



The diversity of endolichenic fungi – A review

Jyotsna Chakarwari^{1,2}, Sanjeeva Nayaka^{1,2*} and Suchi Srivastava^{2,3}

¹Lichenology Laboratory, CSIR-National Botanical Research Institute, Rana Pratap Marg, Lucknow-226001, India

²Academy of Scientific and Innovative Research (AcSIR), CSIR-HRDC Campus, Kamla Nehru Nagar, Ghaziabad - 201002, India

³Plant Ecology and Environmental Technologies Division, CSIR-National Botanical Research Institute, Rana Pratap Marg, Lucknow-226001, India

Chakarwari J, Nayaka S, Srivastava S 2020 – Diversity of endolichenic fungi – A review. Asian Journal of Mycology 3(1), 488–509, Doi 10.5943/ajom/3/1/18

Abstract

Endolichenic fungi reside inside the lichen thalli without showing any visible symptoms of their presence. The fossil record of endolichenic fungi dates back to 415 million years, however, they have been successfully isolated only since the 1990s. Several reviews are available dealing with the bioprospecting potential of unique metabolites produced by endolichenic fungi; however, reviews addressing their taxonomic diversity are lacking. In this review, the names and the current taxonomic status of the endolichenic fungi reported so far are compiled and updated. The study indicated that approximately 500 endolichenic fungi are isolated of which only 135 identified up to species level. A large number of endolichenic fungi are either partially identified up to genus level or treated as unidentified. The reasons for such treatment are discussed. The study also revealed that only 114 well-known species of lichens belonging to 22 families are utilized for isolation of endolichenic fungi, while in some cases hosts were not identified. These lichens belong mostly to macro lichens with Parmeliaceae as the dominant members. The occurrence of the endolichenic fungi on different groups of plants indicates that they are not host-specific.

Keywords – Endosymbionts – lichenicolous fungi – miniature ecosystem – symbiosis

Introduction

Lichens are considered as a miniature ecosystem (Honegger 1991) due to their close interaction with a variety of organisms such as fungi, algae, cyanobacteria, eubacteria, and micro-invertebrates. While a fungus (Ascomycetes or Basidiomycetes) and a photoautotroph (Chlorophyta or Cyanobacteria) make a primary association and form lichen thallus, others make secondary, obligate or opportunistic associations. Recently, yeasts thought to be obligate, third partners in lichen formation (Spribille et al. 2016), however, this claim is not yet accepted (Mark et al. 2020). Due to growing ambiguity over the presence of yeast and other microbes, the lichens are redefined as ‘a self-sustaining ecosystem formed by the interaction of an exhabitant fungus and an extracellular arrangement of one or more photosynthetic partners and an indeterminate number of other microscopic organisms’ (Hawksworth & Grube 2020). Among the secondary associates, the lichenicolous and endolichenic fungi (hereafter referred to as ELF) are interesting groups due to their taxonomic and evolutionary status (Oh et al. 2020), and for bioprospecting (Maduranga et al. 2018). The ELF, which are endosymbionts of lichens (Miadlikowska et al. 2004) are predominantly filamentous, reside inside the lichen thallus without showing any visible symptoms of their

presence and apparently, do not harm the host. The ELF closely associates themselves with the photobiont of the lichen for their nutrition (Arnold et al. 2009). They are similar to endophytic fungi of vascular plants. The endophytic fungi play various functional roles in their plant hosts like altering their disease resistance or susceptibility, augmenting their growth, and ability to survive in extreme environments (Yu et al. 2018). However, the role of endolichenic fungi in increasing the fitness of lichens is not known (Suryanarayan et al. 2017).

Diversity of ELF

The ELF are cosmopolitan in distribution and are known from every lichen species tested from the Arctic to tropics. Around 13,500 species of ELF are estimated to occur in the world (Kellogg & Raja 2016). The ELF exhibits a vast diversity as indicated by Petrini et al. (1990), who isolated 506 fungal taxa from 17 lichen species; of these, 306 were isolated only once. An intensive study of two lichens *Peltigera praetextata* and *Xanthoparmelia taractica* from a coniferous forest (Aosta Valley, Italy) yielded different fungi belonging to 117 taxa (Girlanda et al. 1997). Suryanarayanan et al. (2005) isolated 242 endolichenic fungi from 500 thallus segments of five corticolous lichens. Li et al. (2007) isolated a total of 32 taxa from 488 thallus segments, with 31 ascomycetes and one yeast. Zhang et al. (2016) recovered 247 fungal isolates from 2712 thallus segments of 17 lichen species. Govinda Rajulu et al. (2020) isolated a total of 389 species from 10 lichen species of Western Ghats, Southern India. These reports exemplify the tremendous diversity of ELF. Rashmi et al. (2019) provided a lengthy list of endophytic fungi reported from the world, however, it included very few ELFs (e.g. *Nodulisporium hyalosporum*). The compilation of all the ELF studies carried out so far indicated that about 500 ELFs have been isolated till date, among them only 135 were identified up to species level while most of them are either identified up to the genus or class level or treated as unidentified (Table 1). As the ELFs do not produce sufficient morphological characters such as colouration, conidia or spores in culture, it is difficult to identify under routine microscopic studies (Tripathi & Joshi 2019). The DNA based molecular techniques are only partially helpful due to the lack of sequences in gene bank or library related to ELFs. Usullay, the aim of most of the researchers is to isolate ELFs for bioactive molecule and hence not much attention is paid towards their taxonomy. Recent studies have indicated that ELFs are not different from endophytes and the DNA based techniques are able to unravel their identity (Govinda Rajulu et al. 2020).

Table 1 List of lichens so far explored for ELFs (name in parenthesis are synonyms as originally annotated by authors)

| | Fungi | Host lichen | Reference |
|---|---|---|------------------------------|
| 1 | <i>Acremonium</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| | | <i>Parmotrema thomsonii</i> (= <i>Parmelia thomsonii</i>) | Suryanarayanan et al. (2005) |
| | | <i>Dermatocarpon miniatum</i> ; <i>Melanelia soredata</i> ; <i>Parmotrema thomsonii</i> | Li et al. (2007) |
| | | <i>Parmotrema</i> sp. | Kannangara et al. (2008) |
| | | <i>Lobaria kurokawae</i> ; <i>Parmotrema thomsonii</i> ; <i>P. tinctorum</i> ; <i>Punctelia rudecta</i> | Tripathi et al. (2014) |
| | | <i>Lobaria kurokawae</i> ; <i>Parmotrema tinctorum</i> ; <i>Punctelia rudecta</i> | Suryanarayanan et al. (2017) |
| | | | |
| 2 | <i>Alternaria</i> sp. (= <i>Ulocladium</i> sp.) | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |
| | | <i>Parmotrema hababianum</i> | Suryanarayanan et al. (2017) |
| | | <i>Hypotrachyna</i> sp.; Unknown lichen | Wang et al. (2012) |
| 3 | <i>A. alternariae</i> (Cooke) Woudenb. & Crous (= <i>Ulocladium alternariae</i> (Cooke) Simmons) | <i>Xanthoparmelia taractica</i> (= <i>Parmelia taractica</i>); <i>Peltigera praetextata</i> | Girlanda et al. (1997) |
| 4 | <i>A. alternata</i> (Fr.) Keissl. | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |
| | | <i>Bulbothrix meizospora</i> ; <i>Heterodermia flabellata</i> ; <i>H. hypochraea</i> ; <i>Parmotrema crinitum</i> ; | Suryanarayanan et al. (2005) |

Table 1 Continued.

| | Fungi | Host lichen | Reference |
|----|---|--|--|
| | | <i>P. praesorediosum</i> ; <i>P. nilgherrense</i> ; <i>P. reticulatum</i> ; <i>P. thomsonii</i> ; <i>Physcia dilatata</i> | |
| | | <i>Heterodermia flabellata</i> ; <i>Parmotrema crinitum</i> ; <i>P. thomsonii</i> ; <i>Physcia dilatata</i> | Li et al. (2007) |
| | | <i>Usnea aciculifera</i> | He et al. (2012) |
| | | <i>Bulbothrix meizospora</i> ; <i>Heterodermia flabellata</i> ; <i>H. hypochraea</i> ; <i>Flavoparmelia caperata</i> ; <i>Leptogium burnetiae</i> ; <i>Parmotrema crinitum</i> ; <i>P. graynum</i> ; <i>P. nilgherrense</i> ; <i>P. praesorediosum</i> ; <i>P. reticulatum</i> ; <i>P. thomsonii</i> ; <i>Physcia dilatata</i> | Tripathi et al. (2014) |
| | | <i>Cladonia fruticulosa</i> ; <i>Parmotrema reticulatum</i> ; <i>P. tinctorum</i> | Vinayaka et al. (2016) |
| | | #Not specified – list of several lichens given | Zhang et al. (2016) |
| 5 | <i>A. tenuissima</i> (Kunze) Wiltshire | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 6 | <i>Aphanocladium</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 7 | <i>Apiosordaria</i> sp. | #Not specified – list of several lichens given | Zhang et al. (2016) |
| 8 | <i>Apiotrichum</i> (= <i>Hyalodendron</i> sp.) | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 9 | <i>Arthrimum arundinis</i> (Corda) Dyko & B. Sutton (= <i>Apiospora montagnei</i> Sacc.) | <i>Cladonia</i> sp. | Wang et al. (2017) |
| 10 | <i>Arthrimum phaeospermum</i> (Corda) M. B. Ellis | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| | | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |
| 11 | <i>Ascochyta</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 12 | <i>Aspergillus</i> sp. (= <i>Eurotium</i> sp.) | <i>Pseudocyphellaria</i> sp. | Kannangara et al. (2008) |
| | | <i>Peltigera elisabethae</i> var. <i>mauritzii</i> | Zhao et al. (2014) |
| | | <i>Cetrelia</i> sp. | Chen et al. (2014), Chen et al. (2019) |
| | | <i>Cladina grisea</i> | Chen et al. (2014) |
| | | <i>Parmelia</i> sp. | Padhi and Tayung (2015, 2016) |
| | | <i>Phaeophyscia hispidula</i> | Suryanarayanan et al. (2017) |
| 13 | <i>A. aculeatus</i> Iizuka | <i>Porina tetracerae</i> | Maduranga et al. (2018) |
| 14 | <i>A. coremiiformis</i> Bartoli & Maggi | <i>Flavoparmelia caperata</i> | Tripathi et al. (2014) |
| 15 | <i>A. flavus</i> Link | <i>Bulbothrix meizospora</i> ; <i>Heterodermia flabellata</i> ; <i>H. hypochraea</i> ; <i>Parmotrema crinitum</i> ; <i>P. nilgherrense</i> ; <i>P. praesorediosum</i> ; <i>P. reticulatum</i> ; <i>P. thomsonii</i> ; <i>Physcia dilatata</i> | Suryanarayanan et al. (2005) |
| | | <i>Heterodermia flabellata</i> ; <i>Parmotrema crinitum</i> ; <i>P. thomsonii</i> ; <i>Physcia dilatata</i> | Li et al. (2007) |
| | | <i>Bulbothrix meizospora</i> ; <i>Flavoparmelia caperata</i> ; <i>Heterodermia flabellata</i> ; <i>H. hypochraea</i> ; <i>Leptogium burnetiae</i> ; <i>Parmotrema crinitum</i> ; <i>P. graynum</i> ; <i>P. nilgherrense</i> ; <i>P. praesorediosum</i> ; <i>P. reticulatum</i> ; <i>P. thomsonii</i> ; <i>Physcia dilatata</i> | Tripathi et al. (2014) |
| 16 | <i>A. fumigatus</i> Fresen. | Unidentified | Maduranga et al. (2018) |
| 17 | <i>A. hiratsukae</i> Udagawa, Tsub. & Y. Horie | <i>Opegrapha medusulina</i> ; <i>Pyxine cocoes</i> ; <i>Roccella montagnei</i> ; Unidentified | Maduranga et al. (2018) |
| 18 | <i>A. niger</i> Tiegh. | <i>Heterodermia flabellata</i> ; <i>Parmotrema thomsonii</i> ; <i>Physcia dilatata</i> ; <i>Roccella montagnei</i> | Suryanarayanan et al. (2005) |
| | | <i>Heterodermia flabellata</i> ; <i>Parmotrema thomsonii</i> ; <i>Physcia dilatata</i> | Li et al. (2007), Tripathi et al. (2014) |
| | | <i>Parmotrema cristiferum</i> ; <i>Ramalina arabum</i> ; <i>Teloschistes flavicans</i> ; <i>Usnea galbinifera</i> | Vinayaka et al. (2016) |
| | | <i>Parmotrema ravum</i> | Padhi et al. (2019) |

