



Distribution, biomonitoring and conservation studies of pyrenocarpous lichens in India

Gaurav K. Mishra, Sanjeeva Nayaka* and Dalip K. Upreti

CSIR-National Botanical Research Institute, Rana Pratap Marg, Lucknow-226001 Uttar Pradesh, INDIA

Received: 15 Jan 2020; Revised: 18 Feb 2020; Accepted: 30 Mar 2020

ABSTRACT

India is represented by the occurrence of the 382 species of pyrenocarpous lichens belonging to 49 genera and 12 families. Pyrenulaceae with six genera and 102 species is dominant family followed by Porinaceae with six genera and 88 species. Pyrenocarpous lichen genus *Pyrenula* with 82 species exhibits its dominance over *Porina* with 72 species. A total 25 pyrenocarpous genera are represented by a one or two species. The Western Ghats region exhibit rich diversity of pyrenocarpous lichens in India. The pyrenocarpous lichens commonly grows on smooth bark of trees or sometimes on rock, soil or leaves in tropical and temperate region of the country.

Key words: Biodiversity; ecology; foliicolous; pyrenocarpous lichens; India

1) INTRODUCTION

Pyrenocarpous or pyrenolichens are the group of lichens having flask shaped ascocarps (fruiting bodies) called perithecia. The lichens are externally discernible as patches of mostly dull shades of white, grey, straw, ochre, yellow-brown to brown with black dots of single or stramatoid, naked or covered perithecia. They are commonly growing on the bark of a number of trees or sometimes on rocks, soil or leaves in moist tropical and temperate regions of the world.

Lichenological investigations in India have accumulated considerable information on Indian pyrenocarpous lichens. The revisionary studies on Indian pyrenocarpous lichens initiated simultaneously in the eighties of the last century carried out by various lichenologist [1,2,3,4]. Singh [5] reported the occurrence of 16 foliicolous species of genus *Porina* from Andaman Island, of which 15 were new records for India. Similarly, Singh [6] reported the occurrence of a single species *Raciborskiella janeirensis* (Müll. Arg.) R. Sant (= *Strigula janeirensis* (Müll. Arg.) Lücking) and listed four species of *Strigula* from Andamans. Singh [8] added *Trichothelium epiphyllum* Müll. Arg., from Nilgiri and Palni Hills.

Awasthi and Singh [9,10] reported 14 foliicolous species of *Porina* from Nilgiri and Palni Hills, *Porina nilgiriensis* D.D. Awasthi & Kr. P. Singh and *Porina palniensis* D.D. Awasthi & Kr. P. Singh were new species and *Porina chrysochora* (Stirton) R. Sant., a new record for India. Patwardhan & Badhe [11] described *Endocarpon pusillum* Hedw. from Western India. Singh [12] reported *Trichothelium abloratrum* Vainio from Nilgiri and Palni Hills.

Awasthi & Upreti [13] described three species of *Dermatocarpon* from India. Singh & Upreti [4] described two new species of *Pleurotheliopsis andamanensis* Ajay Singh & Upreti and *Pleurotheliopsis ceylonensis* Ajay Singh & Upreti (= *Pyrenula astroidea* (Fée) R.C. Harris and *Pyrenula ceylonensis* (Ajay Singh & Upreti) Aptroot) from India. Upreti & Singh [14] described a new species of *Porina andamanensis* Upreti & Ajay Singh from Andman Island. Upreti & Singh [15] provided the taxonomic account of ten species of *Laurera* (= *Astrothelium*) from India.

Upreti [16] described ten species of *Pyrenula*, exhibiting *Pyrenula subducta* (Nyl.) Müll. Arg. spore type, of which seven species were new records to the Indian lichen biota. Awasthi [17] consolidated the information of different lichen genera in key of microlichens genera from India, Nepal & Sri Lanka and enumerated 229 species of pyrenocarpous lichens. Upreti [18,19,20,21,22] studied *Pyrenula* genus of pyrenocarpous lichens from India and reported several new records for Indian lichen biota. Upreti & Pant [23] reported nine species of *Arthopyrenia* from India, of which *Arthopyrenia keralensis* Upreti & G. Pant, was a new species. Upreti & Nayaka [24] reported *Anisomeridium calcicolum* Upreti & Nayaka, as new species and *Lithothelium hyalosporum* (Nyl.) Aptroot and *Polymeridium albocinereum* (Krempel) R.C. Harries as new records for Indian lichen biota. Jagadeesh Ram et al. [25] revised the genus *Pyrenula* and reported *Pyrenula subcylindrica* Jagadeesh & Upreti new to science species from India.

