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Review Article

A Review on Lichen: The Oldest Symbiotic Relationship

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Abstract

Lichens are best understood as self-sustaining ecosystems resulting from interacting with a fungus, one or more photosynthetic organisms, and numerous other microscopic entities. The fungal component provides an overall structure and scientific nomenclature. These associations were the first to be described as symbiotic and considered mutualistic, as all participants benefit by enabling the colonization of new environments. This text outlines the current economic and traditional uses of lichens, highlighting the various natural compounds they produce, some of which show potential for pharmaceutical applications.

Keywords: *Lichen, Symbiotic Relationship, Devonian period.*

Introduction

According to fossil evidence, lichens may have existed on Earth for at least 400 million years during the Devonian period. This long-standing partnership is considered essential for the formation of the planet's ecosystems (Hawksworth, *et al.*, 2020). Lichens are believed to be the oldest evolutionary association. Lichen symbioses are found in almost all terrestrial ecosystems, including polar and tropical rainforests. Most lichen symbioses are widely used as biological indicators (Nimis, *et al.*, 2002). However, certain lichen species are not limited to land-based environments. These organisms can adapt to both terrestrial and aquatic settings, thriving in coastal intertidal areas (Grube, *et al.*, 2005) or living entirely submerged in freshwater ecosystems (Thus, *et al.*, 2014). A fungus and photosynthetic partner, such as algae or cyanobacteria, usually produce lichen symbiosis, a mysterious and unusual type of mutualism. Both organisms benefit from one another in this type of symbiotic relationship (Mitchell, 2007).

The fungal components of lichens provide their structure and resistance. It provides the photosynthetic partner with adequate habitat, moisture retention, and defence against damaging UV radiation, much like a shelter. Additionally, the fungus can absorb minerals from its surroundings, which is advantageous for both living organisms. The photosynthetic partner then performs photosynthesis using carbon dioxide, sunlight, and water to form sugar and oxygen, which are essential for fungus nutrition (Jahns, *et al.*, 1988). Therefore, lichen symbiosis survives and is tolerant to extremely harsh conditions such as drought, high UV radiation, and temperature fluctuations. Survival strategies help them survive on their own; that is, they are said to be the oldest relationship between algae and fungi.

Key Feature of Lichen Symbiosis

1. Adaptation or ability to survive in harsh conditions

Lichen adapts themselves or said to they have a combination of special kind of biological strategies that would be explained as follows-

1.1. Tolerance to dryness or prevention of desiccation

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Lichens are poikilohydric, meaning that they do not keep their internal moisture content steady. Instead, they adapt to the moisture present in their surroundings. They hydrate and become metabolically active when water is available; however, they may enter a dormant state when conditions dry up and prevent desiccation (Gasulla, *et al.,* 2021). Some lichens, including cyanobacteria, can fix nitrogen even in severely dry environments.

1.2. Protection from the UV rays

Lichens grow mostly in areas where high exposure to UV radiation i.e. mountain tops or the desert and as we know UV is harmful to living cells.in this adaptation strategy, fungal partners play a crucial role by providing a physical shield that protects the inside present photosynthetic cells (Beckett, *et al.,* 2021).

In addition, certain lichens generate secondary metabolites such as pigments (e.g., melanin) that shield algae or cyanobacteria from UV rays (Leksin, *et al.,* 2024).

1.3. Nutrient efficiency

Lichens are nutrient-poor organisms; often, they are very effective at obtaining nutrients from their surroundings (Nash, *et al.,* 1996). They absorb nutrients from air and rain. They can colonize bare rock surfaces or tree barks in areas with limited soil. Their nitrogen-fixing ability helps them survive in nutrient-deficient environments, such as deserts, tundra, or rocky areas where nitrogen levels are low (Werth, 2021).