Table 1 Continued.

| | Fungi | Host lichen | Reference |
|----|---|---|--|
| 19 | <i>A. versicolor</i> (Vuill.) Tirab. | <i>Lobaria retigera</i> <i>Ricasolia quercizans</i> (= <i>Lobaria quercizans</i>) Unknown | Duo et al. (2014) Li et al. (2015a) Li et al. (2015a) |
| 20 | <i>A. quadricinctus</i> E. Yuill | <i>Usnea longissima</i> | Prateeksha et al. (2020) |
| 21 | <i>Aureobasidium pullulans</i> (de Bary & Löwenthal) G. Arnaud | <i>Canoparmelia texana</i> ; <i>Heterodermia diademata</i> ; <i>H. podocarpa</i> ; <i>Leptogium askotense</i> ; <i>Lobaria kurokawae</i> ; <i>Parmotrema hababianum</i> ; <i>P. tinctorum</i> ; <i>Phaeophyscia hispidula</i> ; <i>Punctelia rudecta</i> ; <i>Ramalina conduplicans</i> ; <i>Usnea</i> sp. <i>Bacidina</i> sp.; <i>Teloschistes flavicans</i> | Suryanarayanan et al. (2017) Govinda Rajulu et al. (2020) |
| 22 | <i>Bahusakala</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 23 | <i>Berkeleyomyces basicola</i> (Berk. & Broome) W.J. Nel, Z.W. de Beer, T.A. Duong & M.J. Wingf (= <i>Thielavia basicola</i> (Berk. & Broome) Zopf) | <i>Polyblastidium dendriticum</i> (= <i>Heterodermia dendritica</i>); <i>Parmotrema reticulatum</i> ; <i>Ramalina arabum</i> ; <i>Usnea galbinifera</i> | Vinayaka et al. (2016) |
| 24 | <i>Biatrispora</i> sp. | <i>Pseudocyphellaria</i> sp. | Zhou et al. (2016) |
| 25 | <i>Biscogniauxia petrensis</i> Z.F. Zhang, F. Liu & L. Cai | <i>Parmotrema</i> sp. | Oh et al. (2020) |
| 26 | <i>Bispora</i> sp. | <i>Canoparmelia texana</i> | Suryanarayanan et al. (2017) |
| 27 | <i>Botrytis</i> sp. | <i>Roccella montagnei</i> <i>Parmotrema tinctorum</i> <i>Dirinaria consimilis</i> | Suryanarayanan et al. (2005) Suryanarayanan et al. (2017) Govinda Rajulu et al. (2020) |
| 28 | <i>B. cinerea</i> Pers. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 29 | <i>Broomella</i> sp. | <i>Parmotrema</i> sp. | Kannangara et al. (2008) |
| 30 | <i>Byssochlamys spectabilis</i> (Udagawa & Shoji Suzuki) Houbraken & Samson | <i>Pyrenula ochraceoflava</i> | Maduranga et al. (2018) |
| 31 | <i>Cadophora bubakii</i> (Laxa) Damm & S. Bien (= <i>Phailophora bubakii</i> (Laxa) Schol-Schwarz) | <i>Dermatocarpon minutum</i> ; <i>Melanelia sorediata</i> ; <i>Ramalina sinensis</i> | Li et al. (2007) |
| 32 | <i>Calonectria gracilis</i> Corus, M.J. Wingf. & Alfenaas (= <i>Cylindrocarpon gracile</i> Bugnic.) | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |
| 33 | <i>Cerrena</i> sp. | <i>Pyrenocarp</i> sp.; <i>Pyrenula indet</i> | Maduranga et al. (2018) |
| 34 | <i>Cerrena unicolor</i> (Bull.) Murrill | <i>Roccella montagnei</i> | Maduranga et al. (2018) |
| 35 | <i>Chaetomella</i> sp. | <i>Parmotrema nilgherrense</i> | Suryanarayanan et al. (2005), Tripathi et al. (2014) |
| 36 | <i>Chaetomium</i> sp. | <i>Roccella montagnei</i> <i>Punctelia borreri</i> <i>Canoparmelia texana</i> ; <i>Heterodermia diademata</i> ; <i>H. podocarpa</i> ; <i>Leptogium askotense</i> ; <i>Lobaria kurokawae</i> ; <i>Parmotrema tinctorum</i> ; <i>Phaeophyscia hispidula</i> ; <i>Punctelia rudecta</i> <i>Heterodermia incana</i> ; <i>Parmotrema cristiferum</i> ; <i>P. reticulatum</i> ; <i>P. tinctorum</i> ; <i>Ramalina arabum</i> ; <i>Ramalina pacifica</i> ; <i>Teloschistes flavicans</i> <i>Bacidina</i> sp.; <i>Dirinaria consimilis</i> ; <i>Evernia prunastri</i> ; <i>Parmotrema</i> sp.; <i>Usnea</i> sp. | Suryanarayanan et al. (2005) Li et al. (2007) Suryanarayanan et al. (2017) Vinayaka et al. (2016) Govinda Rajulu et al. (2020) |
| 37 | <i>C. elatum</i> Kunze | <i>Melanelia sorediata</i> <i>Hypotrachyna cirrhata</i> (= <i>Everniastrum cirrhatum</i>) <i>Parmotrema reticulatum</i> ; <i>Ramalina arabum</i> ; <i>Usnea galbinifera</i> | Li et al. (2007) Chen et al. (2013) Vinayaka et al. (2016) |

Table 1 Continued.

| | Fungi | Host lichen | Reference |
|----|---|--|------------------------------|
| 38 | <i>C. globosum</i> Kunze | <i>Cladonia coniocraea</i> ; <i>Melanelia soredata</i> | Li et al. (2007) |
| | | <i>Hypotrachyna nepalensis</i> (= <i>Everniastrum nepalense</i>) | Zheng et al. (2014) |
| | | <i>Cladonia fruticulosa</i> ; <i>Parmotrema cristiferum</i> ; <i>P. reticulatum</i> ; <i>P. tinctorum</i> ; <i>Polyblastidium dendriticum</i> ; <i>Ramalina pacifica</i> ; <i>Usnea stigmatoides</i> | Vinayaka et al. (2016) |
| | | #Not specified – list of several lichens given | Zhang et al. (2016) |
| 39 | <i>Chalara</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| | | <i>Parmotrema reticulatum</i> ; <i>Ramalina arabum</i> ; <i>Usnea stigmatoides</i> | Vinayaka et al. (2016) |
| 40 | <i>C. constricta</i> NagRaj & W.B. Kendr. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 41 | <i>C. fusidioides</i> (Corda) Rabenh. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 42 | <i>Chrysosporium</i> sp. | <i>Parmotrema</i> sp.; <i>Usnea</i> sp. | Kannangara et al. (2008) |
| 43 | <i>C. pseudomerdarium</i> van Oorschot | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 44 | <i>Cladophialophora chaetospira</i> (Grove) Crous & Arzanlou (= <i>Heteroconium chaetospira</i> (Grove) M. B. Ellis) | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| | | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |
| 45 | <i>Cladosporium</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| | | <i>Roccella montagnei</i> ; <i>Parmotrema nilgherrense</i> ; <i>P. praesorediosum</i> ; <i>Physcia dilatata</i> | Suryanarayanan et al. (2005) |
| | | <i>Physcia dilatata</i> | Li et al. (2007) |
| | | <i>Pseudocyphellaria</i> sp.; <i>Parmotrema</i> sp.; <i>Usnea</i> sp. | Kannangara et al. (2008) |
| | | <i>Parmotrema hababianum</i> ; <i>P. nilgherrense</i> ; <i>P. praesorediosum</i> ; <i>Lobaria kurokawae</i> ; <i>Physcia dilatata</i> | Tripathi et al. (2014) |
| | | <i>Lobaria kurokawae</i> | Suryanarayanan et al. (2017) |
| | | <i>Arthonia</i> sp.; <i>Hypotrachyna crenata</i> ; <i>Parmotrema tinctorum</i> | Govinda Rajulu et al. (2020) |
| 46 | <i>C. cladosporioides</i> (Fr.) de Vries | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| | | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |
| | | <i>Heterodermia incana</i> ; <i>Ramalina arabum</i> ; <i>Teloschistes flavicans</i> ; <i>Usnea stigmatoides</i> ; <i>U. galbinifera</i> | Vinayaka et al. (2016) |
| | | | |
| 47 | <i>C. herbarum</i> (Pers.) Link | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 48 | <i>Colletotrichum</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 49 | <i>C. dematium</i> (Pers.) Grove | <i>Parmotrema tinctorum</i> ; <i>Polyblastidium dendriticum</i> ; <i>Ramalina arabum</i> ; <i>R. pacifica</i> ; <i>Usnea stigmatoides</i> | Vinayaka et al. (2016) |
| 50 | <i>Coniochaeta</i> sp. (= <i>Lecythophora</i> sp.) | <i>Dermatocarpon minutum</i> ; <i>Parmelia</i> sp.; <i>Punctelia borreri</i> ; <i>Zeroviella mandschurica</i> (= <i>Xanthoria mandschurica</i>) | Li et al. (2007) |
| | | <i>Zeroviella mandschurica</i> | Wang et al. (2010) |
| | | #Not specified – list of several lichens given | Zhang et al. (2016) |
| | | <i>Cladonia evansii</i> | Wijeratne et al. (2016) |
| 51 | <i>Cordyceps farinose</i> (Holmsk.) Kepler, B. Shrestha & Spatafora (= <i>Paecilomyces farinosus</i> (Holm ex S. F. Gray) Brown et Smith) | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| | | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |
| 52 | <i>Corynespora</i> sp. | <i>Usnea cavernosa</i> | Paranagama et al. (2007) |

Table 1 Continued.

| | Fungi | Host lichen | Reference |
|----|---|--|--|
| 53 | <i>Cosmospora butyri</i> (J.F.H. Beyma) Gräfenhan, Seifert & Schroers (= <i>Acremonium butyri</i> (Beyma) W. Gams) | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |
| 54 | <i>Cryptocline</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 55 | <i>C. fasciculata</i> (Tode) Petr. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 56 | <i>Curvularia</i> sp. | <i>Pseudocyphellaria</i> sp.; <i>Usnea</i> sp. | Kannagara et al. (2008) |
| 57 | <i>C. australiensis</i> (Bugnic. ex M.B. Ellis) Manamgoda, L. Cai & K.D. Hyde (= <i>Bipolaris australiensis</i> (Bugnic. ex M.B. Ellis) Tsuda & Ueyama) | <i>Heterodermia flabellata</i> ; <i>Physcia dilatata</i> | Suryanarayanan et al. (2005), Li et al. (2007), Tripathi et al. (2014) |
| 58 | <i>C. lunata</i> (Wakker) Boedijn | <i>Polyblastidium dendriticum</i> ; <i>Ramalina pacifica</i> ; <i>Usnea stigmatoides</i> | Vinayaka et al. (2016) |
| 59 | <i>C. spicifera</i> (Bainier) Boedijn (= <i>Drechslera anamorph Cochliobolus spicifer</i> Nelson) | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |
| 60 | <i>C. trifolii</i> (Kauffman) Boedijn | <i>Usnea</i> sp. | Samanthi et al. (2015a) |
| 61 | <i>Cylindromonium lichenicola</i> (W. Gams) Crous (= <i>Acremonium lichenicola</i> W. Gams) | <i>Parmotrema reticulatum</i> | Suryanarayanan et al. (2005), Tripathi et al. (2014) |
| 62 | <i>Cylindrosporium</i> sp. | <i>Bulbothrix meizospora</i> | Suryanarayanan et al. (2005), Tripathi et al. (2014) |
| 63 | <i>Cystobasidium laryngis</i> (Reiersöl) Yurkov | #Not specified – list of several lichens given | Zhang et al. (2016) |
| 64 | <i>Cytospora</i> sp. | <i>Parmelia</i> sp. | Padhi and Tayung (2015) |
| 65 | <i>Daldinia</i> sp. | <i>Dirinaria picta</i> ; <i>Pyxine cocoes</i> | Maduranga et al. (2018) |
| 66 | <i>Daldinia eschscholtzii</i> (Ehrenb.) Rehm | <i>Dirinaria picta</i> ; <i>Opegrapha medusulina</i> ; <i>O. arabica</i> ; <i>Porina tetracerae</i> ; <i>Rocella montagnei</i> | Maduranga et al. (2018) |
| | | <i>Dirinaria consimilis</i> | Govinda Rajulu et al. (2020) |
| | | <i>Leptogium</i> sp. | Oh et al. (2020) |
| 67 | <i>Diaporthe</i> sp. (= <i>Phomopsis</i> sp.) | <i>Cladonia</i> sp.; <i>Porina tetracerae</i> ; <i>Stereocaulon</i> sp. | Petrini et al. (1990), Padhi & Tayung (2015), Maduranga et al. (2018) |
| 68 | <i>D. arengae</i> R.R. Gomes, Glienke & Crous | <i>Arthonia antillarum</i> ; <i>Opegrapha medusulina</i> ; Unidentified | Maduranga et al. (2018) |
| 69 | <i>Endomelanconiopsis</i> sp. | <i>Porina tetracerae</i> ; <i>Pyrenula</i> sp. | Maduranga et al. (2018) |
| 70 | <i>E. endophytica</i> E.I. Rojas & Samuels | <i>Porina tetracerae</i> ; <i>Pyrenula</i> sp.; Unidentified | Maduranga et al. (2018) |
| 71 | <i>Epicoccum nigrum</i> Link (= <i>Epicoccum purpurascens</i> Ehrenb. ex Schlecht) | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 72 | <i>Exophiala</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 73 | <i>E. lecanii-corni</i> (Benedek & G. Specht) Haase & de Hoog, (= <i>E. jeanselmei</i> var. <i>lecanii-corvi</i> (Benedek & Specht) De Hoog) | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 74 | <i>E. mansonii</i> (Castell.) De Hoog | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 75 | <i>Fusarium</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| | | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |
| | | <i>Usnea</i> sp. | Kannagara et al. (2008) |