* Corresponding Author: Dr. Sanjeeva Nayaka

Email address: nayaka.sanjeeva@gmail.com

The pyrenocarpous lichens communities are good indicator of young and regenerated forest type. The rich diversity of lichens clearly indicates that most of the forest within the eastern Himalayan region has good health of forest [26,27,28]. Among the different communities, foliicolous communities are more prone to microclimatic changes based on their substrate specificity and sensitivity. Sipman [29] observed that clearing of forest caused foliicolous lichen species to become discoloured and moribund. Some foliicolous lichens reappear in secondary/ regenerated forest but its frequency is lower as compared to primary forests [30].

A large number of pyrenocarpous lichens from different regions are collected in past and mentioned in a number of revisionary and monographic studies. However, biomonitoring and conservation related studies not done till date. Thus, the present study is based on the biomonitoring and conservation studies of pyrenocarpous lichens are provided.

2) MATERIALS AND METHODS

The present study is based on published literatures; herbarium specimens deposited in the CSIR-National Botanical Research Institute, Lucknow (LWG) and freshly collected specimens from different part of the country. Morphological and anatomical characters were examined using stereo zoom Leica S8APO and light DM2500 microscopes attached with camera. Thin sections of perithecia were cut using razor blade under stereoscope zoom microscope. All anatomical measurements were recorded in plain water, while 10% KOH was used for detailed study of asci and ascospores. For spot tests the usual reagents of K, C and P were used and for identification of lichens substance by thin layer chromatography (TLC) was performed in solvent system C following Orange et al. [31]. The specimens were identified up to species level with the help of keys of Awasthi [17], Aptroot [32], Aptroot et al. [33,34] and Aptroot [35]. The identified specimens deposited in CSIR-National Botanical Research Institute, Lucknow (LWG).

3) RESULTS AND DISCUSSION

India is represented by the occurrence of the 382 species of pyrenocarpous lichens belonging to 49 genera and 12 families. Pyrenulaceae family with six genera and 102 species showed its dominance followed by Porinaceae with six genera and 88 species (Fig. 1). Mycosphaerellaceae, Naetrocymbaceae, Stictidaceae, Strigulaceae and Tephromelataceae families in the country showed poor representation as represented by a single species of each family. The Western Ghats region exhibit 210 species of pyrenocarpous lichens in India. The Western Himalayan region has luxuriance of pyrenocarpous lichens due to its unique topography and climate condition represented 105 pyrenocarpous taxa. However, the Eastern Himalayan region has rich diversity with 295 species of pyrenocarpous lichens due to its warmer and moist climate condition. The rich moist and warmer climate in Eastern Himalayan region supports forest with dominance of evergreen tree vegetation. Lichen genus *Pyrenula* with 82 species exhibits its dominance over *Porina* with 72 species (Fig. 2). A total

25 pyrenocarpous genera represent a single or two species each. Among the different growth forms of pyrenocarpous lichens corticolous dominant with 282 species followed by foliicolous with 56 species, whereas saxicolous and terricolous with 41 and 5 species respectively. *Pyrenula immissa* (Stirt.) Zahlbr., *P. pinguis* Fée, *Porina internigrans* (Nyl.) Müll. Arg., *P. subcutanea* Ach., *P. subhibernica* Upreti and *P. tetracerae* (Afz.) Müll. Arg., are the most common taxa in the country. Out of 384 species of pyrenocarpous lichens the country showed occurrence of 84 endemic species of which 23 species are known from Andaman & Nicobar Islands followed by 12 species from Karnataka (Fig.3).

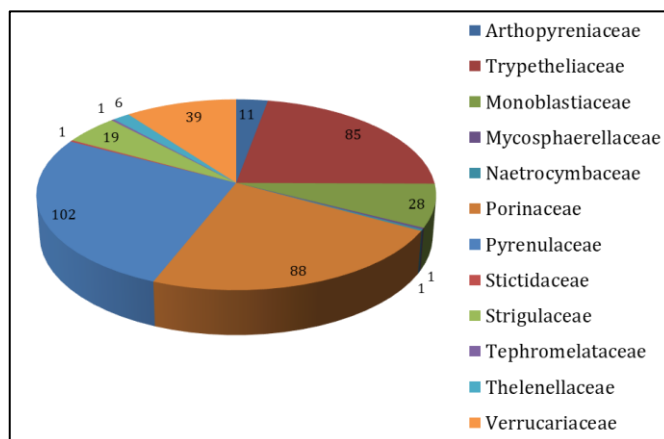


Figure 1: Pyrenocarpous lichens family and their diversity in India.

