NUTRITIONAL PARTICULARITIES OF LICHENS

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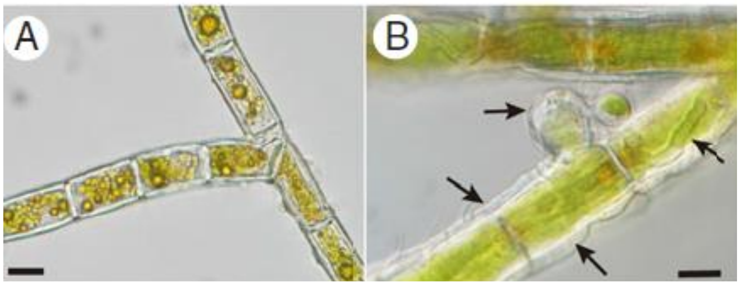
Abstract: In order to characterise lichens nutritional requirements, we considered the following aspects: symbiosis, as a nutritional strategy between the lichen components, mainly the photosynthetic partner (green alga or cyanobacteria) and the heterotrophyc mycobiont; lichen substrate preferences related to resource acquisition and thallus morphology, water supply, poikilohydric nature of the thallus; lichen metabolism limited by water content and light availabulity; nutrition based on synthetic recipes in *in vitro* conditions. For this purpose, we reviewed 45 titles.

Keywords: lichens substrate, lichen thallus hydration, lichens resource, in vitro culture.

INTRODUCTION

Antioxidant activity of lichens, (Luo *et al.*, 2010) beside the symbiosis particularities, promote lichens as source of bioactive compounds and model of symbiosis. Lichenization is a nutritional strategy of lichens (Prieto *et al.*, 2023). Pichler et coworkers (2023) describe the lichen thallus as a fine - tuned symbiotic interplay supporting nutrition, tolerance of irradiation, desiccation and reproduction. Nutritional relationship between lichen symbionts involve the transfer of photosynthate as polyols (ribitol) from the photobiont to the mycobiont through the hydrophobic sealant which includes them (Sanders and Masumoto, 2021). The photobiont may be represented by *Trentepohlia* or *Trebouxia* (Figs. 1, 2)



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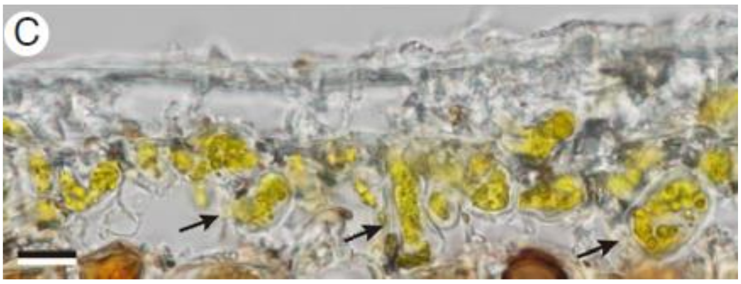
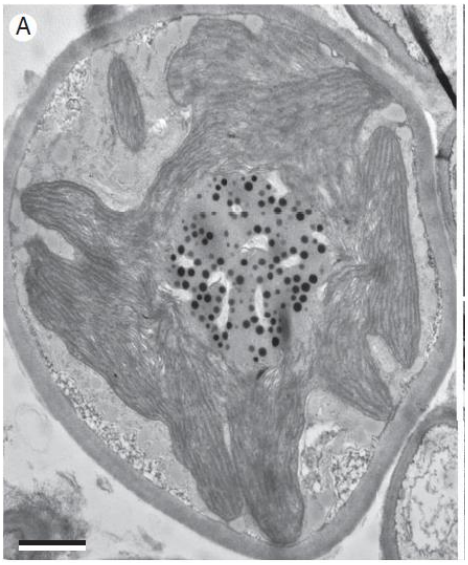


Fig 1 Three filamentous lichen photobiont genera in aposymbiotic and symbiotic states.
A–C, *Trentepohlia*.

A. *Trentepohlia* with branching filament free – living on bark
B. Lichenized by *Coenogonium* hyphae growing over morphologically unchanged algal filaments and new branches
C. Lichenized by *Arthonia rubrocincta*.



Trebouxia, within the thallus of *Lasallia pustulata*.