Table 1 Continued.

| | Fungi | Host lichen | Reference |
|----|---|--|---|
| | | <i>Parmelia</i> sp. | Padhi & Tayung (2015) |
| | | <i>Arthonia</i> sp.; <i>Bacidina</i> sp. | Govinda Rajulu et al. (2020) |
| 76 | <i>F. lateritium</i> Nees | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| | | <i>Heterodermia incana</i> ; <i>Polyblastidium dendriticum</i> ; <i>Ramalina arabum</i> ; <i>Teloschistes flavicans</i> ; <i>Usnea stigmatoides</i> | Vinayaka et al. (2016) |
| 77 | <i>F. lolii</i> (Wm.G.Sm.) Sacc. (= <i>Fusarium heterosporum</i> Nees ex Fr.) | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| | | <i>Cladonia fruticulosa</i> ; <i>Parmotrema cristiferum</i> ; <i>Ramalina pacifica</i> ; <i>Usnea galbinifera</i> | Vinayaka et al. (2016) |
| 78 | <i>F. sublunatum</i> var. <i>sublunatum</i> Nierenb. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 79 | <i>Geopyxis majalis</i> (Fr.) Sacc. | <i>Pseudevernia intensa</i> | Wijeratne et al. (2012) |
| 80 | <i>Geotrichum</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| | | <i>Canoparmelia texana</i> ; <i>Heterodermia diademata</i> ; <i>Lobaria kurokawae</i> ; <i>Parmotrema tinctorum</i> | Tripathi et al. (2014), Suryanarayanan et al. (2017) |
| 81 | <i>Gilmaniella humicola</i> G.L. Barron | <i>Bulbothrix meizospora</i> ; <i>Parmotrema nilgherrense</i> | Suryanarayanan et al. (2005) |
| | | <i>Bulbothrix meizospora</i> ; <i>Leptogium burnetiae</i> ; <i>Parmotrema nilgherrense</i> ; <i>P. graynum</i> ; <i>Punctelia subrudecta</i> | Tripathi et al. (2014) |
| 82 | <i>Heterobasidion annosum</i> Fr. Bref. (= <i>Spiniger meineckellus</i> (Olson) Stalpers) | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 83 | <i>Heteroconium</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 84 | <i>Humicola</i> sp. | <i>Heterodermia diademata</i> ; <i>H. podocarpa</i> ; <i>Lobaria kurokawae</i> ; <i>Parmotrema hababianum</i> ; <i>P. tinctorum</i> ; <i>Punctelia rudecta</i> | Tripathi et al. (2014), Suryanarayanan et al. (2017) |
| 85 | <i>Hypoxylon</i> sp. (= <i>Nodulisporium</i> sp.) | <i>Cladonia fruticulosa</i> ; <i>Parmotrema reticulatum</i> | Vinayaka et al. (2016) |
| | | <i>Dermatocarpon minutum</i> ; <i>Melanelia soredata</i> ; <i>Punctelia borneri</i> | Li et al. (2007) |
| | | <i>Hypotrachyna</i> sp. (= <i>Everniastrum</i> sp.) | Zhao et al. (2015) |
| | | <i>Arthonia</i> sp.; <i>Bacidina</i> sp.; <i>Evernia prunastri</i> ; <i>Hypotrachyna crenata</i> ; <i>Parmotrema tinctorum</i> ; <i>Teloschistes flavicans</i> | Govinda Rajulu et al. (2020) |
| 86 | <i>H. anthochroum</i> Berk. & Broome | <i>Dirinaria picta</i> ; <i>Opegrapha medusulina</i> ; <i>Porina tetracerae</i> | Maduranga et al. (2018) |
| 87 | <i>H. fuscum</i> (Pers.) Fr. | <i>Usnea</i> sp. | Basnet et al. (2019a) |
| 88 | <i>H. fragiforme</i> (Pers.) J. Kickx f. | <i>Lobaria discolor</i> ; <i>L. japonica</i> | Oh et al. (2020) |
| 89 | <i>H. investiens</i> (Schwein.) M.A. Curtis | <i>Dirinaria consimilis</i> ; <i>Evernia prunastri</i> ; <i>Hypotrachyna crenata</i> ; <i>Parmotrema</i> sp.; <i>P. tinctorum</i> ; <i>Ramalina pacifica</i> | Govinda Rajulu et al. (2020) |
| 90 | <i>Lasiodiplodia crassispora</i> T.I Burgess & P.A. Barber | <i>Roccella montagnei</i> | Maduranga et al. (2018) |
| 91 | <i>L. theobromae</i> (Pat.) Griffon & Maubl. | <i>Roccella montagnei</i> | Suryanarayanan et al. (2005) |
| | | <i>Arthonia antillarum</i> ; <i>Opegrapha arabica</i> ; <i>Pyrenula ochraceoflava</i> ; <i>P. parvinuclea</i> ; <i>Roccella montagnei</i> | Maduranga et al. (2018) |
| | | <i>Bacidina</i> sp.; <i>Hypotrachyna crenata</i> | Govinda Rajulu et al. (2020) |
| 92 | <i>L. pseudotheobromae</i> A.J.L. Phillips, A. Alves & Crous | <i>Roccella montagnei</i> ; Unidentified | Maduranga et al. (2018) |
| 93 | <i>Monilinia</i> sp. (= <i>Monilia</i> sp.) | <i>Heterodermia diademata</i> ; <i>Lobaria kurokawae</i> | Tripathi et al. (2014), Suryanarayanan et al. (2017) |
| 94 | <i>Mucor hiemalis</i> Wehmer f. <i>hiemalis</i> | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |
| 95 | <i>M. racemosus</i> Fresen. | <i>Parmotrema reticulatum</i> | Suryanarayanan et al. (2005), Tripathi et al. (2014) |
| 96 | <i>Myrothecium inundatum</i> Tode | <i>Ramalina</i> sp. | Basnet et al. (2019b) |

Table 1 Continued.

| | Fungi | Host lichen | Reference |
|-----|--|---|--|
| 97 | <i>Myxotrichum</i> sp. | <i>Cetraria islandica</i> | Yuan et al. (2013) |
| 98 | <i>Nemania bipapillata</i> (Berk. & M.A. Curtis) | <i>Bacidina</i> sp.; <i>Dirinaria consimilis</i> ; <i>Hypotrachyna crenata</i> ; <i>Parmotrema</i> sp.; <i>P. tinctorum</i> ; <i>Teloschistes flavicans</i> ; <i>Usnea</i> sp. | Govinda Rajulu et al. (2020) |
| 99 | <i>N. serpens</i> (Pers.) Gray (= <i>Geniculosporium serpens</i> Chesters & Greenh.) | <i>Dermatocarpon minutum</i> | Li et al. (2007) |
| 100 | <i>Neocosmospora solani</i> (Mart.) L. Lombard & Crous (= <i>Fusarium solani</i> (Mart.) Sacc.) | <i>Xanthoparmelia taractica</i> ; <i>Peltigera praetextata</i> | Girlanda et al. (1997) |
| | | <i>Bulbothrix meizospora</i> ; <i>Heterodermia flabellata</i> ; <i>H. hypochraea</i> ; <i>Parmotrema crinitum</i> ; <i>P. graynum</i> ; <i>P. praesorediosum</i> ; <i>P. nilgherrense</i> ; <i>P. reticulatum</i> ; <i>P. thomsonii</i> ; <i>Physcia dilatata</i> | Suryanarayanan et al. (2005) |
| | | <i>Heterodermia flabellate</i> ; <i>Parmotrema crinitum</i> ; <i>P. graynum</i> ; <i>P. thomsonii</i> ; <i>Physcia dilatata</i> | Li et al. (2007) |
| | | <i>Bulbothrix meizospora</i> ; <i>Flavoparmelia caperata</i> ; <i>Heterodermia flabellata</i> ; <i>H. hypochraea</i> ; <i>Leptogium burnetiae</i> ; <i>Parmotrema crinitum</i> ; <i>P. graynum</i> ; <i>P. praesorediosum</i> ; <i>P. nilgherrense</i> ; <i>P. reticulatum</i> ; <i>P. thomsonii</i> ; <i>Physcia dilatata</i> ; <i>Punctelia subruducta</i> ; <i>Usnea</i> sp. | Tripathi et al. (2014) |
| | <i>Parmotrema cristiferum</i> ; <i>P. reticulatum</i> ; <i>Ramalina pacifica</i> ; <i>Usnea stigmatoides</i> | Vinayaka et al. (2016) | |
| 101 | <i>Neonectria ditissima</i> (Tul. & C. Tul.) Samuels & Rossman (= <i>Cylindrocarpon heteronema</i> (Berk. & Br.) Wollenw.) | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |
| 102 | <i>Neurospora</i> sp. | <i>Roccella montagnei</i> | Maduranga et al. (2018) |
| 103 | <i>N. crassa</i> Shear & B.O. Dodge | <i>Pyrenula parvinuclea</i> ; <i>Pyxine cocoes</i> | Maduranga et al. (2018) |
| 104 | <i>N. terricola</i> Goch. & Backus | <i>Hypotrachyna cirrhata</i> | Zhang et al. (2009) |
| 105 | <i>Nigrospora</i> sp. | <i>Usnea</i> sp. | Kannangara et al. (2008) |
| | | <i>Roccella montagnei</i> | Maduranga et al. (2018) |
| 106 | <i>N. aurantiaca</i> Mei Wang & L. Cai | <i>Lobaria discolor</i> ; <i>L. japonica</i> | Oh et al. (2020) |
| 107 | <i>N. chinensis</i> Mei Wang & L. Cai | <i>Lobaria discolor</i> ; <i>L. japonica</i> | Oh et al. (2020) |
| 108 | <i>N. oryzae</i> (Berk. & Broome) Petch | <i>Parmotrema reticulatum</i> | Suryanarayanan et al. (2005) |
| | | <i>Leptogium askotense</i> ; <i>Parmotrema reticulatum</i> | Tripathi et al. (2014), Suryanarayanan et al. (2017) |
| | | <i>Parmotrema tinctorum</i> | Govinda Rajulu et al. (2020) |
| 109 | <i>N. oryzae</i> (Berk. & Broome) Petch (= <i>N. sphaerica</i> (Sacc.) E.W. Mason) | <i>Parmotrema thomsonii</i> | Suryanarayanan et al. (2005), Li et al. (2007), Tripathi et al. (2014) |
| | | <i>Parmelinella wallichiana</i> | He et al. (2012) |
| | | <i>Opegrapha medusulina</i> ; Unidentified | Maduranga et al. (2018) |
| 110 | <i>Nodulisporium hyalosporum</i> S.C. Agarwal & J.K. Misra* | <i>Punctelia borrieri</i> | Li et al. (2007) |
| 111 | <i>N. sylviforme</i> Deighton* | <i>Melanelia soredata</i> | Li et al. (2007) |
| 112 | <i>Ochrocladosporium elatum</i> (Harz) Crous & U. Braun (= <i>C. elatum</i> (Harz.) Nannfeldt) | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 113 | <i>Oidiodendron cf. echinulatum</i> Barron | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 114 | <i>O. flavum</i> Svilv. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 115 | <i>Ophiosphaerella korrae</i> (J. Walker & A.M. Sm. Bis) Shoemaker & C.E. Babc. | Unknown | Li et al. (2018) |
| | | <i>Physcia</i> sp. | Li et al. (2019) |