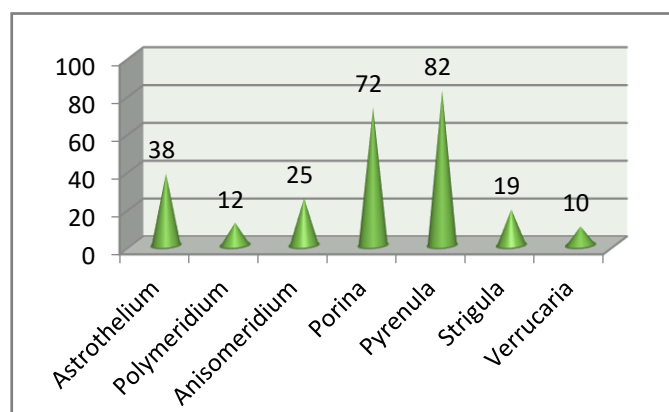


Figure 2: Pyrenocarpous lichens dominant genera in India

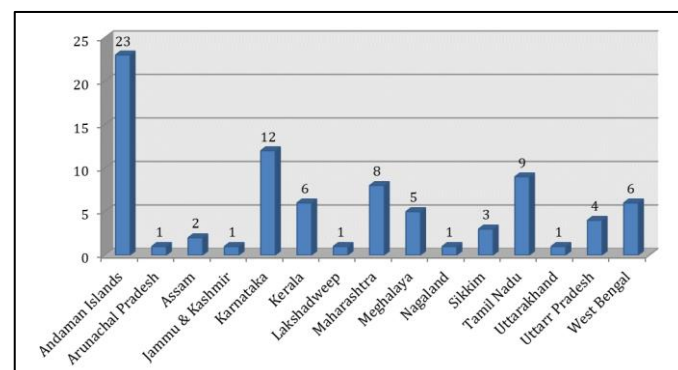


Fig. 3: Pyrenocarpous holotype dominant states in India.

Distribution of corticolous pyrenocarpous lichens: The pyrenocarpous lichens usually prefer a uniform, smooth substance to grow. It may be a rock, bark, or perennial leaf.

The most tropical areas are much preferred by the members of this group. As mentioned earlier in India the Western Ghats, coastal region including of Andaman Island and Eastern Himalayan forest exhibit a luxuriant growth of pyrenocarpous lichens. Both the Western and Eastern Himalayas bear good growth of a variety of smooth barked trees suitable for colonization of pyrenocarpous lichens. The submontane or lower regions (tropical and subtropical) of Siwalik and adjacent area in Western Himalaya have dominance of *Shorea robusta* trees with *Dalbergia sesso*, *Cedrela toona*, *Syzygium cumini* and *Eugenia jaqmbolana*. The young *Shorea robusta* trees in moist places bear *Pyrenula immissa* (Stirt.) Zahlbr. *P. oculata* A. Singh & Upreti, *P. aspistea* (Ach.) Ach. and few other pyrenocarpous species. The temperate or montane area in Western Himalaya is generally dominated by coniferous trees of *Pinus*, *Cedrus deodara*, *Abies pindrow*, *Picea* and *Cupressus*. These trees have mostly thick and rough bark, which do not support colonization of many pyrenolichens. At higher altitudes the *Alnus nepalensis*, *Aesculus indica*, *Quercus semecarpifolia*, *Q. dilatata* are most common phorophytes of vegetation and bear good growth of *Anthracotheceum macrosporum* (Hepp.) Müll. Arg., *Lithothelium himalayense* Upreti & Aptroot, *Pyrenula platystoma* (Müll. Arg.) Aptroot, *Pyrenula papillifera* (Nyl.) Aptroot and other pyrenocarpous lichens.

In Eastern Himalaya, the warm and humid weather is dominated with typical dense forests and the smooth bark trees that of *Artocarpus* type bear luxuriant growth of pyrenolichens. The temperate zone in Eastern Himalaya has luxuriant growth of *Alnus* and *Michelia* trees, most suitable for luxuriant growth of pyrenocarpous lichens.

