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Review Articles

EVALUATION OF LICHENS SERVABILITY IN DIFFERENT MICROCLIMATIC CHANGES AS BIOINDICATORS OF ENVIRONMENT POLLUTION

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ABSTRACT:

Lichens are a unique group of plants that consist by two different organism viz. Fungi and algae with a close symbiotic association. The beneficial study of lichens is neglected in India. Record of Indian Lichens is very small in comparison with the world. India is a rich center of lichen biodiversity, harboring nearly 15% of total global lichen flora. The rapid destruction of Indian lichen habitats due to increase in industrialization, atmospheric pollution, over-exploitation, grazing, frequent forest fires and other anthropogenic disturbances. These activities are responsible for decrease lichen population in India. Terricolous lichen is a lichen that grows on the different soil as a substrate, their distribution ranges from temperate to alpine habitats of the Himalayas. In globalized world more requirement of sustainability for development of lichen population. The identification of lichens by studying their morphology, anatomy, color tests through using TLC techniques in laboratory condition. The objective of this

study systematically identification, documentation and conservation of the lichen flora, which followed by different part of India.

KEY WORD: *Lichens, Soils, Vegetative Growth, Chemical Composition, Pollution Indicator*.

INTRODUCTION:

Lichens are 'dual' organisms. Lichens consist two or more different life forms living together symbiotically in a well-defined body between a fungus and an alga or cyanobacteria. Lichens are fungi that live in intimate symbiotic association with green algae or cyanobacteria. Lichens comprise a unique group of plant that consists of two unrelated organisms, a fungus and an alga. They are growing together with a close symbiotic association. In Indian context, synonyms of lichens are 'Shailaya' and 'ShilaPushp' in Sanskrit meaning Shila=rock Pushp=flower, 'Stone flower' in English, 'Pathar Ka Phul' in Hindi. The study of lichen remains quite neglected throughout the world (Nash & Egan 1928). Lichens are covering 10% of the earth terrestrial part of India at higher elevations. Lichens are cynobacterial blue green symbionts, significantly used in forest nitrogen fixation. Lichens form easily distinguishable colored patches on tree barks, rocks and soil. They are universally distributed organisms occurring in varied climatic conditions ranging from the poles to the tropics in earth. Nordberg & Allard (2002) studied changes of mountainous, dry-heath communities in Sweden using satellite data. The au & al. (2005) employed remote sensing for a study of caribou herd activity in mapping lichen in northern Quebec in Canada. The decreased lichen cover due to human activities is often significant in areas dominated by lichens, especially in mountain regions (Seaward 2009).

Lichens have ability to grow in all climatic conditions ranging from low tide sea shores to the tops of the mountains and from arctic to tropical regions (Ahmad; 1995). These are most significant indicators of air pollution and beneficial for ecosystem health (Richardson 1988). They are an indicator of sensitivity to microclimatic changes. According to their chemical composition. Most lichen substances are phenolic compounds, dibenzofuranes, Usnic acids, depsidones, depsones, lactones, quinines and pulvunic acid derivatives (Boustie and Grube, 2005). About 320 tons of lichens are annually utilized for a different purpose in Nepal and adjoining regions of India (Moxham, 1986). A survey on lichen samples available in local markets of Maharashtra, Karnataka and Tamil Nadu found 11 species of lichens (Upretiet awl., 2005).

Lichens and lichen product have been used in traditional medicines for centuries and still hold considerable interest as alternative treatments in various parts of the world. Lichens are said to effectively cure dyspepsia, bleeding piles, bronchitis, scabies, stomach disorders, and many disorders

of blood and heart (Negi and Kareem, 1996). They produce secondary metabolites that are unique with respect to those of higher plants (Lawrey, 1986). Lichen metabolites are a wide variety of biological agents, including antibiotic, anti-mycobacterial, antiviral, anti-inflammatory, analgesic, antipyretic, anti-proliferative and cytotoxic effects (Muller, 2002).