2. SLOW GROWTH AND LONG LIFESPAN

Lichen uses limited resources and grow slowly i.e. survives for longer time. They slow down their metabolic activity or remain dormant under harsh conditions. By slowing down metabolic activity, they can conserve energy, resources, and nutrient requirements. Some lichens survive decades or even centuries by withstanding long environmental stresses, and when the conditions favour, they actively grow again. The remarkable ability of the majority of lichen-forming fungi and their photobionts to withstand heat, drought, and cold stress is a result of a unique combination of cellular defence and repair systems, the molecular basis of which remains unknown (Honegger., 1998).

3. FUNCTIONAL ASPECTS OF LICHEN SYMBIOSIS

3.1. Moisture retention quality

Water from the environment or precipitation can be absorbed and stored by the fungal matrix, giving photosynthetic cells a consistent source of water during periods of drought (Honegger, 1998). i.e. When water is restricted, cyanobacteria or algae can survive by retaining moisture.

3.2. Nitrogen Fixation

Certain lichen species, especially those that have cyanobacterial companions, may fix nitrogen from the atmosphere. These cyanobacteria transform atmospheric nitrogen (N_2) into ammonia, which lichens and their fungal companions can consume. This also contributed nitrogen to the nitrogen cycle and the nitrogen-deficient ecosystem (Henriksson, *et al.,* 1971).

4. Ecological Function

In many ecosystems, lichens are pioneer species, especially in harsh environments such as bare rock surfaces (Rose. 1976). They also help in the gradual weathering of rocky surfaces and the formation of a soil layer (Zambare, *et al.,* 2021). Their capacity to retain dust, water, and organic matter promotes soil development and the growth of other organisms, and acts as a pollution indicator (Ferry, *et al.,* 1973). Certain types of lichens, like crustose and foliose lichens, are tolerant to pollutants and do not exhibit susceptibility to them. These pollution-tolerant lichens also absorb a lot of heavy metals (Shukla, *et al.,* 2021).

5. Act as Bioindicator

They are sensitive to changes in the environment, especially air quality, contaminants, and climate and lichens are commonly acknowledged as bioindicators (Scheidegger, *et al.,* 2019 & Abas, *et al.,* 2018). They are used as bioindicators, particularly for tracking air pollution (conti, *et al.,* 2001 &

Taufikurahman, *et al.,* 2010 & Ferry, *et al.,* 1973) and heavy metals (Aslan, *et al.,* 2011). Numerous studies have demonstrated their use in monitoring air pollution, particularly in urban and industrial settings (Abas, *et al.,* 2018). These bioindicators can indicate long-term environmental changes and are widely accessible and reasonably priced.

6. Medicinal use of lichen

Since ancient times, lichens have been used in traditional medicine, and their potential medical benefits are now acknowledged in contemporary pharmacology. They are sources of various bioactive compounds, including antibiotics, antifungals, and antioxidants (Ahmad, *et al.,* 2001).

6.1. Antimicrobial and Antifungal Properties

The antibacterial and antioxidant properties of several lichen species have been investigated in several studies. This shows that some lichens have strong antimicrobial properties, especially against gram-positive bacteria, and antioxidant potential that may be effective in medicine. Lichens contain compounds such as usnic acid, lecanoric acid, and other secondary metabolites (Crawford, 2019). These compounds exhibit antibacterial, antifungal, and antiviral activities, rendering lichens valuable for treating infections.

6.2. Lichen Metabolites

Lichen metabolites have potential therapeutic applications. For example, the antibacterial effects of usnic acid and other bioactive compounds used in modern medicine are the most common lichen metabolites that have antimicrobial properties and are also used in some commercial skin products, and atranorin, which is also an antimicrobial property and has potential anticancer and antioxidant activities. One more kind Trentopohlin, a polyphenolic compound, also exhibits antimicrobial and anti-inflammatory actions, which are useful in treating infections and inflammatory disorders (Elkhateeb, *et al.,* 2019).

Lichens have the potential for future pharmaceutical development owing to the diverse range of bioactive chemicals found in lichens.

