. 1987. The occurrence of copper norstictic acid in lichens from cupriferous substrata. *Lichenologist*. Elsevier. Paris. **19**: 193-203.

PURVIS O. W. 2014. Adaptation and interaction of saxicolous crustose lichens with metals. *Botanical Studies*. Springer. Berlin. **55**: 23

PICHLER G., STÖGGL W., TRIPPEL D., CANDOTTO CARNIEL F., MUGGIA L., AMETRANO C. G., TUĞÇE Ç., HOLZINGER A., TRETIACH M., KRANNER I. 2020. Phytohormone release by three isolated lichen mycobionts and the effects of indole-3-acetic acid on their compatible photobionts. *Symbiosis*. BBA Press. London. **82**: 95-108.

RAFAT A., HAYLEY J., RIDGWAY R., CRUICKSHANK H., BUCKLEY H. L. 2015. Isolation and co - culturing of symbionts in the genus *Usnea. Symbiosis*. BBA Press. London. **56**: 23-35.

RAI H. & GUPTA R. K. 2019. Biogenic fabrication, characterization, and assessment of antibacterial activity of silver nanoparticles of a high altitude Himalayan lichen-Cladoniarangiferina (L.) Weber ex FH Wigg. *Tropical Plant Research*. Springer. Berlin. **6**: 293-298.

RASSABINA A., GURJANOV O., BECKETT R., MINIBAYEVA F. V. 2020. Melanin from the Lichens *Cetraria islandica* and *Pseudevernia furfuracea*: Structural Features and Physicochemical Properties. *Biochemistry Moscow*. Springer. Moscow. **85**: 623-628.

RATTAN R., SHUKLA S., SHARMA B., BHAT M. 2021. A mini-review on lichen-based nanoparticles and their applications as antimicrobial agents. *Frontiers Microbiology*. Scimago Press. London: 15-25.

ROLA K., OSYCZKA P., KAFEL A. 2016. Different Heavy Metal Accumulation Strategies of Epilithic Lichens Colonising Artificial Post-Smelting Wastes Arch. *Environ Contam Toxicol*. Springer. Berlin. **70**: 418-428.

ROLA K. 2020. Insight into the pattern of heavy-metal accumulation in lichen thalli. *Journal of Trace Elements in Medicine and Biology*. Springer. Berlin. **61**: 126-512.

SHANMUGAM K., SRINIVASAN M., HARIHARAN G. N. 2016. Developmental stages and secondary compound biosynthesis of mycobiont and whole thallus cultures of *Buellia subsororioides*. *Mycol Progress*. Willey Press. London. **15**: 41.

SIDDIQI K. S., RASHID M., RAHMAN A., TAJUDDIN A., HUSEN A., REHMAN S. 2018. Biogenic fabrication and characterization of silver nanoparticles using aqueous-ethanolic extract of lichen (*Usnea longissima*) and their antimicrobial activity. *Biomater. Res*. NCBI Press. London. **22**: 23.

SINGH G., FRANCESCO DAL GRANDE, PRADEEP K., DIVAKAR P., OTTE J., CRESPO A., SCHMITT I. 2016. Fungal-algal association patterns in lichen symbiosis linked to Macroclimate. *New Phytologist*. Wiley Press. London: 23-35.

SPIELMANN A. & PEREIRA A. B. 2012. Lichens on the maritime Antarctica (A small field guide for some common species). *Glalia*. **4**(3): 1-28.

STEINOVA J., SKALOUD P., YAHR R., BESTOVA H. 2019. Reproductive and dispersal strategies shape the diversity of mycobiont-photobiont association in *Cladonia* lichens. *Molecular Phylogenetics and Evolution*. Elsevier. Paris: 15-22.

SAWIDIS T., CHETTRI M. K., ZACHARIADIS A., STRATIS J. A., SEAWARD M. R. D. 1995. Heavy metal bioaccumulation in lichens from Macedonia in northern Greece. *Toxicological & Environmental Chemistry*. Taylor & Francis Press. **50**(1-4): 157-166.

SHAHID M., DUMAT C., KHALID S., SCHRECK E., XIONG T., NIAZI N. K. 2016. Foliar heavy metal uptake, toxicity and detoxification in plants: A comparison of foliar and root metal uptake. *Journal of Hazardous Materials*. Elsevier. Paris. **325**: 36-58.

SCHUSTER G., OTT S., JAHNS H. M. 1985. Artificial cultures of lichens in the natural environment. *Lichenologist*. Elsevier. Paris. **17**: 247-253.

SPRIBILLE T. 2019. Lichen symbionts outside of symbiosis how do they find their match? A commentary on: A case study on the re-establishment of the cyanolichen symbiosis: where do the compatible photobionts come from? *Annals* of *Botany*. Elsevier. Paris. **124**(6-7): 13-25.

SUEOKA Y., SAKAKIBARA M., SANO S., YAMAMOTO Y. 2016. A new method of enviromnemtal assessment and monitoring of Cu, Zn, As, and Pb pollution in surface soil using terricolous fruticose lichens. *Environments*. MDPI Press. London. **3**: 35.