Different Life Form of Lichens

India ranks among one of the twelve-mega-biodiversity countries in the world. The innumerable life forms from unicellular to multicellular in the forests, deserts, mountains, other land forms. This lichens life has allowed to successfully colonize in different habitats. Lichens have a truly remarkable resistance to drought condition. A dry lichen can quickly absorb three to thirty-five times water from its weight. If the humidity is very high and the temperature is low, lichens self absorb moisture from dew or air. They also dry out slowly and making it possible for the photosynthesizing to make food as possible. This way to quickly absorb water from many sources makes it possible for lichens live in harsh environments like deserts and polar regions. They are exposed surfaces like bare rocks. They are sources of food, fuel, clothing and various others our daily needs and raw material for industries. Bélanger (1838) was the first person to study the lichens in Western Ghats, who described 40 taxa from Pondicherry and Coromandel coast.

Lichens arbitrarily classified into three to seven growth forms.

1. **Crustose Lichens**: These are crust like structure and buried in the tree bark or crystals of rocks. Either, they grow above the surface (endolithic) or grow immersed in plant tissues (endophloidicorendophlodal).

2. **Foliose Lichens**: These are leaf-like lichens withflattered structure.

3. **Fruticose Lichens:** Fruticose lichens are form flattened branches. Thus, they differ from foliose lichens in the presence of branches, aerial lobes. Example, *Ramalina* species have cortex extends round both surfaces of the branch.

4. **Squamulose Lichens:** These lichens are scaly shape, structure form in different mode of numerous small rounded lobes. These are intermediate between foliose and crustose lichens. If they rise from the substrate and appear leafy. This lichens may appear to be a foliage lichen (www.edu/fungi/liches/lichenmm). They nevertheless remain limited in size (James and Wolseley et al., 2009). Example, *Cladonia* species such as *C. digitata* or *C. foliacea*).

5.**Leprose Lichens:** Leprose lichens are thallus shape that composed of granules containing algal cells and fungal hyphae with no overlying cortex in early stages. These are thin underlying medulla. Baron (1999), defined leprose lichens as "those which have not, at least up to the present. It has been contained fruiting bodies, so cannot be ascribed as particular genus.

6. Filamentous Lichens: Filamentous lichens are fungal hyphae, form sheaths around filaments of the alga (Trentepohlia). Filamentous lichens are the retains algal morphology of the algal component, though a robustusstructure and generally darker in color (Pembrokeshire, 2009). E.g. Ephebelanata, the lichen may actually differ little in appearance from the free-livingcyanobacterium.

7. **Terricolous Lichens:** Terricolous lichens are constrained by vascular plants at lower altitudes, mountains and hill hold a rich variety of ecological systems. The gradient temperature is precipitated, and insulation of the terricolous lichens and rapidly deteriorating its richness as well as diversity (James and Wolseley; 2009).

8. **Epiphytic Lichens:** Epiphytic lichens are a plant that grows on another plant and derives its moisture as nutrients, from the air. Epiphytic lichens have been largely used for the estimation of pollution, particularly atmospheric pollution (Nimis et al. 2002). These organisms clearly respond to phytotoxic substances at the cellular levels (Purvis et al. 2006). Losses of lichens are measured by using remote sensing techniques in addition to other techniques. These are classic techniques, as well apply.

Reproductive Structure of Lichen

Lichens reproduce sexually by the production of spores, but vegetative reproduction is also more common. Many species of lichens are used in both methods. Sexual reproduction involves the process of genetic recombination, which enables genetic stability to be maintained within the population whilst allowing variation. But there is a slight problem with spores. A spore represents just a fungal propagule and to become a lichen the germinating spore has that re-license. The spore must germinate in a suitable location and find an algal cell of an appropriate species in order to start a new lichen (Coppins., 2002). In lichens, a vegetative propagule is consisted of both fungal and algal partners and only has to land and stay put in a favorable condition in order to start growing. There are few lichens belong to phylum Basidiomycota in which the spores are produced on the outside of a cell called a basidium (pl. basidia). For these lichens the spore-bearing body is called a basidioma (pl. basidiomata).