In the central Indian region mostly the species of *Ficus*, *Syzygium*, *Artocarpus* and *Mangifera* and *Shorea robusta* have smooth trunk bearing good growth of pyrenocarpous lichens. Andaman Island and coastal vegetation like mangroves, beech forest and coconut and *Areca* trees also bear excellent growth of pyrenocarpous lichens.

The evergreen forest of Western Ghats and Eastern Himalayan region exhibit maximum diversity of pyrenocarpous lichens in India. The smooth bark trees along with streams in moist habitat bear diverse pyrenocarpous species mostly *Porina* and *Pyrenula* species on bark, leaves and rocks.

Among the tropical forest of India, the tropical wet evergreen forest in west coast, Assam, West Bengal, and Andaman Islands have the richest diversity of pyrenocarpous lichens. The forests in the area are multi-storeyed, made up of small trees, shrubs, lianas and dense ground vegetation. The dominant trees such as *Dipterocarpus*, *Artocarpus*, *Mangifera*, *Michelia* and some thick trunked climber's bear diverse pyrenolichens.

The tropical moist deciduous forests of Kerala, Karnataka, South Madhya Pradesh, Bihar, Bengal and Orissa are dominated by species of *Terminalia*, *Grewia*, *Tectona*, *Melia*, *Delbergia* and *Shorea* trees having mostly the dry and rough bark, supports poor growth of pyrenocarpous lichens.

The montane subtropical forest found in hills of South India (Nilgiri Hills, Mahabaleshwar and Panchmarhi) between altitudes of (1000-2000 m) is cooler than the tropical and warmer than the temperate forest. The area also experience

westerly wind, thus bear mostly the lichen elements cosmopolitan in distribution. This region exhibits the maximum diversity of almost all lichen taxa including the pyrenocarpous lichens. The 'Sholas' forests of this area are the excellent abode for a member of pyrenocarpous species. Among the different substrate, the pyrenolichens exhibit a special affinity for bark as compared to the rocks and leaves. The different phorophytes with smooth trunks, such as species of *Alnus*, *Quercus*, *Ficus*, *Artocarpus*, *Shorea*, *Mangifera*, *Michelia* and *Celtis* are preferred by the pyrenocarpous to colonize. Sometimes in Himalayas all the *Quercus* species is moist areas are preferred by pyrenolichens (particularly *Anthracotheceum* and *Pyrenula*) that may be smooth, rough or undulating. *Lithothelium himalayense* Upreti & Aptroot requires an especial habitat to grow, usually this species grows on *Quercus semecarpifolia* trees near stream, which are frequently pruned for their leaves as fodder and exhibit stunted growth. The forest area is mostly thinned out, receive more light and wind.

Alnus nepalensis a dominant phorophyte of both north and east Himalayan region exhibits luxuriant growth of pyrenocarpous lichens. The smooth bark with plenty of moisture allows a number of pyrenolichen taxa to colonize. Almost whole tree trunk together with thick branches bear continuous growth of pyrenocarpous taxa.

Among the different species of *Quercus*; *Q. semecarpifolia* is temperate Himalaya bear good growth of pyrenolichens. The young trees and branches are preferred by the pyrenocarpous taxa while the old bark in mature trees is mostly devoid of this group.

Some pyrenocarpous exhibit substrate specificity as they show restricted occurrence on single photophytes. The species of *Astrothelium* mostly grow on cashew nut trees in South India and Goa. Certain species of *Pyrenula* only grow on *Alnus nepalensis*, while *Lithothelium* species prefers hardwood trees with smooth bark. The species of *Porina* exhibit maximum substrate diversity as they grow on diverse trees, leaves and also on rocks. *Anisomeridium* species also grow on leaves, rocks and barks.

Certain cultivated trees species like *Mangifera indica*, *Artocarpus integra*, *Cocos nucifera*, *Citrus* sp., *Areca catechu*, *Anacardium orientale*, *Hevea brasiliensis*, *Anacardium occidentale* and *Albizia* sp. seem to attract more pyrenocarpous lichens on their bark in the non-forested areas, than other naturally growing trees.