Table 1 Continued.

| | Fungi | Host lichen | Reference |
|-----|--|---|--|
| 116 | <i>Paecilomyces</i> sp. | <i>Roccella montagnei</i> | Suryanarayanan et al. (2005) |
| | | <i>Dirinaria consimilis</i> ; <i>Evernia prunastri</i> ; <i>Hypotrachyna crenata</i> ; <i>Parmotrema</i> sp.; <i>P. tinctorum</i> ; <i>Ramalina pacifica</i> ; <i>Teloschistes flavicans</i> | Govinda Rajulu et al. (2020) |
| 117 | <i>Papulospora</i> sp. | <i>Heterodermia hypochraea</i> ; <i>Parmotrema reticulatum</i> | Suryanarayanan et al. (2005), Tripathi et al. (2014) |
| 118 | <i>Paraboeremia putaminum</i> (Speg.) Qian Chen & L. Cai (= <i>P. putaminum</i> Speg.) | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |
| 119 | <i>Paraphaeosphaeria michotii</i> (Westend) Eriksson | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 120 | <i>Penicillium</i> sp. (= <i>Torulomyces</i> sp.) | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| | | <i>Bulbothrix meizospora</i> ; <i>Parmotrema reticulatum</i> ; <i>Roccella montagnei</i> | Suryanarayanan et al. (2005) |
| | | <i>Leptogium askotense</i> ; <i>Lobaria kurokawae</i> ; <i>Ramalina conduplicans</i> ; <i>Usnea</i> sp. | Suryanarayanan et al. (2017) |
| | | <i>Pseudocyphellaria</i> sp. | Kannangara et al. (2008) |
| | | <i>Bulbothrix meizospora</i> ; <i>Canoparmelia texana</i> ; <i>Heterodermia podocarpa</i> ; <i>Leptogium askotense</i> ; <i>Lobaria kurokawae</i> ; <i>Parmotrema hababianum</i> ; <i>P. reticulatum</i> ; <i>Phaeophyscia hispidula</i> ; <i>Punctelia rudecta</i> | Tripathi et al. (2014) |
| | | <i>Parmelia</i> sp. | Padhi & Tayung (2015) |
| | | <i>Arthonia</i> sp.; <i>Bacidina</i> sp.; <i>Hypotrachyna crenata</i> ; <i>Parmotrema tinctorum</i> | Govinda Rajulu et al. (2020) |
| 121 | <i>P. aurantiogriseum</i> Dierckx (= <i>P. viridicatum</i> Westling) | <i>Xanthoparmelia taractica</i> ; <i>Peltigera praetextata</i> | Girlanda et al. (1997) |
| 122 | <i>P. canescens</i> Sopp (= <i>P. raciborskii</i> Zaleski) | <i>Xanthoparmelia taractica</i> ; <i>Peltigera praetextata</i> | Girlanda et al. (1997) |
| 123 | <i>P. chrysogenum</i> Thom | <i>Parmotrema reticulatum</i> ; <i>Polyblastidium dendriticum</i> ; <i>Usnea stigmatoides</i> | Vinayaka et al. (2016) |
| 124 | <i>P. citrinum</i> Thom | <i>Parmotrema</i> sp. | Samanthi et al. (2015b) |
| 125 | <i>P. griseofulvum</i> Dierckx | <i>Xanthoparmelia taractica</i> ; <i>Peltigera praetextata</i> | Girlanda et al. (1997) |
| 126 | <i>P. melinii</i> Thorn | <i>Xanthoparmelia taractica</i> ; <i>Peltigera praetextata</i> | Girlanda et al. (1997) |
| 127 | <i>P. purpurogenum</i> Stoll | <i>Xanthoparmelia taractica</i> ; <i>Peltigera praetextata</i> | Girlanda et al. (1997) |
| 128 | <i>P. glaucoalbidum</i> (Desm.) Houbraken & Samson (= <i>Thysanophora penicillioides</i> (Roum.) Kendrick) | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 129 | <i>Periconia</i> sp. | <i>Parmotrema</i> sp. | Kannangara et al. (2008) |
| | | <i>Heterodermia podocarpa</i> ; <i>Leptogium askotense</i> ; <i>Lobaria kurokawae</i> ; <i>Parmotrema hababianum</i> ; <i>P. tinctorum</i> ; <i>Phaeophyscia hispidula</i> ; <i>Punctelia rudecta</i> | Tripathi et al. (2014), Suryanarayanan et al. (2017) |
| | | <i>Parmelia</i> sp. | Wu et al. (2015) |
| 130 | <i>Pestalotiopsis</i> sp. | <i>Heterodermia flabellata</i> ; <i>Parmotrema thomsonii</i> | Suryanarayanan et al. (2005), Li et al. (2007), Tripathi et al. (2014) |
| | | <i>Multiclavula</i> sp. | Ding et al. (2009) |
| | | <i>Cetraria islandica</i> | Yuan et al. (2017) |
| | | <i>Bacidina</i> sp. | Govinda Rajulu et al. (2020) |
| 131 | <i>P. hypoderma</i> (Niessl) Steyaert | <i>Parmotrema reticulatum</i> ; <i>P. tinctorum</i> ; <i>Teloschistes flavicans</i> | Vinayaka et al. (2016) |
| 132 | <i>P. maculans</i> (Corda) Nag Raj | <i>Parmotrema reticulatum</i> | Suryanarayanan et al. (2005), Tripathi et al. (2014) |
| 133 | <i>Pezicula</i> (= <i>Cryptosporiopsis</i> sp.) | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |

Table 1 Continued.

| | Fungi | Host lichen | Reference |
|-----|---|--|------------------------------|
| 134 | <i>Phaeoramularia</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 135 | <i>Phaeosphaeria</i> sp. | <i>Heterodermia obscurata</i> | Li et al. (2012) |
| 136 | <i>Phialocephala fortinii</i> C.J.K. Wang & H.E. Wilcox | Unknown | Xie et al. (2016) |
| 137 | <i>Phialophora</i> sp. | <i>Roccella montagnei</i> | Suryanarayanan et al. (2005) |
| | | <i>Dermatocarpon miniatum</i> | Li et al. (2007) |
| | | <i>Cetrelia braunsiana</i> | He et al. (2012) |
| | | <i>Cladonia ochrochlora</i> | Ye et al. (2013) |
| | | <i>Parmotrema tinctorum</i> ; <i>Teloschistes flavicans</i> | Govinda Rajulu et al. (2020) |
| 138 | <i>P. asteris</i> (Dowson) Burge & I. Isaac (= <i>P. fastigiata</i> (Lagerb. et al) Conant) | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 139 | <i>P. verrucosa</i> Medlar | <i>Heterodermia incana</i> ; <i>Ramalina pacifica</i> ; <i>Usnea galbinifera</i> | Vinayaka et al. (2016) |
| 140 | <i>Phoma</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| | | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |
| | | <i>Punctelia borreri</i> | Li et al. (2007) |
| | | <i>Pseudocyphellaria</i> sp. | Kannangara et al. (2008) |
| | | <i>Heterodermia incana</i> ; <i>Parmotrema tinctorum</i> ; <i>Teloschistes flavicans</i> | Vinayaka et al. (2016) |
| | | Unknown | Kim et al. (2018a) |
| | | <i>Arthonia</i> sp. | Govinda Rajulu et al. (2020) |
| 141 | <i>P. leveillei</i> Boerema & G.J. Bollen | <i>Cladonia fruticulosa</i> ; <i>Parmotrema reticulatum</i> ; <i>Polyblastidium dendriticum</i> ; <i>Ramalina arabum</i> | Vinayaka et al. (2016) |
| 142 | <i>Plagiostoma</i> (= <i>Diplodina</i> sp.) | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 143 | <i>Preussia</i> sp. | <i>Opegrapha medusulina</i> | Maduranga et al. (2018) |
| 144 | <i>Preussia africana</i> Arenal, Platas & Pelàez | <i>Ramalina calicaris</i> | Zhang et al. (2012) |
| 145 | <i>P. tenerifae</i> (Arx & Guarro) Kruys | <i>Arthonia parantillarum</i> | Maduranga et al. (2018) |
| 146 | <i>Pseudeurotium</i> sp. | #Not specified – list of several lichens given | Zhang et al. (2016) |
| 147 | <i>Pseudogymnoascus</i> (Link) Minnis & D.L. Lindner (= <i>Geomyces pannorum</i> (Link) Sigler et Carmichael) | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| | | <i>Xanthoparmelia taractica</i> ; <i>Peltigera praetextata</i> | Girlanda et al. (1997) |
| 148 | <i>Purpureocillium lilacinum</i> (Thom) Luangsa-ard, Houbraken, Hywel-Jones & Samson (= <i>Paecilomyces lilacinus</i> (Thorn) Samson) | <i>Xanthoparmelia taractica</i> ; <i>Peltigera praetextata</i> | Girlanda et al. (1997) |
| 149 | <i>P. variotii</i> Bainier | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 150 | <i>Ramichloridium</i> cf. <i>apiculatum</i> (Miller et al.) De Hoog | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 151 | <i>Ramularia</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 152 | <i>Rigidoporus vinctus</i> (Berk.) Ryvarden | <i>Roccella montagnei</i> | Maduranga et al. (2018) |
| 153 | <i>Rhizoctonia</i> sp. | <i>Punctelia subrudecta</i> | Tripathi et al. (2014) |
| 154 | <i>R. solani</i> J.G. Kühn | <i>Heterodermia incana</i> ; <i>Parmotrema cristiferum</i> ; <i>Usnea stigmatoides</i> | Vinayaka et al. (2016) |
| 155 | <i>Rhizopus</i> sp. | <i>Roccella montagnei</i> | Suryanarayanan et al. (2005) |
| 156 | <i>Rhizosphaera kalkhoffii</i> Bubak | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 157 | <i>Schizophyllum commune</i> Fr. | <i>Opegrapha medusulina</i> ; Unidentified | Maduranga et al. (2018) |
| 158 | <i>Scopulariopsis</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |

Table 1 Continued.