Vegetative Condition of Lichen

Vegetation of a forest is generally affected by differences in the microclimatic condition (Pande et al., 1996). The selection of license condition, originating due to the difference in microclimatic and interspecific competition, in the forest ecosystem. The interactive influence of the biotic and abiotic factors of the environment affects the survival and growth of seedlings (Muller-Dombios et al., 1980). The biotic factors and edifice variation have played a dominant role in determining the nature of the

forests growing in the sanctuary. The eastern portion of the sanctuary comprises dry deciduous forests and it gradually changes to moist deciduous type as wet goes towards the west. The above two types of forests are mainly found in the sanctuary. The land use by the local human population is a mainly semipastoral mode of agriculture based mainly on livestock grazing, agriculture, and forest produce (fodder and fuel).

Sensitivity of Lichens

Lichens are sensitive in a wide range of habitat, it changes, most of them man-driven. This sensitivity is due to particular physiological characteristics of lichen, and allows them to be used as indicators and monitors of different changes, providing an integrated measure of all disturbances occurring in their environment. Biomonitoring of lichens also done in three ways as using variations in diversity, using variations in physiological parameters, are accumulate of pollutants (Branquinho et al., 2001). Sensitive lichendominated ecosystems have also been established in both hot and cold deserts, and these ecosystems have been similarly destroyed by human activities. Especially interactions between lichens, and ecological or general environmental factors are still poorly known. There is more evidence of interactions among these factors in urban and suburban areas than in more complex ecosystems in forested areas (Giordani 2007). Several studies (Cristofolini et al., 2008) have dealt with research of interactions of continuous, precipitation amount, influence of annual average temperature in different ways, and proposed different functional models. Especially interactions between lichens and ecological or general environmental factors are still poorly known. There is more evidence of interactions among these factors in urban and suburban areas than in more complex ecosystems in forested areas (Giordani 2007).

Lichen biodiversity is sensitive to abiotic factors related to macro and micro-climatic changes. Regarding macroclimatic changes, we can consider variation in temperature, precipitation, geomorphology, and soil chemistry (Brunialti et al., 2003). These macroclimatic changes cannot be avoided when studying lichen biodiversity for Biomonitoring purposes, particularly in these areas are studied in enough to enclose as different climatic condition (Giordani, et al., 2001). These variations must be considered when comparing lichen biodiversity data from different geographical areas or even within the same area, but with significantly different abiotic factors (Brunialti et al., 2003).) Therefore, atmospheric pollution Biomonitoring studies by lichens, that are able to influence biodiversity in microclimatic condition.

Lichens are particularly valuable for pollution bioindicators. They are very sensitive to changes in air quality due to a lack of a protective cuticle and wax layer and the absence of stomata that facilitate the uptake of gaseous molecules (Häffner et al., 2001). They readily exhibit visible responses in

addition to physiological responses following exposure to atmospheric pollutants. These impacts are usually exacerbated in ecosystems with elevated humidity (Goward and Schofield 1983). The outer fungal layers differ amonglichens in thickness, morphology, density, and detoxificationcapabilities (Miszalski and Niewiadomska1993). Moreover, trace metals are concentrated in lichen tissues by directly proportional to environmental concentrations of metals (Bari et al., 2001). Therefore, lichenslend themselves very well to monitor spatial and temporaldeposition patterns of trace elements (Richardson 1988). The resolving power of lichens is able to distinguish between temporal gradients, is about two weeks (Boonpragob and Nash 1990). Thus, even small deviations in microclimatic condition influence the abundance and diversity of the lichen community (Renhorn et al., 1997). Seasonal and environmental changes influence rates of various metabolic pathways in lichens, including photosynthesis, nitrogen fixation, and respiration (Galen 1988). So, a change inmacroclimatic condition due to natural or anthropogenic influences may result in range extensions in both latitude and elevation and increasing occurrences of thermophilic species in ecosystems from which they were previously absent (Frahm and Klaus 2001).

