Lichens: A Valuable Bioresource for Environmental Monitoring and Sustainable Development

Hans Raj Negi

H R Negi is a Scientist of Plant Ecology at Institute of Himalayan Bioresource Technology (IHBT), CSIR, Palampur. His research interests include inventoring, monitoring and conservation of biological diversity and population dynamics of certain species of economic and ecological importance.

Lichens are a good example of the virtues of simplicity and cooperation. They survive in extremes of climatic conditions, ranging from low tide level on the sea shore to the high reaches of the Himalaya, beyond the tree line, in the arctic Tundra.

What are Lichens?

Lichens are among the simplest forms of plants, consisting of green algal cells protected by strands of mould or fungi. They have no specialized organs such as root, shoot and leaves, and this permits them to live economically in the harshest of environmental conditions. In fact, lichens have evolved a strategy of survival that is worth observing. They have an ability to quickly absorb minute concentrations of water from air or dew and become metabolically active within a few minutes. Inversely, under scorching sunny conditions they lose water and become dry and crisp within an hour. As their water content falls, photosynthesis ceases and respiration then stops, after which they remain inactive until re-moistened. Having photosynthetic ability, the alga synthesizes and shares food with the fungal partner, whereas the latter provides a comfortable shelter to the delicate body of the algal partner, demonstrating a basic form of cooperation called *symbiosis*. This mutually beneficial cooperative association forming a new living identity named as *lichen* grows at an average rate of 1-5 millimeters per year and persists from tens or hundreds of years on substrata like trees and rocks.

Keywords
Lichens, biodiversity, symbiosis, pollution monitoring, ecology.

The growth forms of lichens are usually conspicuous on the substrates, forming grey, green or even orange patches . They are categorized primarily based on their morphology and size into three major types viz. *crustose* (crust like), *foliose* (leaf like) and

Lichens can colonize almost any surface that does not flake off too quickly so long as there is enough light for the contained alga to photosynthesize.

fruticose (shrubby) (*Figure* 1). The lichens belonging to the first category are usually called *microlichens* and the latter two are referred to as *macrolichens*. Lichens can colonize almost any surface that does not flake off too quickly, so long as there is enough light for the contained alga to photosynthesize. Substrates on which lichens grow include rocks, soil, tree trunks, branches and dead wood logs, animal shells, bones, insect backs, synthetic materials such as plastic taps, and substrates derived from mineral sources such as bricks, cement, concrete roofs and walls, and glass and iron amongst others. The fungal partner reproduces by ejecting spores from sacs (asci) within fruiting bodies that form on the surface and edge of the lichen body surface. Such spores, if they land on a suitable substratum, can germinate and entrap nearby compatible photosynthetic algal partners to resynthesise/reproduce a cooperative association of fungus and alga making up the lichen. Since this resynthesis process may be faced with the vagaries of fortuitously finding a compatible partner, lichens have also evolved vegetative means of propagation in which both partners are distributed together from the parent plant. Some species produce small granules called soredia which are dispersed by wind and rain. Others have developed fragile cigar or bun shaped outgrowths, isidia, that break off and can grow into a new lichen on a suitable surface.

Species Identification

A preliminary approach to the identification of species of lichens involves the use of guides with colored pictures. For precise identification up to the species level, specimens of lichens are collected and preserved in bamboo paper pouches (30cm × 30cm) and carried to the laboratories for further sorting and identification. Over-collection of the specimens should be avoided in the interest of biodiversity conservation. It is necessary to examine the collected specimens to determine the shape and colour of the lobes, presence and absence of soredia and isidia, and the size and septation of the spores within the fruiting bodies. There are also simple chemical tests that help to distinguish certain species. These tests can be performed at home or in a school level laboratory, and typically involve applying a tiny drop of test chemical that contains potassium hydroxide, sodium hypochlorite or paraphenylene diamine. A color change, usually red or yellow, is then looked for. With the help of such observations, identification keys can be used to identify each lichen specimen. Taxonomic keys can be found in the lichen floras which are published for India, and most other parts of the world.

Lichens have also evolved vegetative means of propagation in which both partners are distributed together from the parent plant.