| | Fungi | Host lichen | Reference |
|-----|---|---|--|
| | | <i>Cladonia coniocraea</i> ; <i>Dermatocarpon miniatum</i> ; <i>Melanelia sorediata</i> ; <i>Parmelia</i> sp.; <i>Punctelia borreri</i> ; <i>Zeroviella mandschurica</i> | Li et al. (2007) |
| 159 | <i>Scutula</i> sp. (= <i>Karsteniomyces</i> sp.) | <i>Xanthoparmelia taractica</i> ; <i>Peltigera praetextata</i> | Girlanda et al. (1997) |
| 160 | <i>Sordaria</i> sp. | <i>Heterodermia diademata</i> ; <i>H. podocarpa</i> ; <i>Leptogium askotense</i> ; <i>Lobaria kurokawae</i> ; <i>Parmotrema tinctorum</i> ; <i>Phaeophyscia hispidula</i> ; <i>Punctelia rudecta</i> ; <i>Usnea</i> sp. | Tripathi et al. (2014), Suryanarayanan et al. (2017) |
| | | Unidentified | Maduranga et al. (2018) |
| 161 | <i>S. fimicola</i> (Roberge ex Desm.) Ces. & De Not. | <i>Parmotrema reticulatum</i> | Tripathi et al. (2014), Suryanarayanan et al. (2005) |
| | | <i>Myelochroa</i> sp.; <i>Parmotrema</i> sp.; <i>Phaeophyscia</i> sp.; <i>Physcia</i> sp.; <i>Stereocaulon</i> sp. | Oh et al. (2020) |
| 162 | <i>Spegazzinia tessarthra</i> (Berk. & M.A. Curtis) Sacc. | <i>Heterodermia flabellata</i> | Suryanarayanan et al. (2005), Li et al. (2007), Tripathi et al. (2014) |
| 163 | <i>S. lobulata</i> Thower | <i>Punctelia rudecta</i> | Tripathi et al. (2014), Suryanarayanan et al. (2017) |
| 164 | <i>Spiniger</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 165 | <i>Sporormiella</i> sp. | <i>Zeroviella mandschurica</i> | Li et al. (2007) |
| 166 | <i>S. intermedia</i> (Auersw.) Ahmed & Cain | <i>Roccella montagnei</i> | Suryanarayanan et al. (2005) |
| | | <i>Arthonia</i> sp.; <i>Dirinaria consimilis</i> ; <i>Hypotrachyna crenata</i> ; <i>Parmotrema</i> sp.; <i>P. tinctorum</i> ; <i>Ramalina pacifica</i> ; <i>Teloschistes flavicans</i> | Govinda Rajulu et al. (2020) |
| 167 | <i>S. minima</i> (Auersw.) S.I. Ahmed & Cain | <i>Zeroviella mandschurica</i> | Li et al. (2007) |
| | | <i>Canoparmelia texana</i> ; <i>Heterodermia diademata</i> ; <i>H. podocarpa</i> ; <i>Lobaria kurokawae</i> ; <i>Parmotrema hababianum</i> ; <i>P. tinctorum</i> ; <i>Phaeophyscia hispidula</i> ; <i>Punctelia rudecta</i> ; <i>Ramalina conduplicans</i> ; <i>Usnea</i> sp. | Tripathi et al. (2014), Suryanarayanan et al. (2017) |
| 168 | <i>S. muskokensis</i> (Cain) S.I. Ahmed & Cain | <i>Zeroviella mandschurica</i> | Li et al. (2007) |
| 169 | <i>Sporothrix</i> sp. | <i>Dermatocarpon miniatum</i> ; <i>Parmelia</i> sp.; <i>Ramalina sinensis</i> | Li et al. (2007) |
| 170 | <i>Sydowia polyspora</i> (Bref. & Tavel) E. Müll. (= <i>Hormonema dematioides</i> Lagerberg et Melin) | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 171 | <i>Taeniolella</i> sp. | <i>Teloschistes flavicans</i> | Govinda Rajulu et al. (2020) |
| 172 | <i>Talaromyces</i> sp. | <i>Leptogium askotense</i> ; <i>Lobaria kurokawae</i> | Tripathi et al. (2014) |
| | | <i>Canoparmelia texana</i> ; <i>Heterodermia podocarpa</i> ; <i>Leptogium askotense</i> ; <i>Lobaria kurokawae</i> ; <i>Parmotrema hababianum</i> ; <i>Phaeophyscia hispidula</i> ; <i>Punctelia rudecta</i> | Suryanarayanan et al. (2017) |
| | | <i>Porina tetracerae</i> | Maduranga et al. (2018) |
| | | <i>Xanthoparmelia angustiphylla</i> | Yuan et al. (2018) |
| | | <i>Parmotrema tinctorum</i> ; <i>Ramalina pacifica</i> | Govinda Rajulu et al. (2020) |
| 173 | <i>T. funiculosus</i> (Thom.) Samson | <i>Diorygma hieroglyphicum</i> | Padhi et al. (2019) |
| 174 | <i>T. tratensis</i> Manoch, Dethoup & N. Yilmaz | <i>Lecanora</i> sp. | Jayakumar et al. (2016) |
| 175 | <i>T. verruculosus</i> (Peryonel) Samson, N. Yilmaz, Frisvad & Seifert (= <i>Penicillium</i> <i>verruculosum</i> Peyronel) | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |

Table 1 Continued.

| | Fungi | Host lichen | Reference |
|-----|---|--|---|
| 176 | <i>Teichospora striata</i> (Kohlm. & Volkm. -Kohlm.) Jaklitsch & Voglmayr (= <i>Floricola striata</i> Kohlm. & Volkm.-Kohlm.) | <i>Umbilicaria</i> sp. | Li et al. (2016) |
| 177 | <i>Thielavia</i> sp. | <i>Melanelia sorediata</i> ; <i>Parmelia</i> sp.; <i>Punctelia borreri</i> <i>Dermatocarpon miniatum</i> ; <i>Melanelia sorediata</i> | Li et al. (2007) Vinayaka et al. (2016) |
| 178 | <i>Tolypocladium</i> sp. (= <i>Chaunopycnis</i> sp.) | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> <i>Parmelia</i> sp. <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Girlanda et al. (1997) Hu et al. (2017) Petrini et al. (1990) |
| 179 | <i>T. cylindrosporum</i> W. Gams | <i>Lethariella zahlbruckneri</i> | Li et al. (2015b) |
| 180 | <i>T. geodes</i> W. Gams | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |
| 181 | <i>T. inflatum</i> W. Gams (= <i>T. niveum</i> (Rostr.) Bissett) | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |
| 182 | <i>Torula</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 183 | <i>Tremella</i> sp. | #Not specified – list of several lichens given | Zhang et al. (2016) |
| 184 | <i>Trichobotrys</i> sp. | | Li et al. (2007) |
| 185 | <i>Trichoderma</i> sp. | <i>Roccella montagnei</i> <i>Cladonia coniocraea</i> ; <i>Melanelia sorediata</i> ; <i>Punctelia borreri</i> <i>Phaeophyscia hispidula</i> ; <i>Punctelia rudecta</i> <i>Pamelia</i> sp. | Suryanarayanan et al. (2005) Li et al. (2007) Tripathi et al. (2014) Padhi & Tayung (2015) |
| 186 | <i>T. hamatum</i> (Bon.) Bain. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 187 | <i>T. harzianum</i> Rifai | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp.; <i>Xanthoparmelia taractica</i> <i>Peltigera praetextata</i> <i>Heterodermia flabellata</i> ; <i>Parmotrema crinitum</i> ; <i>P. thomsonii</i> ; <i>Physcia dilatata</i> <i>Heterodermia flabellata</i> ; <i>Parmotrema crinitum</i> ; <i>P. thomsonii</i> ; <i>Physcia dilatata</i> <i>Heterodermia flabellata</i> ; <i>Parmotrema crinitum</i> ; <i>P. thomsonii</i> ; <i>Physcia dilatata</i> ; <i>Usnea</i> sp. | Petrini et al. (1990) Girlanda et al. (1997) Suryanarayanan et al. (2005) Li et al. (2007) Tripathi et al. (2014) |
| 188 | <i>T. koningii</i> Oud. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 189 | <i>T. polysporum</i> (Link ex Pers.) Rifai | <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> | Girlanda et al. (1997) |
| 190 | <i>T. viride</i> Pers. ex S. F. Gray | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. <i>Peltigera praetextata</i> ; <i>Xanthoparmelia taractica</i> <i>Cladonia fruticulosa</i> ; <i>Parmotrema tinctorum</i> ; <i>Ramalina arabum</i> ; <i>Usnea stigmatoides</i> | Petrini et al. (1990) Girlanda et al. (1997) Vinayaka et al. (2016) |
| 191 | <i>Trichophyton roseum</i> E. Bodin | <i>Parmotrema graynum</i> | Tripathi et al. (2014) |
| 192 | <i>Umbelopsis vinacea</i> (Dixon-Stew.) Arx (= <i>Mortierella vinacea</i> Dixon-Stewart) | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 193 | <i>Verticillium</i> sp. | <i>Cladonia</i> sp.; <i>Stereocaulon</i> sp. | Petrini et al. (1990) |
| 194 | <i>Xylaria</i> sp. | <i>Leptogium saturninum</i> <i>Canoparmelia texana</i> ; <i>Heterodermia diademata</i> ; <i>H. podocarpa</i> ; <i>Leptogium askotense</i> ; <i>Lobaria kurokawae</i> ; <i>Parmotrema hababianum</i> ; <i>P. tinctorum</i> ; <i>Phaeophyscia hispidula</i> ; <i>Punctelia rudecta</i> ; <i>Ramalina conduplicans</i> ; <i>Usnea</i> sp. <i>Opegrapha medusulina</i> | Wu et al. (2011) Tripathi et al. (2014), Suryanarayanan et al. (2017) Maduranga et al. (2018) |
| 195 | <i>X. apiculata</i> Cooke | <i>Arthonia</i> sp. | Govinda Rajulu et al. (2020) |
| 196 | <i>X. arbuscula</i> Sacc. | <i>Lobaria discolor</i> ; <i>L. japonica</i> | Oh et al. (2020) |
| 197 | <i>X. castorea</i> Berk. | <i>Roccella montagnei</i> | Maduranga et al. (2018) |
| 198 | <i>X. feejeensis</i> (Berk.) Fr. | <i>Opegrapha medusulina</i> | Maduranga et al. (2018) |
| 199 | <i>X. grammica</i> (Mont.) Mont. | <i>Menegazzia</i> sp. | Kim et al. (2018b) |

Table 1 Continued.

| | Fungi | Host lichen | Reference |
|-----|--|--|---|
| 200 | <i>X. hypoxylon</i> (L.) Grev. | <i>Parmotrema reticulatum</i> | Suryanarayanan et al. (2005), Tripathi et al. (2014) |
| 201 | <i>X. primorskensis</i> Y.M. Ju, H.M. Hsieh, Lar. N. Vassiljeva & Akulov | <i>Hypotrachyna crenata</i> ; <i>Parmotrema</i> sp.; <i>Ramalina pacifica</i> ; <i>Usnea</i> sp. | Govinda Rajulu et al. (2020) |
| 202 | <i>X. psidii</i> J.D. Rogers & Hemmes | <i>Amandinea</i> sp. | Maduranga et al. (2018) |
| 203 | <i>X. vaporaria</i> Berk. | <i>Parmotrema cristiferum</i> ; <i>Ramalina arabum</i> ; <i>R. pacifica</i> | Vinayaka et al. (2016) |
| 204 | <i>Zygosporium</i> sp. | <i>Parmotrema tinctorum</i> | Govinda Rajulu et al. (2020) |

Note: #List of 17 species utilized by Zhang et al. (2016) for isolation of ELF. *Acarospora molybdina* (Ach.) Trevis., *Allantoparmelia alpicola* (Th. Fr.) Essl., *Cetraria delisei* (Bory ex Schaer.) Nyl. (= *Cetrariella delisei* (Bory ex Schaer.) Kärnefelt & A. Thell), *Cladonia arbuscula* (Wallr.) Flot., *C. borealis* S. Stenroos, *C. pocillum* (Ach.) O.J. Rich., *Nephromopsis nivalis* (L.) Divakar, A. Crespo & Lumbsch (= *Flavocetraria nivalis* (L.) Kärnefelt & A. Thell), *Ochrolechia frigida* (Sw.) Lyngé, *Peltigera canina* (L.) Willd., *Placynthium asperellum* (Ach.) Trevis., *Pseudephebe pubescens* (L.) M. Choisy, *Stereocaulon alpinum* Laurer, *S. botryosum* Ach., *S. vesuvianum* Pers., *Umbilicaria aprina* Nyl., *U. arctica* (Ach.) Nyl., *U. torrefacta* (Lightf.) Schrad. *status of the species is unconfirmed under the genus.

The ELFs identified till date belongs to three phyla, 32 orders, 70 families and 112 genera (Table 2, according to Wijayawardene et al. 2020). Majority of them belong to Ascomycota, followed by Basidiomycota, and very few belong to Mucoromycota. Within the Ascomycota, the classes Dothideomycetes and Sordariomycetes represent the largest number of ELFs reported so far. *Alternaria*, *Aspergillus*, *Chaetomium*, *Cladosporium*, *Curvularia*, *Fusarium*, *Penicillium*, *Trichoderma*, and *Xylaria* are some of the most common genera. *Alternaria alternata*, *Aspergillus flavus*, *A. niger*, *Neocosmospora solani*, and *Trichoderma harzianum* are the most frequently occurring ELF species.