Biotic and Abiotic Factors of Lichens

The interactive influence of the biotic and abiotic factors of the environment affects in survival and growth of seedlings and sprouts. Lichens have been used as bioindicators of environmental stress in a number of studies, using different techniques including single species distribution maps, analysis of the whole flora, transplant experiments, analysis of morphological injury. The highest diversity in evergreen forests is associated with an increase in crustose species and decrease in foliose lichens. Therefore, any natural, man-made disturbances are bound to affect lichen populations (James and Wolseley; 2009). Requisite moisture, and light, unpolluted air and undisturbed substratum often favor optimum growth and abundance of lichens.

Lichens are widely used in Biomonitoring. They provide cost effective tools for mapping, spatial and temporal patterns of atmospheric contamination. Lichens have been used as bioindicators of environmental stress in a number of studies, using different techniques including single aspect distribution maps, analysis of the whole flora (LeBlanc & De Sloover 1970). It's modification of photosynthetic performance, and indices of atmospheric purity (IAP). IAP, a quantitative approach, employing a mathematical calculation is best known method to evaluate the level of pollution affecting epiphytic lichen flora (Svoboda 2007). A test carried out by Deruelle (1978) proved the validity of this index to monitor SO_2pollution in western France. IAP is frequently used for summarizing information about pollution tolerance of lichens and their spatial variation (LeBlanc & De Sloover 1970), and reflects a gradation of lichens richness from "good" to "worst" (Kricke&Loppi

2002) and sums up the effects of long term environmental conditions. Chemical reagents can be applied to the lichen tissues and the presence or absence of a color change noted, but such 'spot' andchromatographic methods are yielding more precise analyses. The usefulness of the chemical tests lies in the fact that the chemical substances are used for species specific.

Effect of Pollution in Development of Lichen

The influence of pollution on epiphytic lichens is well-known and is sufficiently described for several pollutants (Nimis et al., 2002). Indirect estimations of air quality, in eutrophication, in general impact of anthropogenic alteration as a whole have been widely used over time (Gombert 2004,). Several long-term monitoring studies were conducted especially in European countries and in North America (Liška&Herben 2008). Its favorable for tropical climatic condition and suitable for rainfall sanctuary. This conditionreceives from south west monsoon and exposed to showers staring from April to May and September to October. Heavy to very heavy showers in June, July and August the erosive action of the torrential rains can be noticed in open areas on hill rocks or forest clearings due to deforestry activities. In areas benefit of vegetation the top soil gets washed away resulting in open blanks incapable of supporting any vegetations. The average rainfall of the area is 2000mm sometime northeast monsoon is received during November. Lichens, may indicate species turnover rather than accumulation during the lifetime of the host tree for species and their relationship.

These have a humid climate and wet environment with average minimum and maximum temperature about 15°C to 38°C respectively. Water supply is adequate during rainy season but not so during summer small check dams to streams in the catchment may help in solving the problem. Grazing, tourism and unconstrained forest management are affecting the overall biodiversity of the Himalayan habitats. In general, lichens are habitat degradation, fragmentation and loss, over exploitation, species invasions and climate change (Scheidegger and Werth 2009). Lichen population in the Indian Himalayas is threatened by uncontrolled livestock grazing, over exploitation and habitat destruction. There are some sporadic studies on climate change and grazing pressures in Indian Himalayan temperate and alpine habitats (Nautiyal et al. 2004).

Favorable Soils in Development of Lichen

Soils are indicating terricolous lichens i.e., good indicating ecosystem function (Will-Wolf et al., 2002) and their requirement of greater environmental stability make them highly sensitive indicators of overall ecosystem functioning and various environmental disturbances (Lalley and Villas 2005; Lalley et al. 2006). These soil crusts are also important for changing the physicochemical properties of soil, enhancing their stability and fertility (Belnap& Lange 2005). The topography of the area comprises of ridges of exposed rocks and patches of flat alpine grassland. The crust of the area is

made up of crystalline and metamorphic weathering bedrock with sedimentary deposits formed during the Paleozoic. Soils in the area are of coarse textured loam and sandy loam at lower altitudes and sandy at higher altitudes (Sundriyal 1992), as well drained and acidic condition (pH 4.0-5.5).