Species Diversity and Regional Distribution Pattern

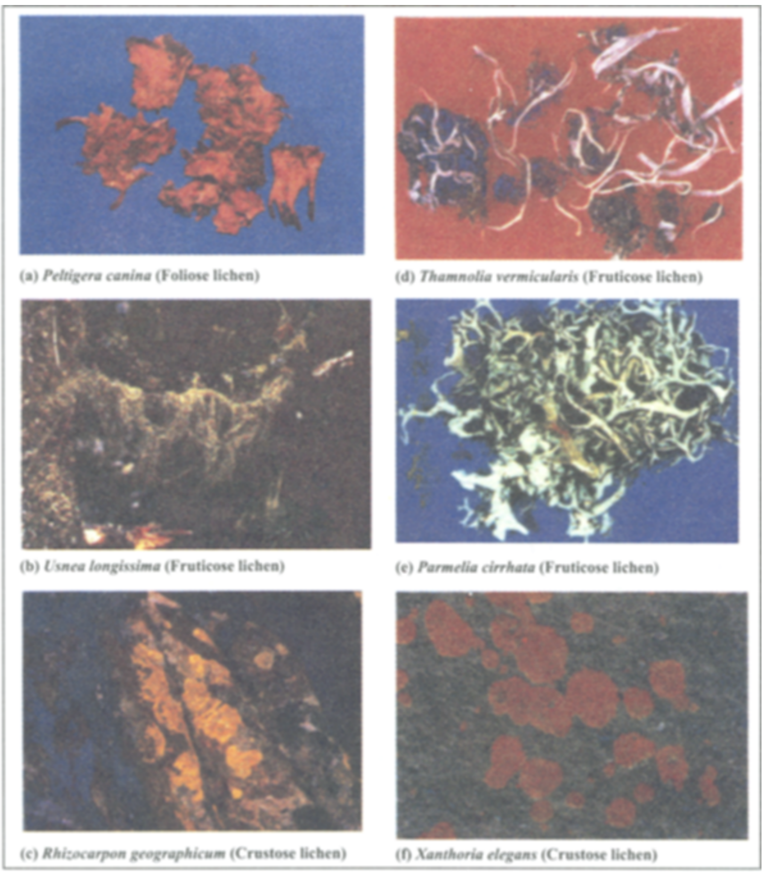
Life in all its physical and chemical complexity exists in a multitude of forms or species. Current estimates are that about 1.7 million species of plants and animals have been recognized by biologists, of which about 20,000 are lichens. One of the recent global assessments on the status of lichens and their conservation revealed that the majority of lichen surveys are concentrated in temperate and boreal zones of the world, as opposed to the tropics, where there are extensive areas of forests forming a major component of Earth's vegetation. Many lichen rich areas remain unexplored, and it is thought that the total number of lichen species in the world may well be close to 100,000.

India is one of the 12 megadiversity countries in the world, with a potential of supporting as many as 500,000 species of sexually reproducing organisms, of which only about 27% have been so far described. The number of described species from India includes 17,500 species of flowering plants, 2021 species of lichens, 2825 species of bryophytes and 86,874 species of animals that include 59,352 species of insects, accounting for 7% of the total described animals and flowering plants of the world. However, in contrast to the global projections of 10-30 million species, India probably harbours between 2-5% of this species diversity variation commensurate with its 2.2% share of land surface of the Earth. This tremendous diversity of species, harbouring diverse genetic variations, is believed to be due to the great variety of ecological conditions in India, and its posi-

Many lichen rich areas remain unexplored, and it is thought that the total number of lichen species in the world may well be close to 100,000.

tion* at the confluence of the Palaearctic, Afrotropical and Indomalayan biogeographic realms. If the Indian landmass supports 7% of the total estimated 100,000 species of lichens, in line with the most studied taxa of flowering plants and the higher animals, it still adds 5,000 species to the so far described 2,021 lichen species in the country. However, in terms of species-area ratio, India would harbor only 2200 species of lichens, commensurate with its 2.2% land area of the world. Thus, the total number of estimated species of lichens in India could vary between 2200 and 7200 species. Although inventorying of the Indian species of lichens is quite incomplete, India still emerges as the fifth richest country sharing 10.11% of 20,000 species of lichens recorded in the world.

There are 8 lichen regions in India that have been ranked based



(a) *Peltigera canina* (Foliose lichen)
(d) *Thamnolia vermicularis* (Fruticose lichen)
(b) *Usnea longissima* (Fruticose lichen)
(e) *Parmelia cirrhata* (Fruticose lichen)
(c) *Rhizocarpon geographicum* (Crustose lichen)
(f) *Xanthoria elegans* (Crustose lichen)

Figure 1. Some species of lichens.