SUNDSTROM K. R. & HALLGREN J. E. 1973. Using lichens as physiological indicators of sulfurous pollutants. *Ambio*. Springer. Berlin. **2**: 13-21.

SUHARNO T., CHRYSTOMO L. Y., SUJARTA P., TANJUNG R. H. R. 2020. Rapid assessment of lichen diversity in Baliem Valley. *Biodiversitas*. Jayawijaya, Papua. **21**(6): 2403-2409.

ŞTEFĂNUŢ S., MANOLE A., ION C. M., ÖLLERER K. Á., ONETE MARILENA, MANU MINODORA, VICOL IOANA, MOLDOVEANU MIRELA, MAICAN SANDA, BANCIU C., COBZARU IOANA, NICOARĂ R. G., FLORESCU L .I, MOGÎLDEA E. D, PURICE D-M, NICOLAE C. D., CATANĂ R., VĂLEANU V. D. F., CONSTANTIN M. 2017. *Ghid de utilizare a speciilor in programele de biomonitorizare*. Edit. Ars Docendi. Bucureşti. 106 pp.

ŞTEFĂNUŢ S., MANOLE A., ION M. C., CONSTANTIN M., BANCIU C., ONETE M., MANU M., VICOL I., MOLDOVEANU M. I., MAICAN S. COBZARU I., NICOARĂ R. G., FLORESCU L. I., MOGÎLDEA E. D., PURICE D. M., NICOLAE C. D., CATANĂ R. D., TEODOSIU G., DUMITRACHE C. A., MARIA G. M., VÂTCĂ C., OANŢĂ M., ÖLLERER K. 2018. Developing a novel warning-informative system as a tool for environmental decision-making based on biomonitoring. *Ecological Indicators*. Elsevier. Paris. **89**: 480-487.

TRIPP E. A. & LENDEMER J. C. 2018. Twenty - seven modes of reproduction in the obligate lichen symbiosis. *Brittonia*. Springer. Berlin. **70**(1): 1-14.

VICOL IOANA. 2016. Ecological patterns of lichen species abundance in mixed forests of Eastern Romania. *Annals of Forest Research*. Springer. Berlin. **59**(2): 237-248.

VICOL IOANA. 2018. The assessment of the atmospheric pollution by accumulation of the heavy metals in central and peripheral parts of *Xanthoria parietina* (l.) Th. Fr., Romania. *Oltenia. Studii si comunicari. Ştiinţele Naturii*. Muzeul Olteniei Craiova. **34**(1): 12-22.

VOICU DIANA & GAVRILOAIE I. C. 2007. Efectul concentraţiei crescute de sulfat de zinc asupra speciei *Xanthoria parietina* Beltr. (Ascomycetes, Teloschistaceae) în condiţiile cultivării *in vitro*. *Environment & Progress*. Wiley Press. London. **10**: 477-481.

VOICU DIANA, BREZEANU A., TOMA N. 2017. Lichens - some relevant aspects of the *in vitro* culture and ultrastructural peculiarities. *Rom. J. Biol. - Plant Biol*. Wiley Press. London. **62**(2): 77-88.

VOICU DIANA & GAVRILOAIE C. 2017. An overview to lichens. *Ecoterra*. University Press. Toronto. **14**(4): 31-40.

VOICU D. M. F., MITOI M. E., GAVRILOAIE C., HELEPCIUC F. E., TOMA N. 2019. Chemical investigations of lichen Biomass in *Usnea barbata*, *Cetraria islandica*, and *Xanthoria parietina* species. *ELBA Bioflux*. Edit. Bioflux. Cluj-Napoca. **11**(1): 1-8.

WEISSMAN L., GARTY J., HOCHMAN A. 2005. Rehydration of the lichen *Ramalina lacera* results in production of reactive oxygen species and nitric oxide and a decrease in antioxidants. *Appl Environ Microbiol*. American Society for Microbiology. New York. **71**(4): 2121-2129.

WEGRZYN M., WIETRZYK P., LISOWSKA M., KLIMEK B., NICIA P. 2016. What influences heavy metals accumulation in arctic lichen *Cetrariella delisei* in Svalbard. *Polar Science*. Elsevier. Paris. **10**: 532-540.

YAVUZ M. & ÇOBANOĞLU G. 2019. A biomonitoring study on *Xanthoria parietina* (L.) Th.Fr. in Isparta, Turkey. *Oltenia. Studii si comunicari. Stiintele Naturii.* Muzeul Olteniei Craiova. **35**(1): 71-81.

ZACHARIAH S. A. & VARGHESE S. K. 2018. The Lichen Symbiosis: A Review. *IJSRR*. University Press. New York. **7**(3): 1160-1169.

ZHAO L., ZHANG C., JIA S., LIU Q., CHEN Q., LI X., LIU X. 2019. Element bioaccumulation in lichens transplanted along two roads: The source and integration time of elements. *Ecological Indicators*. Elsevier. Paris. **99**: 101-107.

ZHAO Y, WANG W, XU B. 2021. A comprehensive review on secondary metabolites and health – promoting effects on edible lichens. *Journal of Functional Foods*. Elsevier. Paris. **80**: 104-283.

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