Lichens substrat:

Lichens are addicted with their substrate regarding their morphology and physiology: terricolous lichens, saxicolous, epiphytes. Some lichens are strictly limited to a particular habitat. Crustose heteromerous lichens have a stronger adaptation to different environments in contrast to homeomerous lichens (Aprile *et al.*, 2011). Lichen substances influence indirectly the nutrients cycling and biogeochemical processes in forest ecosystems (Furmanek *et al.*, 2022). At the contact of the lichen thallus with the substrate as in *Xanthoparmelia farinosa* we can discerne the soredia relation with this, consisting in a discontinuous layer (the outline of the lower cortex) (Garcia and Rosato, 2018), these structures having an important role in ontogenetic development of thallus, by fusion, in time, the mass of soredia becoming a protolobe. Lichens erode substrate as rock stones or buildings, statues (Piervittori *et al.*, 2004) by expansion of lichen thalli in cracks (Richardson 1975) or by hyphae entering 10 mm on lithotype of the rock (Favero – Longo *et al.* 2005). Also lichen carboxylic acids (oxalic, citric, gluconic, lactic) function as chelators and corrosive agents (Kiurski *et al.*, 2005). The main factor required for lichens nutrition and growth is water.

MATERIAL AND METHODS

We analyzed the scientific dates from about 49 articles regarding substrate preferences, water supply, poikilohydric nature of lichens, *in vitro* culture.

RESULTS AND DISCUSSION

Water supply. First, lichens benefits from atmospheric hydration sources as dew, rain and humid air for lichen thallus development (Gauslaa, 2014). Dew formation sustain photosynthetic activity and carbon assimilation of chlorolichens in precipitation-limited habitats (Lakatos and Obregon, 2012). Water holding capacity of lichens provide informations about how long they remain metabolically active and hidrated. This aspect has been determinated by Olsson (2014). For the study, Olsson (2014) used epiphytic hair lichens as components of the boreal forest flora community and model systems (*Bryoria, Usnea, Alectoria* chlorolichens). Hydration dynamic is correlated with poikilohydric status and also poikilothermic. Key adaptation of lichens to air humidity and core traits of the thallus are growth form, colour, melanin, hydrophobicity (repelling water/acid rain protection), photobiont (nutrients cycle water related), hairs, tomentum (more water gain), medulla pores, cyphellae (water - related, carbon dioxide facilitation and respiration), cilia (involved in water gain)(Canali *et al.*, 2025). The same work reveals underline that humid air determine the photobiont cells to reach full turgidity with the increasement of the photosynthetic capacity while fungal cells that have highly hydrophobic surfaces do not requires full turgidity. The wetting and drying cycles determine the changing morphology of thalli. Exposure to light and hydration is beneficial for growth of lichen thallus sensitive as *Lobaria pulmonaria* (Borge and Ellis, 2024). Ambient warming and drying decrease growth of boreal epiphytic lichen *Evernia*, an moisture indicator losses, influencing evem local and regional populations (Smith *et al.*, 2018). This fact is argumented as a reversal of carbon uptake induced by novel climates. Photosynthesis reaches a maximum threshold when the thallus is saturated in terms of hydration. Thus, the hydration degree of the lichen thallus is correlated with the photosynthesis process of the photobiont cells and is directly proportional to it (Solhaug *et al..*, 2021; Ellis, 2020). On the other hand, supersaturation causes the accumulation of excess water on the thallus surface, thus reducing the rate of photosynthesis and limiting gas exchange (Lange *et al.*, 1996, 2000, 2004). Prolonged dry or prolonged wet periods are detrimental for lichens. González-Hourcade *et al.*, (2020) revealed by ultrastructural analyses, the biochemicall remodelling of the cell wall in microalgae exposed to cycles of drying and rehidration resulted in increased flexibility. Cyanolichens have a particular affinity for water; some lichens classified in the *Collemataceae* (*Peltigerales, Ascomycota*) become gelatinous in moisture conditions because they contain cyanobacteria as filamentous *Nostoc* in their symbiosis with lichen forming fungi (Wedin *et al.*, 2009).

Lichens exposure in experimental condition to different concentrations of lead solutions, trigger the alteration of physiological parameters inside the thalli by significant accumulation of lead in different manner via cations exchange mechanisms (Kouadria *et al.*, 2020). This aspect point out the employment of A wide list of the lichen species as *Xanthoria parietina* and *Hylocomium splendens* as bio-indicators of air quality.