Distribution and ecology of foliicolous pyrenolichens

The foliicolous lichens found on certain leaves of very long durability. The fern fronds, phylloidia, perennial leaves of many shrubs and trees in moist shady places are the excellent habitat for foliicolous lichens. Among the different foliicolous lichens the species of *Strigula elegans* exhibit the maximum host diversity. It grows on *Mangifera*, *Citrus* and many more evergreen perennial leaves. The *Porina* species also exhibit wide host diversity, found growing on leaves of *Palmae*, *Araceae*, *Liliaceae*, *Cycadaceae* and more than 30 families of Angiosperms, Gymnosperms and Pteridophytes. The *Strigula* species mostly prefer the monocotyledonous genera, while *Porina* species mostly grow on fern genera and few monocotyledonous genera. The perennial shrubs

also bear luxuriant growth of foliicolous lichens such as *Strigula antillarum* (Fée) Müll. Arg., *S. janeirensis* (Müll. Arg.) Lücking, *S. phyllogena* (Müll. Arg.) R.C. Harris, *Porina karnatakensis* Makhija, Adaw. & Patw., *P. nitidula* Müll. Arg. and *P. pallescens* R. Sant. Exclusive topography and humid climate condition of Eastern Himalayan exhibit luxuriance of foliicolous lichens. Foliiicolous lichen *Porina* genera dominance with 35 species followed by *Strigula* with 21 species in India. Eastern Himalayan region shows maximum diversity with 37 species, while Western Ghats exhibit 19 species of foliicolous taxa. Andaman and Nicobar Island has rich diversity of foliicolous lichens with 30 species [36, 37]. The humidity, light and other microclimatic condition play a much more important role for the occurrence of the foliicolous lichens. The anatomy and physiology condition of leaves also influence the growth of foliicolous lichens. The hairy as well as glossy leaves are not infrequently overgrown by lichens.

The majority of foliicolous lichens grow on the upwardly exposed leaf surface, while *Strigula janeirensis* (Müll. Arg.) Lücking grows regularly on lower surface of leaves [38]. Numerous species 15-25 of lichens usually grow together on the leaf surface and are considered very fast growing. In contrast to many other lichens they become fertile very quickly and so their generation may be very short.

The foliicolous lichens occurs mainly in tropical rain forests, but also in other forests in more or less humid areas in tropical, subtropical and even in temperate zones and becoming gradually rare towards the alpine zone. The number of species in the temperate zones is low.

Distribution of saxicolous pyrenocarpous lichens

In India saxicolous species found growing on rock, monuments and old buildings in tropical, temperate and alpine region. Tropical regions of Kerala, Karnataka, Madhya Pradesh, Bihar, Bengal, Orissa, Uttar Pradesh and foot hills of Himalayas has luxuriant growth of *Endocarpon nanum* Ajay Singh & Upreti, *E. pusillum* Hedw., *E. rosettum* Ajay Singh & Upreti, *Verrucaria elaeomelaena* (A. Massal.) Arnold, and *V. muralis* Ach., while *Endocarpon* species mostly grow on monuments and old buildings.

In temperate regions of Eastern and Western Himalaya most of saxicolous species *Catapyrenium cinereum* (Pers.) Körb., *Dermatocarpon miniatum* (L.) W. Mann., *D. vellereum* Zschacke, *Endocarpon pallidulum* (Nyl.) Nyl., *Staurothele clopima* (Wahlenb.) Th. Fr., *S. fissa* (Taylor) Zwackh, *Thelenella brasiliensis* (Müll. Arg.) Vain. and *Verrucaria acrotella* Ach. exhibit dominantly grows on calcicolous and another rock of the region. *Dermatocarpon* species luxuriantly grows in Western Himalayan region due to open thinned out area. *Awasthiella indica* Kr.P. Singh, monotypic genus reported from tropical region Manipur. Among the saxicolous pyrenocarpous lichens *Catapyrenium* and *Dermatocarpon* grows on soil over rocks in temperate and alpine areas, while *Endocarpon*, *Staurothele* and *Verrucaria* grows mostly on rocks from tropical to alpine areas.

In alpine region the tree growth is almost absent and thus allows few pyrenocarpous to colonize on soil and rocks, such as species of *Catapyrenium*, *Placidium*, *Endocarpon*, *Staurothele* and *Verrucaria*.

Distribution of terricolous pyrenocarpous lichens

Eastern Himalaya has evergreen typical dense and moist forests exhibit dominance of *Agonimia allobata* (Stizenb.) P. James, *A. opuntiella* (Buschardt & Poelt) Vězda and *A. tristicula* (Nyl.) Zahlbr. species in Arunachal Pradesh, Assam and Sikkim, while *Catapyrenium cinereum* (Pers.) Körb., found in Maharashtra state. Due to warmer and open thin out forests in Western Himalaya lacking of terricolous pyrenolichen taxa.