The climate of the area is characterized by heavy frost, blizzards and hail storm most of the month of the year. Precipitation occurs in the form of snow, hail, heavy rains and showers during the year. Lichens are important in making soil from litter formation. Soil is made up of organic matter, such as decayed plants, and minerals (Nash et al., 1996). Thus, these are beneficial to microorganismgrow on rocks infiltrate and wedge apart pieces of the rock by both pressure and chemical action. Some of their acidic condition dissolves the rock's surface, freeing mineral grains. This is an extremely slow process, but the resilience and endurance of the lichen fungi put time on their side. Lichenisation is a phenomenon that has developed many times within the fungi, and convergent evolution of similar thallus types is substantial and by no means surprising. Some lichens are very effective sand and soil binders that help in stabilization and erosion control (Negi et al., 2005). In arid and sub-arid areas lichens, has an association with bryophytes, can create extensive on the soil and such crusts help maintain the underlying soil structure.

The temperature of an area is moderate by summer season is quite short and sometimes reaches 30ºC while the winter season is long for five months starting from October to February (0-3ºC). Raining season starts on may mid to august last with an average rainfall of 55.56 mm. The nature of the soil is acidic due to the presence and abundance of cedrusdeodaratrees. Sometimes the color of the soil changes from reddish to black. Attitudinal defined climatic and soil factors are deemed to be the primary determining of change in species composition and community structure in undisturbed mountains (Whittaker and Marks, 1975). Economic change and population increase are threatening the ecology of the Himalayas. Simultaneously, natural resources are depleting at an alarming rate. The repercussion of these factors can be observed in lichen diversity of that area.

Pollution Indicator Activity in Lichens

Many lichens are sensitive to airborne pollutants such as sulfur dioxide, oxides of nitrogen, NPK fertilizer and ammonia, etc. They are excellent barometers of air quality, environmental management and ecological value and lichen distribution. Some species are highly adapted to a particular ecological niche such as a dry underhangon an old oak trunk or a dried up wound track from a broken branch. Also, these species are often poor colonizers. This means that their existence at a particular location is dependent on the continuous local availability of that particular niche. Lichens are used to infer continuity of management and as part of the evidence to determine the age of a woodland. This has led to the development of indices of ecological continuity for various microorganism types where

the total number of certain indicator species is used as a measure of the conservation importance of that microorganism (Vecsey et al., 1980). A good site for rare lichens is also likely to be rich in other things such as invertebrates, profits and higher plants. In contrast, higher plants are not such good indicators; if you clear-fell an ancient woodland, almost all the herbs and trees will still survive. But the rare lichens, bryophytes and invertebrates will almost all disappear, leaving only common (Ghilidiyal., et al., 2008), weedy species, and it may take many centuries for them depending on population.

Lichens show a great ability to concentrate nutrients from a dilute sources and indiscriminately absorb many toxic substances from the atmosphere (e.g. sulphurdioxide, fluorides and heavy metals). Many lichens are highly susceptible to air pollutants, especially in pollution by sulfur dioxide. Most species of lichens are found in areas specifically sulfur dioxide show an increased concentration of sugar in theirthalli. The sulfur damages the chlorophyll and with a sufficiently high sugar level thephotobiont will die, thereby bringing about the death of the fungal component. It is incapable of surviving alone. As a general rule fruticose lichen is the least resistant and crustose lichens the most resistant to air pollution (Clause; 2001). Different types of lichens are showing varying levels of sensitivity to pollutants and by noting the species occurring in an area and their state of health as possible to monitor pollutant levels.

Nitrogen constitutes about 80% of the volume of the earth's atmosphere are essential for life, yet the majority of organisms cannot make direct use of atmospheric nitrogen. Cyanobacteria are amongst the organisms that are able to make direct use of atmospheric nitrogen and such organisms are said to be able to fix atmospheric nitrogen. Hence, lichens with cyanobacterial photobionts fix atmospheric nitrogen. After fixation the nitrogen becomes available to plants following the death and decay of the lichens through herbivore defecation after consumption of such lichens (Gilbert; 2000). Some nitrogen may be leached from the lichen and be trapped by other epiphytes drain into the soil.