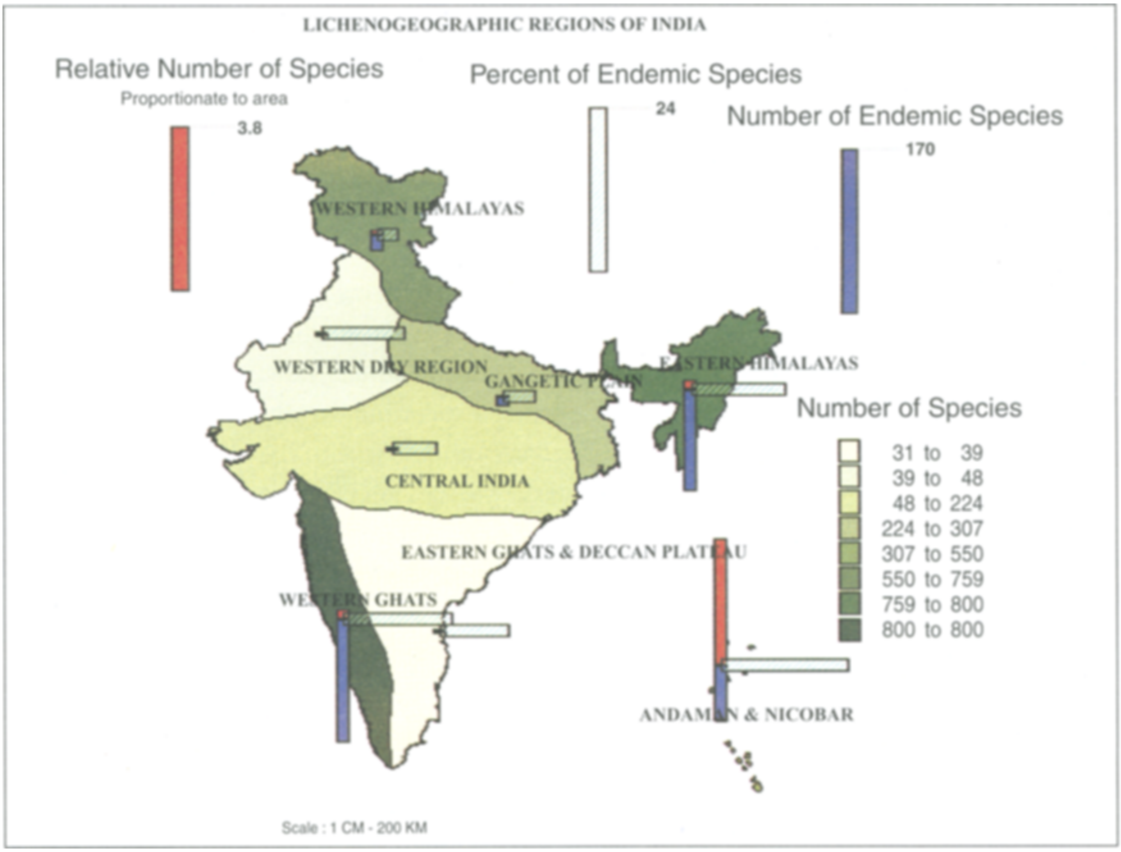


Figure 2.

on their area, species and their endemism (*Figure* 2). While Western Ghats, Western Himalaya and Eastern Himalaya, harboring 550 to 800 species, seem to be the rich centres of lichen diversity, Andaman and Nicobar islands emerge as a lichen 'hot spot', ranking first in terms of endemic species with smallest area as compared to the rest of the lichenogeographic regions in the country. There seem to be a higher concentration of endemics in the tropics than in the temperate to alpine regions of the Western Himalayas. Lower endemism in the Himalayas is probably due to the greater affinity of their elements with Europe and arid regions of Central and Western Asia. The very poorly surveyed Eastern Ghats and Central Indian regions with dense forests may equally prove biological treasure troves of lichens, as have the Western Ghats, provided that investigations are exhaustively organized to explore these virgin areas. Gangetic plains with agricultural predominance, and the western parts of

Lichens have evolved efficient mechanisms for accumulating nutrients from the environment in which they live. They have an active uptake system for anions like nitrate and sulphate, with the algal partner expending metabolic energy to take in these anions which accumulate within the cells.

the country with arid climatic conditions may be poor habitats for lichens. However, the taxa adapted to these dry climatic conditions render endemism as high as 15% of the total regional species pool.

Bio-indicators of Environmental Pollution

Lichens have evolved efficient mechanisms for accumulating nutrients from the environment in which they live. They have an active uptake system for anions like nitrate and sulphate, with the algal partner expending metabolic energy to take in these anions which accumulate within the cells. Lichens adsorb metal ions such as Ca^{2+} via an ion exchange mechanism and can trap tiny particles of rock, soil or any other heavy metal pollutants within their structure. Some of the metabolites produced by lichens can break down such particles, releasing nutrients, which may then be taken up into the cells of the lichen. It is this ability of lichens that can be efficiently exploited for monitoring the pollution levels in and around industrial installations. The ability of lichens to accumulate substances from the air has already been exploited for geobotanical prospecting and for monitoring the fallout of radionuclides from atmospheric nuclear testing. There is a tolerance limit associated with each species. A majority of the species, for example *Usnea longissima* (*Figure* 1b), *Lobaria pulmoneria* and *Parmelia cirrhata* (*Figure* 1e) only occur in a clean environment, whereas some tolerant lichen species like *Lecanora conizaeoides* and *Cladonia coniocraea* also survive in polluted areas. There are many other species that resist moderate to slight levels of pollution. Therefore, a survey of lichen communities may provide an indication of quality in and around industrial installations and cities that are main sources of air pollution. Chemical analysis of lichen samples can also be used to determine the extent and type of pollutant emissions around a particular industrial installation. Furthermore, by moving healthy lichens from clean places to polluted areas, it is possible to monitor the appearance of damage symptoms and changes in chemical composition and use these to help establish patterns of air quality. While in many countries such as Britain and Ireland, school and university students have already made important contributions to research on air quality monitoring using lichens, India still needs to integrate such studies at school and college curriculum. The rich resources of biodiversity, with equally diverse young talents spreading across length and breadth of the country, call for such programmes to be initiated at the local, regional and national levels.