Biomonitoring of pyrenolichens

The characteristic of lichens to accumulate substances is in more in use to monitor the air-transported pollution. The use of the lichen vegetation is a cheap means to map air contamination in an area. The foliicolous lichens are promising bioindicators in the tropics. Their dependency on the leaf on which they grow is limited, hence foliicolous lichens are mainly dependent on atmospheric factors for the survival. Foliiicolous lichens exhibit an accelerated life cycle and immediately react upon environmental changes [39]. They are suitable for indication of the environmental parameters, as altitudinal zonation, reasonability, i.e. the amount of precipitation and their annual distribution and anthropogenic disturbance, together with micro-site, differentiating between light intensities in the shady understory, natural light gaps and the outer canopy. Good growth of the foliicolous lichens clearly indicates the shady and moist condition of the forest.

All over the world the lichens growth of the lichens has been greatly influenced by the human activity. Mostly the pyrenolichens are corticolous in nature, their existence and growth is subjected to condition imposed on the tree species by human beings, sometimes promoting, sometimes hampering the growth of different taxa.

In Andaman Islands and parts of Eastern Himalaya where many moist evergreen forests have undergone deforestation for a long time, the lichen growth occupied the deeper parts of such forests Sethy & Patwardhan [40] and Singh [8, 41]. Dense virgin forests that cover tracts of land in moist regions of the India subcontinent are suitable for growth of pyrenocarpous lichens. In very dense forests where light does not sufficiently penetrate to the ground level or the lower part of the tree, there is poor or no lichen growth on trees. The trees at fringes of such forests where they are thin, good lichen growth were observed. Thinning out of forests by human agency has extended the zone of lichen growth to deeper parts of such forests. Thinning out also promotes under growth that support rich growth of understory shrubs with foliicolous lichens. Road construction through dense forests, produce similar conditions, promoting lichen growth on the roadside trees. But in other part of the county like Indo-gangetic plain, major parts of Deccan plateau, the deforestation has been more or less complete, denying the lichens their substratum and creating dry conditions unsuitable for their existence.

Conservation of pyrenolichens

Upreti [42] mentioned the ethnobotanical commercial utilization of lichens and the decline of forests cover are the leading factors to loss of lichen diversity in India. Singh and Sinha [43] mentioned agricultural, urbanization, construction of road, buildings on hills, mineral extraction, hydroelectric projects, shifting cultivation, common

practice adopted by tribal societies in the entire north-eastern states and excessive use of fire wood in hilly regions and preparation of charcoal by burring the trees (a common in hills of Meghalaya and north-west Himalayas) are another factor responsible for depletion of many lichen rich habitats. For conservation of the lichens in India, it is a need of the time that the areas having rich lichen biodiversity should be protected and declared as lichen sanctuaries. In India, the tropical regions in Western Ghats, forest area along the coast, eastern Himalaya and Andaman Island harbor the rich pyrenocarpous lichen biota. Within these tropical zones some localities having rich diversity of pyrenocarpous lichen are in need of protection in the form of declaring the habitat as 'Pyrenocarpous lichens Sanctuaries'.

The areas having rich pyrenocarpous lichen diversity in India also need protection in the form of 'Lichens Sanctuaries'. Upreti & Nayaka [44] already suggested few localities as 'Lichen Sanctuaries' in India. The Nilgiri and Palni Hills, Saryu river valley, Nain Singh top area in route to Milam glacier, Chopta Tungnath peak and Great Himalayan National Park (GHNP), are already protected areas under the boundaries of Nilgiri Biosphere Reserve, Nanda Devi Biosphere Reserve and Great Himalayan National Park, respectively. The Tiger Hill in West Bengal (Darjeeling), Phek district in Nagaland, Ranikhet in Uttarakhand, Amarkantak in Madhya Pradesh, Achanakamar in Chhattisgarh are also in need of protection in the form of describing the habitats as 'Lichen Sanctuaries'. Only the declaration of 'Lichen Sanctuaries' is not sufficient for conservation of lichen in general and pyrenocarpous in particular. Some contractive approaches, which may be useful for better conservation of Indian lichen biota.