Conservation of lichens in India

The pollutants are responsible for loss of lichen diversity in the study area include changes in the ecological condition, forest cover, loss of habitat and increase of the urban and industrial areas. The anthropogenic activities in hilly regions such as ‘Jhoom' cultivation, agriculture, mineral extraction, tourism, hydroelectric and road building activities are leading to the rapid deterioration of lichen rich habitats. The weight of lichens was very little when dry, thus a vast bulk of these plants is harvested for utilization (A.M. & B.J.; 2002). In the global scenario of evidences show that many lichen rich sites are facing threats, mainly associated with human activities such as

air pollution, habitat destruction, unsystematic forestry practices, forest fire, tourism, over exploitation and illegal collections.

CONCLUSIONS:

The favorable climatic conditions of the lichens are influence the luxuriant growth of lichens flora. Therefore, it considered as a biodiversity of India. Lichens are beneficial to indigenous tribes who totally depend on local plant diversity of daily requirement. Pollutants are increasing by anthropogenic pressure in the lichens ecosystem. Therefore, lichens protection is necessary requirement for regional plant diversity. So, a protected area of lichen community is provided by a comprehensive and rich ecological niche (Reid et al., 2005). In Canada, numerous industries and federal government offices are provided by lichen biomonitoring programs with a monitoring protocol, but in India neither any program nor any awareness plans are followed for lichens protection while their requirement is more in medicinal and disease cure value. All plans should be lichens specific and pollutant resolution in ecophysiological and tourism region. Such as, Nova Scotia Protected Areas Program (NSPAP), is a part of the department of environment and labour. Lichens are proposing a mind make up plan to establish a wide network for long-term monitoring as assess impacts of air quality and climate changes on forest communities as well as forest productivityand biodiversity (Cameron., 2003). Epiphyteare mainly caused by deterministic processes, such as changes in habitat conditions as the host tree grows, ages and dies, rather than by stochastic population processes (Löbel et al., 2006).This approach, important in conservation biology, has been widely used and modified especially in Western Europe (Johansson et al., 2003).

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REFERENCES:

Baron, G. 1999. Understanding lichens, Richmond Publishing Co., Slough.

Belnap, J. & Lange, O. L. 2005. Lichens and microfungi in biological soil crusts: community structure, physiology, and ecological functions. In: Dighton J., White J.F. &Oudemans P. (eds.): The fungal community: Its organization and role in the ecosystem, Vol. 3, Boca Raton – CRC Press, 117–138

Boonpragob, K. and T. H. Nash III. 1990. Seasonal variation of elemental status in the lichen RamalinamenziesiiTayl. from two sites in southern California: evidence for dry deposition accumulation. *Environ. Exp. Bot.* 30: 415–428.

Belanger M. C. 1838. Voyage aux IndesOrientalesAnnees 1825-29. Botanique. II. Partie. Cryptogamic par Ch. Belanger etBory de st.Vincet 1834-38. Paris. Lichens. pp113-114.

Branquinho, C. 2001. "Lichens". In: Prasad MNV (eds.), Metals in the environment: analysis by biodiversity, New York, Marcel Dekker, pp:117-158.

Cristofolini, F., Giordani P., Gottardini E. &Modenesi P. 2008. The response of epiphytic lichens to air pollution and subsets of ecological predictors: A case study from the Italian Prealps. – *Environmental Pollution* 151: 308–317.

Cameron, R. 2003. Lichen indicators of ecosystem health in Nova Scotia's protected areas. Proceedings of the 5th International Conference on Science and Management of Protected Areas,Victoria, B.C.

Coppins, A.M. & B.J.2002. British Lichen Society.Indices of Ecological Continuity for Woodland Epiphytic Lichen Habitats in the British Isles.

Dordredht Ghilidiyal, J.C. Bisth, S. Jadli, R. 2008. A contribution to the biological diversity of Tarkeshwar Sacred grove in Garhwal Himalayas. Kluwer Academic Publishers, *Indian forester* 134: 789-800.

Deruelle, S., 1978. Les Lichens et la Pollution atmospherique. *Bull. Ecol.* 9(2), 2-128.