Table 2 Classification of endolichenic fungi (sensu Wijayawardene et al. 2020)

| Phylum | Class | Order | Family | Genus | | |
|---------------|--------------------|---------------------------------------|---|--|---|--------------------------|
| Ascomycota | Dothideomycetes | Botryosphaeriales | Botryosphaeriaceae | <i>Endomelanconiopsis</i> ; <i>Lasiodiplodia</i> | | |
| | | Capnodiales | Cladosporiaceae | <i>Cladosporium</i> | | |
| | | | Dissoconiaceae | <i>Ramichloridium</i> | | |
| | | | Mycosphaerellaceae | <i>Phaeoramularia</i> ; <i>Ramularia</i> | | |
| | | | Dothideales | Dothideaceae | <i>Sydowia</i> | |
| | | Dothideomycetes genera incertae sedis | Dothideales | Sacotheciaceae | <i>Aureobasidium</i> | |
| | | | | Dothideales genus incertae sedis | <i>Rhizosphaera</i> | |
| | | | Kirschsteinietheliales genus incertae sedis | Pleosporales | Biatriosporaceae | <i>Biatriospora</i> |
| | | | | | Coniothyriaceae | <i>Ochrocladosporium</i> |
| | | | Eurotiomycetes | Chaetothyriales | Corynesporascaceae | <i>Corynespora</i> |
| | Didymellaceae | | | | <i>Ascochyta</i> ; <i>Epicoccum</i> ; <i>Paraboeremia</i> ; <i>Phoma</i> | |
| | Didymosphaeriaceae | | | | <i>Paraphaeosphaeria</i> ; <i>Spegazzinia</i> | |
| | Periconiaceae | | | | <i>Periconia</i> | |
| | Pleosporaceae | | | | <i>Alternaria</i> ; <i>Curvularia</i> | |
| | Phaeosphaeriaceae | | | | <i>Ophiosphaerella</i> ; <i>Phaeosphaeria</i> | |
| | Sporormiaceae | <i>Preussia</i> ; <i>Sporormiella</i> | | | | |
| | Teichosporaceae | <i>Teichospora</i> | | | | |
| | | | Torulaceae | <i>Torula</i> | | |
| | | | | <i>Bahusakala</i> ; <i>Heteroconium</i> | | |
| | | | | <i>Cladophialophora</i> ; <i>Exophiala</i> ; <i>Phialophora</i> | | |
| | | | <i>Aspergillus</i> ; <i>Penicillium</i> | | | |
| | | | <i>Paecilomyces</i> | | | |

Table 2 Continued.

| Phylum | Class | Order | Family | Genus |
|---|--|--|----------------------------|--|
| | | | Trichocomaceae | <i>Talaromyces</i> ; <i>Thysanophora</i> ; <i>Byssoschlamys</i> |
| | | Onygenales | Arthrodermataceae | <i>Trichophyton</i> |
| | | | Onygenaceae | <i>Chrysosporium</i> |
| | Lecanoromycetes | Lecanorales | Ramalinaceae | <i>Scutula</i> |
| | Leotiomycetes | Chaetomellales | Chaetomellaceae | <i>Chaetomella</i> |
| | | Helotiales | Amorphothecaceae | <i>Myxotrichum</i> |
| | | | Dermateaceae | <i>Pezicula</i> |
| | | | Mollisiaceae | <i>Phialocephala</i> |
| | | | Myxotrichaceae | <i>Oidiodendron</i> |
| | | | Ploettnerulaceae | <i>Cadophora</i> ; <i>Cylindrosporium</i> |
| | | | Sclerotiniaceae | <i>Botrytis</i> ; <i>Monilinia</i> |
| | | Helotiales <i>genus incertae sedis</i> | | <i>Cryptocline</i> |
| | | Thelebolales | Pseudeurotiaceae | <i>Pseudeurotium</i> ; <i>Pseudogymnoascus</i> |
| | Leotiomycetes <i>family and genus incertae sedis</i> | | Hamatocanthoscypha ceae | <i>Chalara</i> |
| | Pezizomycetes | Pezizales | Tarzettaceae | <i>Geopyxis</i> |
| | Saccharomycetes | Saccharomycetales | Dipodascaceae | <i>Geotrichum</i> |
| | Sordariomycetes | Amphisphaeriales | Apiosporaceae | <i>Arthrinium</i> ; <i>Nigrospora</i> |
| | | | Sporocadaceae | <i>Broomella</i> ; <i>Pestalotiopsis</i> |
| | | Coniochaetales | Coniochaetaceae | <i>Coniochaeta</i> |
| | | Diaporthales | Cytosporaceae | <i>Cytospora</i> |
| | | | Diaporthaceae | <i>Diaportha</i> |
| | | | Gnomoniaceae | <i>Plagiostoma</i> |
| | | Glomerellales | Glomerellaceae | <i>Colletotrichum</i> |
| | | | Plectosphaerellaceae | <i>Verticillium</i> |
| | | Hypocreales | Bionectriaceae | <i>Acremonium</i> ; <i>Cylindromonium</i> |
| | | | Cordycipitaceae | <i>Cordyceps</i> |
| | | | Hypocreaceae | <i>Trichoderma</i> |
| | | | Nectriaceae | <i>Aphanocladium</i> ; <i>Calonectria</i> ; <i>Cosmospora</i> ; <i>Fusarium</i> ; <i>Neocosmospora</i> ; <i>Neonectria</i> |
| | | | Ophiocordycipitaceae | <i>Purpureocillium</i> ; <i>Tolypocladium</i> |
| | | | Stachybotryaceae | <i>Myrothecium</i> |
| | | Microascales | Ceratocystidaceae | <i>Berkeleyomyces</i> |
| | | | Microascaceae | <i>Scopulariopsis</i> |
| | | Ophiostomatales | Ophiostomataceae | <i>Sporothrix</i> |
| | | Sordariales | Chaetomiaceae | <i>Chaetomium</i> ; <i>Humicola</i> ; <i>Thielavia</i> |
| | | | Lasiochaetiaceae | <i>Apiosordaria</i> |
| | | | Sordariaceae | <i>Neurospora</i> ; <i>Sordaria</i> |
| | | Xylariales | Graphostromataceae | <i>Biscogniauxia</i> |
| | | | Hypoxylaceae | <i>Daldinia</i> ; <i>Hypoxylon</i> |
| | | | Xylariaceae | <i>Nemania</i> ; <i>Xylaria</i> |
| | | | Zygosporiaceae | <i>Zygosporium</i> |
| | Sordariomycetes <i>genus incertae sedis</i> (?) | | | <i>Papulospora</i> |
| Ascomycota <i>genera incertae sedis</i> | | | | <i>Bispora</i> ; <i>Gilmaniella</i> ; <i>Trichobotrys</i> |
| Basidiomycota | Agaricomycetes | Cantharellales | Ceratobasidiaceae | <i>Rhizoctonia</i> |
| | | Agaricales | Schizophyllaceae | <i>Schizophyllum</i> |
| | Bartheletiomycetes | Russulales | Bondarzewiaceae | <i>Heterobasidium</i> ; <i>Spiniger</i> |
| | Cystobasidiomycetes | Cystobasidiales | Cystobasidiaceae | <i>Cystobasidium</i> |
| | Tremellomycetes | Tremellales | Tremellaceae | <i>Tremella</i> |
| | | Trichosporonales | Trichosporonaceae | <i>Apiotrichum</i> |
| | | Polyporales | Polyporaceae | <i>Cerrena</i> |
| | | | Meripilaceae | <i>Rigidoporus</i> |
| Mucoromycota | Mucoromycetes | Mucorales | Mucoraceae | <i>Mucor</i> |
| | | | Rhizopodaceae | <i>Rhizopus</i> |
| | Umbelopsidomycetes | Umbelopsidales | Umbelopsidaceae | <i>Umbelopsis</i> |

ELF host diversity and ecology

The ELFs are not host-specific and behave as generalists (Chagnon et al. 2016). Studies have shown that certain endolichenic fungal species are widespread and occur in different lichen species (Tripathi et al. 2014). The ELF communities, their incidence, diversity, and composition reflect the interplay of climatic patterns, geographic separation, host type, and host lineage (U'Ren et al. 2012). Their composition depends on the environment of the lichens and the chemical ambience of the thalli (Arnold & Herre 2003, Suryanarayanan & Thennarasan 2004). In addition, the altitude and the geographical location also affect the ELF composition as disclosed by 18S rDNA sequencing study (Wang et al. 2016). The compilation of ELF studies carried out to date shows that a total of 114 species of lichens belonging to 22 families were explored for ELFs (see name list). In few cases, the host species are partially identified (Petrini et al. 1990, Kannangara et al. 2008, Chen et al. 2014, 2019, Samanthi et al. 2015a, Wang et al. 2017, Govinda Rajulu et al. 2020) or unidentified (Wang et al. 2012, Kim et al. 2014, 2018a, b, Li et al. 2015a, Xie et al. 2016, Li et al. 2018). The present study shows that only a fraction of the 20000 species of lichens (Lücking et al. 2017) have been explored for their ELF. A majority of the host lichens studied for their ELF belong to the macro lichens (foliose and fruticose), probably because they are easy to handle and identify. Among them, members of families Parmeliaceae, Physciaceae, Peltigeraceae and Cladoniaceae have been studied more intensely. Also, species of *Parmotrema* were most preferred for isolation of ELF (Name list. Lichen hosts of endolichenic fungi).

It is clear from the species diversity of ELF that most of the taxa (*Alternaria*, *Aspergillus*, *Chaetomium*, *Cladosporium*, *Curvularia*, *Fusarium*, *Penicillium*, *Trichoderma*, and *Xylaria*) are generalists that occur as saprotrophs (Arnold 2009). Their invasion into lichen thallus and association with the photobiont of the lichen suggests that they form an opportunistic interaction. It is speculated that the high level of fungal diversity may be due to highly porous and heterogeneous nature of the lichen thalli (Stone et al. 2012). Petrini et al. (1990) categorized ELFs into three ecological groups, of which the first one comprised of the species known as soil and litter inhabitants. Several of these belonged to genera frequently identified as plant pathogens or plant symbionts. The other groups reported as epiphytes or pathogens of higher plants (Dettki 1998, Arnold 2003). Several examples can be cited to show ELFs are not specific to lichens. *Alternaria alternata* isolated from a large number of lichens found in angiosperm *Hedychium spicatum* Ham ex Sm. (Sarma et al. 2020) and gymnosperm *Pinus tabulaeformis* Carr. (Guo et al. 2004). *Cladosporium cladosporioides* is also isolated from the leaves of medicinally important pteridophyte *Huperzia serrata* (Thunb. ex Murray) Trev. (Zhang et al. 2011).

Name list. Lichen hosts of endolichenic fungi

Acarosporaceae

Acarospora molybdina (Ach.) Trevis.

Arthoniaceae

Arthonia sp.

Arthonia antillarum (Fée) Nyl.

Arthonia parantillarum Aptroot

Caliciaceae

Dirinaria consimilis (Stirt.) D.D. Awasthi

Cladoniaceae

Cladonia sp.

C. arbuscula (Wallr.) Flot.

C. borealis S. Stenroos

C. grisea (Ahti) Trass

C. coniocraea (Flörke) Spreng.

C. evansii Abbayes

C. fruticulosa Kremp.

C. ochrochlora Flörke
C. pocillum (Ach.) O.J. Rich.
Stereocaulon sp.
Stereocaulon alpinum Laurer
S. botryosum Ach.
S. vesuvianum Pers.

Collemataceae

Leptogium askotense D.D. Awasthi
L. burnetiae Dodge
L. saturninum (Dicks.) Nyl.

Graphidaceae

Diorygma hieroglyphicum (Pers.) Staiger & Kalb

Hydnaceae

Multiclavula sp.

Lecanoraceae

Lecanora sp.