Acknowledgements: Authors are thankful to the Director, CSIR-National Botanical Research Institute, Lucknow for providing facilities. One of the authors GKM would like to thanks to the Department of Science & Technology, New Delhi for award of N-PDF (PDF/2017/000356).

REFERENCES

- 1) Patwardhan, P.G. and Makhija, U. 1980a. The genus *Anthracotheceum* Hampe ex Massal. in the Western Ghats, S. W. India, Kavaka 8, 17-27.
- 2) Patwardhan, P.G. and Makhija, U. 1980b. Three interesting pyrenolichens from the rain forests of Karnataka state. *Current Science*, 49, 917-918.
- 3) Singh, A. and Upreti, D.K. 1984. The lichen genus *Endocarpon* from India. *Candollea* 39, 539-548.
- 4) Singh, A. and Upreti, D.K. 1986. Lichen genus *Pleurotheliopsis* from the Indian Subcontinent. *Geophytology*, 16(1), 261-263.
- 5) Singh, A. 1970a. On foliicolous species of *Porina* from Andaman Islands. *Rev Lithothelium himalayense* ue *Bryologist* et *lichénologique*, 37, 973- 982.
- 6) Singh, A. 1970b. *Strigula* and *Raciborskiella* species from the Andaman Islands, India. *Bryologist* 73, 719-722.
- 7) Singh, A. 1970c. On foliicolous species of *Porina* from Andaman Islands. *Revue Bryologique et lichénologique*, 37, 973- 982.
- 8) Singh, A. 1971. Some unrecorded and interesting Pyrenocarpous lichens from Andaman Islands, India. *Bryologist*, 74(2), 195-198.
- 9) Awasthi, D.D. and Singh, K.P. 1972. Foliicolous lichens from the Palni and Nilgiri hills, India. *Proceedings of Indian Academy of Sciences, section- B*, 76(3), 117-133.
- 10) Awasthi, D.D. and Singh, K.P. 1973. A synopsis of foliicolous lichens from Nilgiri and Palni hills, India. *Geophytology*, 3, 13-25.
- 11) Patwardhan, P.G. and Badhe, P. 1973. Contributions to the lichen flora of Western India -V. *J. Univ. Poona, Sci. Technol. Sect 44*, 53-55.
- 12) Singh, K.P. 1973. Additions to the lichen flora of India II. *Kavaka* 1, 43-46.
- 13) Awasthi, D.D. and Upreti, D.K. 1985. Lichen genus *Dermatocarpon* in India. *Journal of Economic and Taxonomic Botany*, 7(1), 7-12.
- 14) Upreti, D.K. and Singh, A. 1987a. A new species of *Porina* from the Andaman Islands, India. *Botanical Journal of Linnean Society*, 94, 399-402.
- 15) Upreti, D.K. and Singh, A. 1987b. Lichen genus *Laurera* from the Indian Subcontinent. *Bulletin du Jardin Botanique National de Belgique*, 57(3-4), 367-383.
- 16) Upreti, D.K. 1990. Lichen genus *Pyrenula* in India: I *Pyrenula subducta* spore type. *Journal of Hattori Botanical Laboratory*, 68, 269-278.
- 17) Awasthi, D.D. 1991. A key to the Microlichens of India, Nepal & Sri Lanka. *Bibliotheca Lichenologica*, 40, 1-336.
- 18) Upreti, D.K. 1991a. Lichen genus *Pyrenula* from India: The species with spores of *Pyrenula brunnea* type. *Bulletin de la Société Botanique de France. Actualités Botaniques*, 138(3), 241-247.
- 19) Upreti, D.K. 1991b. Lichen genus *Pyrenula* from India: IV. *Pyrenula cayennensis* spore type. *Cryptogamie Bryologie Lichénologie*, 12(1), 41-46.
- 20) Upreti, D.K. 1992. Lichen genus *Pyrenula* from India: VII. *Pyrenula mastophora* spore type. *Feddes Repert.* 103(3-4), 279-296.
- 21) Upreti, D.K. 1993a. Lichen genus *Pyrenula* from India: II. *Pyrenula camptospora* spore type, III, *Pyrenula pinguis* spore type. *Acta Botanica Gallica*, 140(5), 519-523.
- 22) Upreti, D.K. 1993b. Notes on *Arthopyrenia* species from India. *Bryologist*, 96(2), 226-232.
- 23) Upreti, D. K. and Pant, G. 1993. Notes on *Arthopyrenia* species from India. *Bryologist*, 96, 226-232.
- 24) Upreti, D.K. and Nayaka, S. 2005. *Anisomeridium calciccolum* sp. nov. and further new records of pyrenocarpous lichens from India. *Lichenologist*, 38, 231-233.
- 25) Jagadeesh Ram, T.A.M., Upreti, D.K. and Sinha, G.P. 2005. *Pyrenula subcylindrica*, a new pyrenocarpous lichen from India. *Lichenologist*, 37(2), 109-110.
- 26) Singh, K.P. 1999. Lichens of Eastern Himalaya region. In: Mukerji KG, Upreti DK, Upadhyay (eds) *Biology of*