Noxes from environment. Lichens can bind metal cations to extracellular sites of symbiotic partners and subsequently form oxalates in order to overcome the toxicity of metals (Rucova *et al..*, 2022). Calcium can function as a metal ligand but in elevated concentration can be toxic. Lichen squamule contain the highest concentration of calcium; these morphological structures of the thallus are seen as final deposit for detoxification. Also, lichens have mechanisms of neutralize the harmful effects of nitrogen excess as accumulating nitrogen in a non toxic form of chitin (the major constituent of fungal cell wall). Munzi *et al.*, 2023 quantified chitin in two oligotrophic lichens *Usnea* and *Cladonia rangiferina* after a method of Dahlman ey al, (2003). Differences between the response to the same amount of nitrogen in the tissue have been observed to the lichen species used as experimental model. The results revealed that *Cladonia* has the ability to cope with increased nitrogen availability by inducing a protection mechanisms. Nitrophytic lichens as *Physconia grisea* are a good indicator species for NH_3 pollution correlated with bark pH (Frati *et al.*, 2007). In tripartite lichens, fungus receive and fixed nitrogen from the cyanobiont or cephalobiont (a cyanobacteria included in structures named cephalodia) (Rascio and La Rocca, 2008) beside the fixed carbon from the photobiont. Tripartite lichens as *Ricasolia virens* (García-Breijo *et al.*, 2021) are abundant in cephalodia. Nitrogen additions to bipartite green algal lichens in most cases increase thallus growth (Dahlman, 2003).

Lichen polysaccharides. Lichens contains three main structural types of olysaccharide: alfa – glucans, beta – glucans, and galactomannans (Olafsdottir and Ingólfsdottir 2007, Akbulut and Yildiz, 2010). Lichen polysaccharides, produced in considerable amounts exhibit immunostimulating effects. *Cetraria islandica* and *Alectoria ochroleuca* have the greatest lichenin content (Podterob, 2008). Extracellular polysaccharide EPS - secreting cyanobacterium Nostoc PCC 7413 cultured together with fungal *Aspergillus nidulans* increase total biomass 3 or – fold higher than the axenic *Nostoc* cultures. The range of fatty acids generated in co – culture differed from the individual species (Tingting Li *et al.*, 2019). In axenically conditions *in vitro* culture medium provide nutriments for photobiont component of lichens as for mycobiont, corresponding to the particular requirements. The mycobiont of the lichens transform the fixed carbon by the photobiont photosynthesis into acyclic polyols. Another part of carbon is deployed in cell walls or mucilaginous intercellular matrices or used for synthesis of secondary metabolites (Fahselt, 1994).

In vitro culture. Growth rate of lichens and antioxidant metabolites production can be enhanced by in *in vitro* culture with standardized culture conditions provided by nutrient media as Bold basal medium (BBM) (1% glucose, 50 ppb asparagines, pH 6.5) and Murashige Skoog medium (3% sucrose, 100 ppb thiamine, pH 5.9, (Verma *et al.*, 2004). In experimental conditions, *Peltigera praetextata* cyanolichen thallus has nutritional preferences for 2% water agar medium (Yoshimura and Yamamoto, 1991), most amenable for thallus development of the lichen, from the other variants of culture media tested as Modified Deter Medium (MDM) (Watanabe, 1960) and Malt-Yeast Extract Medium (MY)(Ahmadjian,1967).

Mycobiont *in vitro* cultures are amenable for production of secondary metabolites (Rosabal and Pino – Bodas) (2024) as norstictic acid (*Buellia* and *Graphis handelii* Zahlb (Hamada *et al.*, 2001), atranorin (*Buellia* sp., *Dirinaria applanata* and *Lecanora niponica*, divaricatic acid and sekikaic aicd (*D. applanata*) (Valarmathi *et al.*, 2007) stearic acid, linoleic acid and oleic acid (*Physconia distorta*)(Molina *et al.*, 2003), protocetraric acid, hypoprotocetraric acid, salazinic acid, consalazinic acid and usnic acid (*Ramalina farinacea L.* cultures), usnic acid (*Usnea ghattensis*) (Stocker-Worgotter, E. *et al.*, 2004; Behera *et al.*, 2009).

Future research aims to develop new biotechnological methods in order to increase the accumulation of biologically active compounds in lichens.

CONCLUSIONS

The hedge like structure created by the mycobiont scavenge the photobiont from the ecological noxes and environment parameters that can interact with the physiological funtion of photobiont as dessication or excess moisture, limiting conditions for other species.

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