Lobariaceae

Lobaria discolor (Bory) Hue
Lobaria japonica (Zahlbr.) Asahina

Ochrolechiaceae

Ochrolechia frigida (Sw.) Lynge

Parmeliaceae

Allantoparmelia alpicola (Th. Fr.) Essl.
Bulbothrix meizospora (Nyl.) Hale
Canoparmelia texana (Tuck.) Elix & Hale
Cetraria islandica (L.) Ach.
Cetraria delisei (Bory ex Schaer.) Nyl.
Cetrelia sp.
C. braunsiana (Müll. Arg.) W.L. Culb. & C.F. Culb.
Evernia prunastri (L.) Ach.
Flavoparmelia caperata (L.) Hale
Hypotrachyna cirrhata (Fr.) Divakar et al.
H. crenata (Kurok.) Hale
H. nepalensis (Taylor) Divakar et al.
Lethariella zahlbruckneri (Du Rietz) Krog.
Melanelia sorediata (Ach.) Goward & Ahti
Menegazzia sp.
Nephromopsis nivalis (L.) Divakar et al.
Parmelia sp.
Parmelinella wallichiana (Taylor) Elix & Hale
Parmotrema sp.
P. austrosinense (Zahlbr.) Hale
P. cristiferum (Taylor) Hale
P. critinum (Ach.) Choisy
P. graynum (Hue) Hale
P. hababianum (Gyeln.) Hale
P. nilgherrense (Nyl.) Hale
P. praesorediosum (Ny) Hale
P. ravum (Krog Swinscow) Sérus.
P. reticulatum (Taylor) Choisy
P. thomsonii (Stirt.) A. Crespo, Divakar & Elix
P. tinctorum (Despr. ex Nyl.) Hale

Pseudevernia intensa (Nyl.) Hale & W.L. Culb.
Pseudephebe pubescens (L.) M. Choisy
Punctelia borreri (Turner) Krog
P. rudecta (Ach.) Krog.
P. subrudecta (Nyl.) Krog
Usnea sp.
U. aciculifera Vain.
U. cavernosa Tuck.
U. galbinifera Asahina
U. longissima Ach.
U. stigmatoides G. Awasthi
Xanthoparmelia angustiphylla (Gyelnik) Hale.
X. taractica (Kremp.) Hale

Peltigeraceae

Lobaria kurokawae Yoshim.
L. retigera (Bory) Trevis.
Peltigera canina (L.) Willd.
P. elisabethae var. *mauritzii* (Gyeln.) J.C. Wei
P. praetextata (Flörke ex Sommerf.) Zopf
Pseudocyphellaria sp.
Ricasolia quercizans (Michx.) Stizenb.

Pertusariaceae

Pertusaria laeviganda Nyl.

Physciaceae

Amandinea sp.
Dirinaria picta (Sw.) Clem. & Shear
Heterodermia diademata (Taylor) D.D. Awasthi
H. flabellata (Fée) D.D. Awasthi
H. hypochraea (Vain.) Swinsc & Krog
H. incana (Stirt.) D.D. Awasthi
H. obscurata (Nyl.) Trevis.
H. podocarpa (Bél) D.D. Awasthi
Phaeophyscia hispidula (Ach.) Moberg
Physcia sp.
P. dilatata Nyl.
Polyblastidium dendriticum (Pers.) Kalb
Pyxine cocoes (Sw.) Nyl.

Placynthiaceae

Placynthium asperellum (Ach.) Trevis.

Porinaceae

Porina tetracerae (Ach.) Müll. Arg.

Pyrenulaceae

Pyrenula sp.
P. ochraceoflava (Nyl.) R.C. Harris
P. parvinuclea (Meyen & Flot.) Aptroot

Ramalinaceae

Bacidina sp.
Ramalina sp.
R. arabum (Dill. ex Ach.) Meyen & Flot.
R. calicaris (L.) Röhl.
R. conduplicans Vain.
R. pacifica Asahina

R. sinensis Jatta

Roccellaceae

Opegrapha arabica (Müll. Arg.) Vain.

O. medusulina Nyl.

Roccella montagnei Bél.

Teloschistaceae

Teloschistes flavicans (Sw.) Norman

Zeroviella mandschurica (Zahlbr.) S.Y. Kondr. & Hur

Umbilicariaceae

Umbilicaria sp.

U. aprina Nyl.

U. arctica (Ach.) Nyl.

U. torrefacta (Lightf.) Schrad.

Verrucariaceae

Dermatocarpon miniatum (L.) W. Mann.

Conclusion

Lichens establish successful symbiotic associations for over 600 million years (Yuan et al. 2005). However, the origin and evolution of ELF is not well-understood as lichens, and their components do not preserve well as fossils. Some of the fossil lichen thalli obtained from the Lower Devonian period showed evidence of endolichenic fungal association, which suggests that ELF association existed since 415 million years ago. Such a long association of these fungi with lichens indicate that they have evolved a successful strategy for survival within the lichen thallus (Honegger et al. 2013). Apart from being poorly understood for their diversity and ecology, the ELFs are still unexplored treasures for biomolecules which could lead to the development of novel drugs. More studies are needed with culture-dependent and culture-independent approaches to estimate the true diversity of ELFs. Furthermore, lichens in different environments must be explored to understand their distribution patterns, the influence by abiotic and biotic factors, and host recurrence of ELFs. The estimated diversity of ELFs is undocumented while many sequences deposited in GenBank typically provide limited taxonomic details. Furthermore, the interaction of ELF with the host lichenized fungi as well as with the co-occurring symbionts needs to be studied using modern techniques such as isotopologue profiling. This result will be useful to understand the cross-relationship between the different constituencies of the microbiome of lichens (Götz et al. 2010). The culture-independent techniques and high-throughput sequencing methods are helpful in taxonomic placement, understanding ecological role and evolutionary details of endophytes.

Acknowledgments

We are thankful to Director, CSIR-NBRI, Lucknow for providing laboratory facilities and partial financial support under project OLP101 and to Council of Scientific and Industrial Research, New Delhi, for financial support under JRF/SRF Fellowship. (CSIR-NBRI manuscript number CSIR-NBRI_MS/2020/08/02).

References

- Arnold AE, Mejía LC, Kyllö D, Rojas EI et al. 2003 – Fungal endophytes limit pathogen damage in a tropical tree. *Proceedings of the National Academy Science* 100, 15649–15654.
- Arnold AE, Miadlikowska J, Higgins KL. 2009 – Aphylogenetic estimation of trophic transition networks for ascomycetous Fungi: Are lichens cradles of symbiotrophic Fungal diversification? *Syst Biol* 58(3), 283–297.
- Basnet BB, Chen B, Suleimen YM, Ma K et al. 2019a – Cytotoxic secondary metabolites from the endolichenic fungus *Hypoxylon fuscum*. *Planta Medica* 85 (13), 1088–1097.

- Basnet BB, Liu L, Chen B, Suleimen YM et al. 2019b – Four new cytotoxic arborinane-type triterpenes from the endolichenic fungus *Myrothecium inundatum*. *Planta Medica* 85 (09/10), 701–707.
- Chagnon P, U'Ren JM, Miadlikowska J, Lutzoni F et al. 2016 – Interaction type influences ecological network structure more than local abiotic conditions: evidence from endophytic and endolichenic fungi at a continental scale. *Oecologia* 180, 181–191.
- Chen GD, Chen Y, Gao H, Shen LQ et al. 2013 – Xanthoquinodins from the endolichenic fungal strain *Chaetomium elatum*. *Journal of Natural Products* 76, 702–709.
- Chen GD, Bao YR, Huang YF, Hu D et al. 2014 – Three pairs of variecolortide enantiomers from *Eurotium* sp. with caspase-3 inhibitory activity. *Fitoterapia* 92, 252–259.
- Chen M, Wang R, Zhao W, Yu L et al. 2019 – Isocoumarindole A, a chlorinated isocoumarin and indole alkaloid hybrid metabolite from an endolichenic fungus *Aspergillus* sp. *Organic Letters* 21(5), 1530–1533.
- Dettki H, Esseen PA. 1998 – Epiphytic macrolichens in managed and natural forest landscapes: a comparison at two spatial scales. *Ecography* 21, 613–624
- Ding G, Li Y, Fu S, Liu S et al. 2009 – Ambuic acid and torreyanic acid derivatives from Endolichenic fungus *Pestalotiopsis* sp. *Journal of Natural Products* 72, 182–186.
- Duo Y, Wang X, Jiang D, Wang H et al. 2014 – Metabolites from *Aspergillus versicolor*, an endolichenic fungus from the lichen *Lobaria retigera*. *Drug discoveries & Therapeutics* 8, 84–88.
- Girlanda M, Isocrono D, Bianco C, Luppi-Mosca AM. 1997 – Two foliose lichens as microfungal ecological niches. *Mycologia* 89, 531–536.
- Götz A, Eylert E, Eisenreich W, Goebel W. 2010 – Carbon metabolism of enterobacterial humn pathogens growing in epithelial colorectal adeno carcinoma (Caco-2) cells. *PloS ONE*. 5: e10586
- Govinda Rajulu MB, Thirunavukkarasu N, Kumar SS, Kaur T et al. 2020 – Endolichenic fungal diversity associated with some lichens of Western Ghats. *Plant Medica* 86, 960–966.
- Guo LD, Xu L, Zheng WH, Hyde KD. 2004 – Genetic variation of *Alternaria alternata*, an endophytic fungus isolated from *Pinus tabulaeformis* as determined by random amplified microsatellites (RAMS). *Fungal Diversity* 16, 53–65.
- Hawksworth DL, Grube M. 2020 – Lichens redefined as complex ecosystems. *New Phytologist*. Doi 10.1111/nph.16630
- He JW, Chen GD, Gao H, Yang F et al. 2012 – Heptaketides with antiviral activity from three endolichenic fungal strains *Nigrospora* sp. *Alternaria* sp. and *Phialophora* sp. *Fototerapia* 83, 1087–1091.
- Honegger R. 1991 – Fungal evolution: symbiosis and morphogenesis. In *Symbiosis as a Source of Evolutionary Innovation*. Margulis, L., and Fester, R. (eds). Cambridge, MA, USA. The MIT Press 319–340.
- Honegger R, Axe L, Edwards D. 2013 – Bacterial epibionts and endolichenic actinobacteria and fungi in the lower Devonian lichen *Chlorolichenomycites salopensis*. *Fungal Biol* 117, 512–518.
- Hu CH, Zhou YH, Xie F, Li YL et al. 2017 – Two new α -pyrone derivatives from an endolichenic fungus *Tolypocladium* sp. *Journal of Asian Natural Products Research* 19, 786–792.
- Jayakumar K, Prasad BG, Charan TP, Swarana KG et al. 2016 – Biomedical potential of *Talaromyces tratensis* – A New endolichenic fungi associated with high altitude crustose lichen *Lecanora* sp. *Research J. Pharma. Biol. Chem. Sci* 7(5), 1412–1419.
- Kannangara BTSDP, Rajapaksha RSCG, Paranagama PA. 2008 – Nature and bioactivities of endolichenic fungi in *Pseudocyphellaria* sp., *Parmotrema* sp. and *Usnea* sp. at Hakgala montane forest in Sri Lanka. *Letters in applied microbiology* 10(7), 3412–3420.
- Kellogg JJ, Raja HA. 2016 – Endolichenic fungi: a new source of rich bioactive secondary metabolites on the horizon. *Phytochemistry Reviews* 16(2), 271–293.