- lichens. Aravali Books International, New Delhi, pp 153-204.
- 27) Bajpai, R., Nayaka, S. and Upreti, D.K. 2011. Distribution of lichens on four trees in east and south district of Sikkim. *Biozone*, 3(1-2), 406-419.
 - 28) Rout, J., Das, P. and Upreti, D.K. 2010. Epiphytic lichen diversity in a reserve forest in south Assam, north India. *Tropical Ecology*, 51(2), 281-288.
 - 29) Sipman, H.J.M. 1997. Observations on the foliicolous lichen and bryophyte flora in the canopy of a semi-deciduous tropical forest. *Abstracta Botanica*, 21, 153-161
 - 30) Nimis, P.L., Scheidegger, C. and Wolseley, P.A. 2002. *Monitoring with lichens—monitoring lichens*. Kluwer Academic Publishers, Berlin.
 - 31) Orange, A.P, James, W. and White, F.J. 2001 *Microchemical Methods for the Identification of Lichens*. British Lichen Society, U.K.
 - 32) Aptroot, A. 2012. A world key to the species of *Anthracotheicum* and *Pyrenula*. *Lichenologist*, 44, 5-53.
 - 33) Aptroot, A. and Cáceres, M.E.D.S. 2016b. New Trypetheliaceae from the Amazon basin in Rondônia (Brazil), the centre of diversity of the genus *Astrothelium*. *The Lichenologist*, 48(6), 693-712.
 - 34) Aptroot, A. and Lücking, R. 2016a. A revisionary synopsis of the Trypetheliaceae (Ascomycota: Trypetheliales). *The Lichenologist*, 48(6), 763-982.
 - 35) Aptroot, A. 2006. Three new species of *Lithothelium* (*Pyrenulaceae*) from China and Thailand, with a revised world key and annotated list of species. *The Lichenologist*, 38(6), 541-548.
 - 36) Singh, A. 1969. On some foliicolous lichens from Andaman. *Plant Science*, 1, 97-100.
 - 37) Singh, A. 1978. Three foliicolous lichen species from Andaman Islands, New to Indian Flora. *New Botanist An International Quarterly Journal of Plant Science Research*, 5, 11-14.
 - 38) Santesson, R. 1952. Foliicolous lichens-I. A revision of the taxonomy of the obligately foliicolous lichenized fungi. *Symbolae Botanicae Upsalienses*, 12, 1-690.
 - 39) Lücking, R. 1997. The use of foliicolous lichens as bioindicators in the tropics, with reference to the microclimate. *Abstracta Botanica*, 21(1), 99-116.
 - 40) Sethy, P.K. and Patwardhan, P.G. 1987. Some foliicolous lichens from the Nicobar and Andaman Islands, India. *Biovigyanam*, 13(2), 52-59.
 - 41) Singh, A. 1979. The lichen flora of India with special reference to Andaman Islands: In T. N. Khoshoo & P. K. K.Nair (eds.) *Progress of Plant Research*, Lucknow, pp. 39-56.
 - 42) Upreti, D.K. 1995. Loss of lichen diversity in Indian lichen flora. *Environmental Conservation*, 22(4), 362-363.
 - 43) Singh, K.P. and Sinha, G.P. 1997. Lichen diversity of the eastern Himalayas and its conservation. In: *Recent research in Ecology, Environment and Pollution* (eds. S.C. Sati, J. Saxena and R.C. Dubey). Today and Tomorrow's Printers & Publishers, New Delhi, pp 349-359.
 - 44) Upreti, D.K. and Nayaka, S. 2008. Need for creation of lichen gardens and sanctuaries in India. *Current Science*, 94(8), 976-78.