The ability of lichens to accumulate substances from the air has already been exploited for geobotanical prospecting and for monitoring the fallout of radionuclides from atmospheric nuclear testing.

Economic Potential and Conservation Implications

A number of lichen species such as *Peltigera polydactyla*, *Thamnolia vermicularis* (*Figure* 1d), *Parmelia cirrhata* (*Figure* 1e) are used in traditional and folk medicines, sold as condiments in the Indian bazaars, cooked as a vegetable curry by the tribal people of Sikkim, particularly during the scarcity of food, and are even utilized as common livestock fodder in some parts of South. India. Some of the lichens, including species of *Umbilicaria* and *Usnea*, are well known to serve as a staple diet for the Alaskan reindeer and the Himalayan musk deer. Notably, a few species such as *Peltigera canina* (*Figure* 1a), *Parmelia tinctorum* and *Umbilicaria pustulata* have been demonstrated to contain significantly high levels of edible proteins and carbohydrates, along with some essential amino acids. Some lichens have reportedly shown anti-tumor activity, and even inhibitory effects on HIV *in vitro*. Many lichen species possess antibacterial and antimicrobial properties that may be tapped for further research and development. Many of the lichen species have already proved economically very beneficial and continue to hold significant commercial implications particularly in cosmetic and perfumery industries. Approximately 10% of the lichen species contain cyanobacterial algae as the primary symbiont that contributes to the nitrogen economy of the ecosystems, as high as 40 kg $ha^{-1}yr^{-1}$ in the birch-pine forests of Sweden. These lichens constitute a rich source of nitrogen and may, therefore, be sustainably harvested as green organic manure. Ironically, these very natural sources are being wasted unnoticed with unsystematic forest

This article is an outcome of a lecture delivered for "Vacation Training Programme on Bioresources for School Children jointly organized by Institute of Himalayan Bioresource Technology (IHBT) and Wildlife Institute of India (WII) at Palampur and Dehra Dun respectively from 20 May -7 June 2002. The program was sponsored by National Bioresource Development Board, Department of Biotechnology, Government of India, New Delhi.

management practices and due to various other factors responsible for the loss of lichen biodiversity.

As a number of factors such as urbanization, forest fires and deforestation have been identified as the major threats to the lichen flora of India, holistic efforts are needed to measure and monitor the extent of actual impact of these land use changes on the lichen abundance and diversity. India as a mega-diverse country, supporting over a billion people distributed in 2600 distinct ethnic communities with varied resource use patterns, should therefore be prepared to face this immense task of inventorying, monitoring and developing ways for the sustainable utilization of this bioresource wealth. This can be undertaken by organizing conservation science activities through linking a cross-section of people including taxonomists, ecologists, computer wizards, tribals, traditional healers, school and college teachers and students. This cross-sectional networking approach may facilitate cooperative conservation of such valuable bioresources. Furthermore, this democratic science approach may help striking a sustainable balance between economic growth and ecological permanence ensuring a clean environment, and thus the aesthetic, food and health security of the nation and the world.

Selected Reading

[1] D D Awasthi, A key to the macrolichens of India and Nepal, *Journ. Hattori Bot. Lab.*, 65, pp.207-302, 1988.

[2] M E Hale, *The Biology of Lichens*, 3rd ed. London, Edward Arnold, 1983.

[3] H R Negi, Assessing and Conserving India's Biodiversity of Lichens, In *Sustainable Management of Forests-India* (edited by A Arunachalam and M L Khan), International Book Distributors, Dehra Dun, India, pp. 77-109, 2001.

[4] D H S Richardson, *Pollution Monitoring with Lichens*, England, Richmond Publishing Co. Ltd., 1992.

[5] M R D Seaward, *Lichen Ecology*, London, Academic Press, 1977.

Address for Correspondence
Hans Raj Negi
Biodiversity Division
Institute of Himalayan Bioresource Technology
(CSIR), Post Box No. 6
Palampur 176 061, India.
Email: negiihbt@yahoo.co.in