Frahm, J.-P. and D. Klaus. 2001. Bryophytes as indicators of recent climate fluctuations in central Europe. *Lindbergia* 26: 97–104

Goward, T. and W.B. Schofield. 1983.The lichens and bryophytes of Burns Bog, Fraser Delta, southwestern British Columbia. *Syesis* 16: 53–69.

Gombert, S., Asta J. & Seaward M.R.D. 2004. Assessment of lichen diversity by Index of atmospheric purity (IAP), Index of human impact (IHI) and other environmental factors in an urban area (Grenoble, southeast France). – *The Science of the total environment* 324: 183–99.

G. Brunialti, P. Giordani,2003. "Variability of lichen diversity in a climatically heterogeneous area (Liguria, NW Italy)", Lichenologist, 35, pp. 55-69.

Galun, M. (ed.). 1988. CRC Handbook of Lichenology. CRC Press, Boca Raton, FL.

Häffner, E., B. Lomsky, V. Hynek, J.E. Hällgren, F. Batic and H. Pfanz. 2001. Air pollution and lichen physiology. Physiological responses of different lichens in a transplant experiment following an SO_2 -gradient. *Water Air Soil Pollut*. 131: 185–210.

Gadgil, M. Vartak, V.D.1976. Sacred Groves of Western Ghats of India. *Economic Botany* 30: 152-160.

Giordani, P. Brunialti, G. Modensi, P. 1997. "Applicability of the lichen biodiversity method (L.B.) to a Mediterranean area (Liguria, northwest Italy)", *Cryptogamie, Micologie,* 22, 2001, pp. 193-208.

Gilbert, Collins. H. O. L. 2000. Lichens. The New Naturalist.

Jatta, A. 1911. Lichens Asia meridionalislecti B. Luthi in Malabar et a E.Long et W.Gollan in Himalayas. Bull. Orto Bot. d. R. univ. *Napoli* 3: 309-312.

Kricke, R. & S. Loppi. 2002. Bioindication: The I.A.P. approach. pp. 21-37. In: P. L. Nimmis, C. Scheidegger& P. A. Worsley (eds.) Monitoring with Lichens - Monitoring Lichens. Kluwer Academic Publishers, The Netherlands.

LeBlanc, F. & J. De Sloover. 1970. Relationship between industrialization and the distribution and growth of epiphytic lichens and mosses in Montreal. *Canadian Journal of Botany* 48: 1485-1496.

Liška, J. &Herben T. 2008. Long-term changes of epiphytic lichen species composition over landscape gradients: an 18 year time series. – *Lichenologist* 40: 437–448.

Lawrey, J. D. 1986. Biology of lichenized fungi. Praeger Publishers, New York ISBN 0-03-060047-2.

Lalley, J.S. and Viles H.A. 2005. Terricolous lichens in thenorthern Namib desert of Namibia: distribution and community composition. *The Lichenologist37*: 77–91.

Lalley, J.S., Viles H.A., Henschel J.R. and Lalley V. 2006. Lichendominated soil crusts as arthropod habitat in warm deserts. *Journal of Arid Environments* 67: 579–593

Moxham, T.H. 1986. The commercial exploitation of lichens for perfume industry. In progress in essential oil research (ed. E.J. Brunke). Walter de gruyter, Berlin.

Muller, K. 2002. Pharmaceutically relevant metabolites from lichens. *Applied Microbiology And Biotechnology*, 56: 9-16.

Miszalski, Z. and E. Niewiadomska. 1993. Comparison of sulphite oxidation mechanisms in three lichen species. *New Phytologist* 123: 345–349.

Nash, T.H. 2008. Lichen Biology (2nd Edition), Cambridge University Press.

Nordberg, M.L., Allard A. 2002. A remote sensing methodology for monitoring lichen cover. – *Canadian Journal of Remote Sensing* 28: 262–274.

Nordberg, M.L., Allard A. 2008. A remote sensing methodology for monitoring lichen cover. – *Canadian Journal of Remote Sensing* 28: 262–274.

Negi, C.S. 2005. Socio-cultural and ethno botanical value of a sacred forest. ThalKedhar, Central Himalaya. *Indian Journal of Traditional Knowledge* 4: 190-198.