7. Traditional Uses

Ethnolichenology, also known as lichentherapy, is a subset of ethnobotany that examines the traditional human application of lichens (Julien, 1982). Bioactive compounds present in lichens have great potential for use in biopharmaceuticals as cytotoxic, antioxidant, and antibacterial agents (Elkateeb, *et al.,* 2022). The lichens represent a distinct division within the plant kingdom. They have been employed in Traditional systems of medicine including Traditional Indian Medicine (TIM), Traditional Chinese Medicine (TCM), homeopathic, and Western medical herbs.

7.1. Medical uses

Folk medicine science has used lichens, especially in many Asian, European, and North American civilizations. They serve as a remedy for conditions such as colds, coughs, wounds, and gastrointestinal issues (Elkhateeb, *et al.,* 2021), and are also used in smoking mixes and to treat eye conditions, two less widespread but still prevalent uses across many cultures (Elkhateeb, *et al.,* 2019).
In some traditional medicines, several lichens have been used to treat digestive problems, such as ulcers, indigestion, and gastritis. Additional typical topical lichen applications include treating mouth sores and skin infections (Elkhateeb, *et al.,* 2021& Elkhateeb, *et al.,* 2019) Many traditional applications, lichens are boiled to produce a mucilage that is administered topically or consumed to treat digestive or pulmonary conditions (Ahmed, *et al.,* 2017& El-Garawani, *et al.,* 2019).

7.2. Food and Fodder

Humans can benefit from lichens in various ways, including pharmacological, nutritional, and medical applications. Further research into their active compounds could lead to the development of new therapeutic agents and natural alternatives in healthcare. In India, *Parmelia* species are used as curry powders. Lichens are utilized in confections in France to make pastries and chocolates (Elkhateeb, *et al.,* 2022).

Cladonia rangiferina (Reindeer moss) is a type of food for reindeer that is present in polar countries. *Cetraria islandica* is also used as a horse fodder. Species of some lichen, such as *Evernia, Stereocaulon*, *Lecanora*, and *Parmelia,* are also used as fodder (Manoharachary, *et al.,* 2021). A large number of animals, such as caterpillars, mites, termites, and slug snails, feed partly or completely on lichens of different species.

7.3. Cosmetics and Perfumes:
Lichen-derived products are widely available in the US and Europe, and extracts of lichens and other botanicals are increasingly being used as additives in personal care products, ranging from "baby creams" to deodorants to face and body lotions (Elkhateeb, *et al.,* 2022).

In one report, it was estimated that more than 90 deodorants, fragrances, and cologes that specifically identify components derived from lichen were included, and there have been reports that fragrant volatile oils would be pseudorinas (Schalock., 2009).

Lichens are utilized in the preparation of many kinds of aromatic compounds found in the thallus of lichens and various fragrance products, such as cosmetic items, dhoops, and hawan samagri (Manoharachary, *et al*., 2021).

8. MINERALS
The involvement of lichens in rock weathering has been discussed since the end of the 19th century. Both physical and chemical processes are involved in the weathering of lichens on the mineral surfaces.

Physical methods include hyphae penetration and thallus expansion or contraction, whereas oxalic acid and several other lichen compounds are crucial for chemical action. Many of these secondary metabolic products are potent metal-complexing agents that cause rock disintegration (Manoharachary, *et al*., 2019).

Julien (1883) noted that lichens are an organic agent that contributes to the degradation of stone material (Elkhateeb, *et al.,* 2021). Large amounts of calcium oxalate crystals, which grow in limestone deserts, were produced by Lecanora esculenta. This amounted to 60% of the dry weight (Manoharachary, *et al.,* 2021).

CONCLUSION
Lichen symbiosis is a complex relationship between two different organisms that allows them to survive in very harsh environments and is said to be the oldest surviving fungal and algal relationship. Their ecological role in the environment is an important contribution to soil formation and the establishment of biodiversity. Their survival strategies have been remarkable and have helped in their survival. A special example of mutualism in nature is demonstrated by the partnership between the fungus and its algal partners.

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