- Kim KH, Beemelmanns C, Murillo C, Guillen A et al. 2014 – Naphthalenones and isocoumarins from a costarican fungus Xylariaceae sp. CR1546C. *The Journal of Chemical Research* 38, 722–725.
- Kim JW, Ko W, Kim E, Kim GS et al. 2018a – Anti-inflammatory phomalichenones from an endolichenic fungus *Phoma* sp. *The Journal of Antibiotics* 71, 753–756.
- Kim TY, Jang NH, Chi WJ, Bae CH et al. 2018b – Nematicidal activity of grammicin produced by *Xylaria grammica* kctc 13121BP against *Meloidogyne incognita*. *Pest Management Science* 74, 384–391.
- Li WC, Zhou J, Guo SY, Guo LD. 2007 – Endophytic fungi associated with lichens in Baihua Mountain of Beijing, China. *Fungal Divers* 25, 69–80.
- Li G, Wang H, Zhu R, Sun L et al. 2012 – Phaerosphaerins A-F, cytotoxic perylenequinones from an endolichenic fungus *Phaeosphaeria* sp. *Journal of Natural Products* 75, 142–147.
- Li XB, Zhou YH, Zhu RX, Chang WQ et al. 2015a – Identification and biological evaluation of secondary metabolites from the endolichenic fungus *Aspergillus versicolor*. *Chemistry & Biodiversity* 12, 575–592.
- Li XB, Li L, Zhu RX, Li W et al. 2015b – Tetramic acids and pyridine alkaloids from the endolichenic fungus *Tolypocladium cylindrosporum*. *Journal of Natural Products* 78, 2155–2160.
- Li W, Gao W, Zhang M, Li YL et al. 2016 – p-Terphenyl derivatives from the endolichenic fungus *Floricola striata*. *Journal of Natural Products* 79, 2188–2194.
- Li Y, Zhu R, Zhang J, Xie F et al. 2018 – Ophiosphaerellins A–I, polyketide-derived compounds from the endolichenic fungus *Ophiosphaerella korrae* ACS Omega 3, 176–180.
- Li YL, Zhu RX, Li G, Wang NN et al. 2019 – Secondary metabolites from the endolichenic fungus *Ophiosphaerella korrae*. *RSC Advances* 9, 4140–4149.
- Lücking R, Hodkinson BP, Leavitt SD. 2017 – The 2016 classification of lichenized fungi in the Ascomycota and Basidiomycota – approaching one thousand genera. *Bryologist* 119, 361–416.
- Maduranga K, Attanayake RN, Santhirasegaram S, Weerakoon G et al. 2018 – Molecular phylogeny and bioprospecting of Endolichenic Fungi (ELF) inhabiting in the lichens collected from a mangrove ecosystem in Sri Lanka. *PLoS ONE* 13(8), e0200711.
- Mark K, Laanisto L, Bueno CG, Niinemets Ü et al. 2020 – Contrasting co-occurrence patterns of photobiont and cystobasidiomycete yeast associated with common epiphytic lichen species. *New Phytologist* 227(5), 1362–1375.
- Miadlikowska J, Arnold AE, Lutzoni F. 2004 – Diversity of cryptic fungi inhabiting healthy lichen thalli in a temperate and tropical forest. *Ecol. Soc.* 89, 349–350.
- Oh SY, Yang JH, Woo JJ, Oh SO et al. 2020 – Diversity and distribution patterns of Endolichenic Fungi in Jeju Island, South Korea. *Sustainability* 12, 3769.
- Padhi S, Tayung K. 2015 – *In vitro* antimicrobial potentials of endolichenic fungi isolated from thalli of *Parmelia* lichen against some human pathogens. *Beni-Suef University Journal of Basic and Applied Sciences* 4(4), 299–306.
- Padhi S, Das D, Panja S, Tayung K. 2016 – Molecular characterization and antimicrobial activity of endolichenic fungus *Aspergillus* sp. isolated from *Parmelia caperata* of Similipal Biosphere Reserve, India. *Interdiscip. Sci.* 9(2), 237–246.
- Padhi S, Masi M, Cimmino A, Tuzi A et al. 2019 – Funiculosone, a substituted dihydroxanthene-1,9-dione with two of its analogues produced by an endolichenic fungus *Talaromyces funiculosus* and their antimicrobial activity. *Phytochemistry* 157, 175–183.
- Paranagama PA, Wijeratne EMK, Burns AM, Marron MT et al. 2007 – Heptaketides from *Corynespora* sp. inhabiting the cavern beard lichen, *Usnea cavernosa*: first report of metabolites of an endolichenic fungus. *J Nat Prod* 70, 1700–1705.
- Petrini O, Hake U, Dreyfuss MM. 1990 – An analysis of fungal communities isolated from fruticose lichens. *Mycologia* 82, 444–451.

- Prateeksha, Bajpai R, Yusuf MA, Upreti DK et al. 2020 – Endolichenic fungus, *Aspergillus quandricinctus* of *Usnea longissima* inhibits quorum sensing and biofilm formation of *Pseudomonas aeruginosa* PAO1. *Microbial pathogenesis* 140, 103933.
- Rashmi M, Kushveer JS, Sarma VV. 2019 – A worldwide list of endophytic fungi with notes on ecology and diversity. *Mycosphere* 10(1), 798–1079.
- Samanthi KAU, Wickramarachchi S, Wijeratne EMK, Paranagama PA. 2015a – Two new bioactive polyketides from *Curvularia trifolii*, an endolichenic fungus isolated from *Usnea* sp., in Sri Lanka. *Journal of the National Science Foundation Sri Lanka* 43 (3), 217–224.
- Samanthi KAU, Wickramaarachchi S, Wijeratne E, Paranagama P. 2015b – Two new antioxidant active polyketides from *Penicillium citrinum* an endolichenic fungus isolated from *Parmotrema* sp. in Sri Lanka. *Journal of the National Science Foundation of Sri Lanka* 43(2), 119–126.
- Sarma P, Dkhar MS, Kayang H, Kumar M et al. 2020 – Diversity of endophytic fungi associated with *Hedychium spicatum* Ham ex Sm. and their antifungal activity against the phytopathogen *Alternaria solani*. *Studies in Fungi* 5(1), 84–93.
- Spribille T, Tuovinen V, Resl P, Vanderpool D et al. 2016 – Basidiomycete yeasts in the cortex of ascomycete macrolichens. *Science* 353, 488–492.
- Stone JK, Polishook JD, White JF. 2012 – Endophytic fungi. In: *Encyclopedia of Science and Technology*, McGraw-Hill Education, USA. 241–270.
- Suryanarayanan TS, Thennarasan S. 2004 – Temporal variation in endophyte assemblages of *Plumeria rubra* leaves. *Fungal Diversity* 15, 197–204
- Suryanarayanan TS, Thirunavukkarasu N, Hariharan GN, Balaji P. 2005 – Occurrence of non-obligate inside lichen thalli. *Sydowia* 57, 120–130.
- Suryanarayanan TS, Govinda Rajulu MB, Rajamani T, Tripathi M et al. 2017 – Endolichenic fungi in lichens of Champawat district, Uttarakhand, Northern India. *Mycol Prog* 16, 205–211.
- Tripathi M, Gupta RC, Joshi Y. 2014 – Assessment of endolichenic fungal diversity in some forests of Kumaun Himalaya. *Current Science*. 107(5), 745–748.
- Tripathi M, Joshi Y. 2019 – Taxonomic Descriptions of Endolichenic Fungi. In: *Endolichenic Fungi: Present and Future Trends*. Springer, Singapore.
- U'Ren JM, Lutzoni F, Miadlikowska J, Laetsch AD, Arnold AE. 2012 – Host and geographic structure of endophytic and endolichenic fungi at a continental scale. *American Journal of Botany* 99(5), 898–914.
- Vinayaka K, Krishnamurthy YL, Shivakumar B, Prashith KTR. 2016 – Association and variation of Endophytic fungi among some Macrolichens in Central Western Ghats, Southern India. *International Journal of Current Microbiology & Applied Sciences*. 5(6), 115–124.
- Wang Y, Niu S, Liu S, Guo L et al. 2010 – The first naturally occurring thiepinols and thienol from an endolichenic fungus *Coniochaeta* sp. *Organic Letters* 12, 5081–5083.
- Wang QX, Bao L, Yang XL, Guo H et al. 2012- Polyketides with antimicrobial activity from the solid culture of endolichenic fungus *Ulocladium* sp. *Fitoterapia* 83, 209–214.
- Wang Y, Zheng Y, Wang X, Wei X, Wei J. 2016 – Lichen associated fungal community in *Hypogymnia hypotrypa* (Parmeliaceae, Ascomycota) affected by geographic distribution and altitude. *Front Microbiol* 7, 1231.
- Wang H, Umeokoli BO, Eze P, Heering C et al. 2017 – Secondary metabolites of lichen associated fungus *Apiospora montagnei*. *Tetrahedron Letters*, 58, 1702–1705.
- Wijayawardene NN, Hyde KD, Al-Ani LKT, Tedersoo L et al. 2020 – Outline of fungi and fungus like-taxa. *Mycosphere* 11(1), 1060–1456.
- Wijeratne EK, Bashyal BP, Liu MX, Rocha DD et al. 2012 – Geopyxins A–E, ent-kaurane diterpenoids from endolichenic fungal strains *Geopyxis* aff. *Majalis* and *Geopyxis* sp. AZ0066: structure–activity relationships of geopyxins and their analogues. *Journal of Natural Products* 75, 361–369.
- Wijeratne EK, Gunaherath GKB, Chapla VM, Tillotson J et al. 2016 – Oxaspirol b with p97 inhibitory activity and other oxaspirols from *Lecythophora* sp. FL1375 and FL1031,

- Endolichenic fungi inhabiting *Parmotrema tinctorum* and *Cladonia evansii*. *Journal of Natural Products* 79, 340–352.
- Wu W, Dai H, Bao L, Lu J et al. 2011 – Isolation and structural elucidation of proline-containing cyclooctapeptides from an endolichenic *Xylaria* sp. *Journal of Natural Products* 74, 1303–1308.
- Wu YH, Chen GD, Wang CX, Hu D et al. 2015 – Pericoterpenoid A, a new bioactive cadinane-type sesquiterpene from *Periconia* sp. *Journal of Asian Natural Products Research* 17(6), 671–675.
- Xie F, Chang W, Zhang M, Li Y et al. 2016 – Quinone derivatives isolated from the endolichenic fungus *Phialocephala fortinii* are MDR1 modulators that combat azole resistance in *Candida albicans*. *Scientific Reports* 6, 33687.
- Ye F, Chen GD, He JW, Li XX et al. 2013 – Xinshengin, the first altenusin with tetracyclic skeleton core from *Phialophora* spp. *Tetrahedron Letters* 54, 4551–4554.
- Yuan C, Wang HY, Wu CS, Jiao Y et al. 2013 – Austdiol, fulvic acid and citromycetin derivatives from an endolichenic fungus, *Myxotrichum* sp. *Phytochemistry Letters* 6, 662–666.
- Yuan C, Ding G, Wang HY, Guo YH et al. 2017 – Polyketide-terpene hybrid metabolites from an endolichenic fungus *Pestalotiopsis* sp. *BioMed Research International* 10 Article ID 6961928 pages.
- Yuan WH, Teng MT, Sun SS, Ma L et al. 2018 – Active metabolites from endolichenic fungus *Talaromyces* sp. *Chemistry & Biodiversity* 5, e1800371
- Yuan X, Xiao S, Taylor TN. 2005 – Lichen-like symbiosis 600 million years ago. *Science* 308, 1017–1020.
- Yu NH, Park SY, Kim JA, Park CH et al. 2018 – Endophytic and endolichenic fungal diversity in maritime Antarctica based on cultured material and their evolutionary position among Dikarya. *Fungal Systematic Evolution* 22, 263–272.
- Zhang F, Liu S, Lu X, Guo L et al. 2009 – Allenyl and alkynyl phenyl ethers from endolichenic fungus *Neurospora terricola*. *Journal of Natural Products* 72, 1782–1785.
- Zhang ZB, Zeng QG, Yan RM, Wang Y et al. 2011 – Endophytic fungus *Cladosporium cladosporioides* LF70 from *Huperzia serrata* produces Huperzine A. *World J Microbiol Biotechnol* 27, 479–486.
- Zhang F, Li L, Niu S, Si Y et al. 2012 – A thiopyranchromenone and other chromone derivatives from an endolichenic fungus, *Preussia africana*. *Journal of Natural Products* 75, 230–237.
- Zhang T, Wei XL, Wei YZ, Liu HY, Yu LY. 2016 – Diversity and distribution of cultured endolichenic fungi in the Ny-Ålesund Region, Svalbard (High Arctic). *Sci Rep* 20, 461–470.
- Zhao H, Wang GQ, Tong XP, Chen GD et al. 2014 – Diphenyl ethers from *Aspergillus* sp. and their anti-Ab42 aggregation activities. *Fitoterapia* 98, 77–83.
- Zhao Q, Wang CX, Yu Y, Wang GQ et al. 2015 – Nodulisporipyrones A-D, new bioactive α -pyrone derivatives from *Nodulisporium* sp. *Journal of Asian Natural Products Research* 17, 567–575.
- Zheng QC, Kong MZ, Zhao Q, Chen GD et al. 2014 – Chaetoglobosin Y, a new cytochalasan from *Chaetomium globosum*. *Fototerapia* 93, 126–131.
- Zhou YH, Zhang M, Zhu RX, Zhang JZ et al. 2016 – Heptaketides from an endolichenic fungus *Biatrispora* sp. and their antifungal activity. *Journal of Natural Products* 79, 2149–2157.