Nautiyal, M.C., Nautiyal, B.P. and Prakash, V. 2004. Effect of grazing and climatic changes on alpine vegetation of Tungnath, Garhwal Himalaya, India. *The Environmentalist* 24: 125–134.

Nimis P.L., Scheidegger C. & Wolseley P. 2002. Monitoring with Lichens –Monitoring Lichens. – Kluwer Academic, Dordrecht.

Renhorn, K.-E., P.-A. Esseen, K. Palmqvist and B. Sundberg.2002. Growth and vitality of epiphytic lichens. I. Response to microclimate along a forest edge-interior gradient. *Oecologia* 109: 1–9

Richardson, D.H. 1988. Medicinal and other economic aspects of lichens. InM. Galun (ed.). CRC Handbook of Lichenology, Vol. 3. pp. 93–108. CRC Press, Boca Raton, FL.

Svoboda, D. 2007. Phaeophyscia hirsute- a little known lichen in the Czech Republic *GraphisScripta* 19:33-36.

Seaward, M.R.D. 2009. Environmental role of lichens, In: Nash III. T.H. (ed.): Lichen biology. – Cambridge University Press, 274–298.

Seaward M.R.D. 2009. Environmental role of lichens, In: Nash III. T.H. (ed.): Lichen biology. – Cambridge University Press, 274–298.

Scheidegger, C. and Werth S. 2009. Conservation strategies for lichens: insights from population biology. *Fungal Biology* Reviews23: 55–66.

Sundriyal, R.C. 1992. Structure, productivity and energy flow in an alpine grassland in the Garhwal Himalaya. *Journal of Vegetation Science3*: 15–20.

Singh, H., Agnihotri P., Pande PC., Husain T. 2011. Biodiversity conservation through a traditional beliefs system in Indian Himalaya: A case study from Nakuleshwar sacred grove. *Environmentalist* 31: 246-253.

Türk, R., V. Wirth and O.L. Lange. 1974. CO2 -GaswechselUntersuchungenzur SO 2 -Resistenz von Flechten. *Oecologia* 15: 33–64.

Smith, Aptroot, Coppins, Fletcher, Gilbert, James and Wolseley.2009. British Lichen Society. The Lichens of Great Britain and Ireland.

Upreti, D.K., Nayaka S. and Satya. 2005. Enumeration of lichens from Madhya Pradesh and Chhattisgarh, India. *J. Appl. Biosci.*, 31(1): 55-63.

Theau, J., Peddle D.R. &Duguay C.R. 2005. Mapping lichen in a caribou habitat of Northern Quebec, Canada, using an enhancement classification method and spectral mixture analysis. – *Remote Sensing of Environment* 94: 232–243.

Vecsey, C. 1980. American Indian environmental religions, In: American Indian Envrionments: Ecological Issues in Native American history, edited by Vecsey CT &Venables RW, Syracuse University Press, Syracuse, New York.

Will-Wolf, S., Esseen P.A. and Neitlich P. 2002. Methods for monitoring biodiversity and ecosystem function. In: Monitoring with Lichens: Monitoring Lichens., pp. 147–162.

W.V. Reid, H.A. Mooney, A. Cropper, D. Capistrano, S.R. Carpenter, K. Chopra, P. Dasgupta, T. Dietz, A.Kumar-Duraiappah, R. Hassan, R. Kasperson, R. Leemans, R.M. May, T.A.J. McMichael, P. Pingali, C. Samper, R. Scholes, R.T. Watson, A.H. Zakri, Z. Shidong, N.J. Ash, E. Bennett, P. Kumar, M.J. Lee, C. Raudsepp-Hearne, H. Simons, J. Thonell, M.B. Zurek. 2005. Millennium Ecosystem Assessment, Ecosystems and Human Wellbeing, Report Synthesis Washington DC, World Resources Institute.

Whittaker, R.J., Willis K.J. and Field R. 2001. Scale and species richness: towards a general hierarchical theory of species diversity. *Journal of Biogeography*, 28: 453-470.