Cryptogam Biodiversity and Assessment
Vol 3, No. 2 (2018), e-ISSN : 2456-0251, 08-22

Species and Chemical Diversity in Lichen Family Teloschistaceae, and their Bioprospecting Potential: A Review in Indian Context

Gaurav K. Mishra[1], Sanjeeva Nayaka[1#], Dalip K. Upreti[1], S.Y. Kondratyuk[2]

[1]CSIR-National Botanical Research Institute, Rana Pratap Marg, Lucknow-226001 Uttar Pradesh, India
[2]M. H. Kholodny Institute of Botany, Tereshchenkivska str. 2, 01004 Kiev, Ukraine

Publication Info

Article history:
Received : 2019
Accepted : 2019
DOI: 10.21756/cab.v3i2.16254

Keywords:
Biodiversity, Bioprospecting, Chemotaxonomy, Lichenized fungi, Teloschistaceae,

Corresponding author:
e-mail: sanjeeva.nayaka@gmail.com

ABSTRACT

Teloschistaceae is one of the largest families of lichenized fungi in the world with more than a thousand species. In India, the family is represented by 111 species under 35 genera. Most of the species of the family are bright yellow, orange or red due to the presence of anthraquinone pigments. Parietin is the most common pigment found in the family that acts as a light screening agent for the lichen. In this article, both species and chemical diversity within Teloschistaceae occurring in India are discussed. Further, the utilization of some species of the family such as *Teloschistes flavicans*, *Massjukiella candelaria*, *Rusavskia elegans*, *Oxneria huculica*, and *Xanthoria parietina* in bioprospection studies are documented.

INTRODUCTION

Lichens are being used in traditional medicine since the beginning of Chinese and Egyptian civilizations. Their usage in the medieval period was well documented in different pharmacopoeias of the world. Lichen *Evernia furfuracea* (L.) W. Mann (= *Pseudevernia furfuracea* (L.) Zopf) found in an antique Egyptian vase belonging to the 18th Dynasty (1700-1600 BC) was presumed to be used as a drug (Llano 1948). Hale (1983) first report of the medicinal value of lichens figured prominently used by medicinal practitioners.

In the ancient Indian literature Rigveda (6000-4000 BC), first mentioned records of 'Oushadhi' (medicine) are reported, 'Shipal' is the word used for lichens. The medicinal properties attributed to Shipal are also available in Athraveda (1500 BC). A number of Sanskrit synonyms for lichens such as 'Shailaya' and 'Shilapushp' – are referred in Sushruta Samhita (1000 BC), Charaka Samhita (300-200 BC) and Nighantu (1100-1800 AD). These Sanskrit names are later traced to several species of Parmelioid lichens, such as *Parmelia cirrhata* Fr. (= *Hypotrachyna cirrhata* (Fr.) Divakar et al.) and *P. perforata* (Jacq.) Ach. (= *Parmotrema perforatum* (Jacq.) Mass.) (Kumar and Upreti 2001). Chharila name is widely used for lichens in Ayurveda, since from ancient time. Chandra and Singh (1971) provided a detailed description of crude drug 'Chharila' sold in Indian markets which comprises mainly three species of *Parmelia*; *P. perlata* (L.) Ach. (= *Parmotrema chinense* (Osbeck) Hale & Ahti), *P. perofrata* and *P. sanacti-angelii* Lynge (= *Parmotrema sancti-angeli* (Lynge) Hale). The drug has astringent, resolvent, laxative, carminative properties and is also supposed to possess aphrodisiac property. The drug is considered to be useful in several diseases like amenorrhoea, bronchitis, calculi, diseases of blood and heart, stomach disorders, dyspepsia, spermatorrhoea, leprosy, enlarged spleen, bleeding piles, scabies, tooth-ache, and general pain, etc. The drug powdered is applied to wounds, besides a good cephalic snuff. Some other medicinal plant lore of India mentioned *Parmotrema sulcatum* (Taylor) M. Choisy as medicinally useful for cranial maladies (Hale 1983).

The fame of many lichens as medicinally important is due to their Doctrine Signature in nature. It is a very old concept and was raised to an accepted science by Paracelsus but is now discredited. The Doctrine Signature relies on the concept that like affects the like. Hence plants designed by the creator for human beings may be expected to bear a sign pointing to its special use. *Lobaria pulmonaria* (L.) Hoffm. was used to treat lung disease because of its superficial resemblance to lung tissue. Hippocrates recommended long filaments of *Usnea barbata* Wigg, were used for uterine complaints. *Xanthoria parietina* (L.) Th. Fr. being yellow supposed to cure jaundice, while *Peltigera apthosa* (L.) Willd. which has dots and small warts like tubercles on thallus, was recommended for children who suffer from 'Thrush (mouth ulcers)' and used for the treatment of rabies.

During the last five decades of the last century, ethnobotanical work has been completed by different workers in different regions of the country. Lal (1988, 1990), Lal and Upreti (1995), Saklani and Upreti (1992) have collected ethnomedicinal knowledge of lichens used by the different tribal and non-tribal communities of India. Upreti et al. (2005) listed 15 lichen species used by various tribes in India in their daily life either as medicine or as esthetics. Upreti and Chatterjee (2007) reviewed world-wide ethnomedicinal information on more than 50 lichen taxa. Asahina and Shibata (1954) carried out antibacterial or antiviral studies from some lichens used by the tribals.

About 800 metabolites produced by lichens are identified (Huneck and Yoshimura 1996) and new ones are being identified every now and then. The secondary metabolites produced by lichens are unique with respect to those of higher plants. Biological activities of lichens are mostly due to the presence of the secondary metabolites present in them. However, their therapeutic potential not yet fully explored and thus remains pharmaceutically unexploited. This is certainly due to difficulties encountered in the identification of species and collection in bulk quantity. Müller (2001) provided a list of such pharmaceutically relevant metabolites belonging to group aliphatic acids, anthraquinones, pulvinic acid derivatives, depsides and depsidones, dibenzofurans, naphthoquinones, and epidithiopiperazinediones.

Similarly, Boustie and Grube (2005) discussed the diversity of secondary metabolites, their evolutionary pattern, genes involved in their production, bioactive molecules, and their potential use. The slow growth of lichens in axenic culture is the major hurdle for easily obtaining the desired metabolite. Hence, the cultural situation of the mycobiont can be optimized to synthesize interesting secondary compounds and researches are underway elsewhere in this direction.

Teloschistaceae is one of the largest lichen families in the world with more than 1000 species, and India is represented by 111 species under 35 genera (Table 2). The Teloschistacean lichens are a unique group not only for their species diversity but also for their occurrence on diverse environments conditions. The family has a cosmopolitan distribution and is represented in most of the major biomes. The Indian species ranges from arid regions to Eastern Himalayas and from the coastal region up to the alpine zone. The species of *Caloplaca* are found growing in all the phytogeographical regions of India, while xanthorioid lichens (*Oxneria*, *Rusavskia,* and *Xanthoria*) are reported from the Western Himalayas, *Ioplaca* from Central Himalayas and *Teloschistes* from the tropical regions of Western Ghats. Parietin is the dominant compound found in the family besides emodin, teloschistin, fallacinal, parietinic acids, atranorin and various depsidones (Table 1). Nayaka et al. (2010) provided list of thirty six species are used in traditional medicine in the county including three species of Teloschistaceae taxa. Upreti et al. (2015) reported 21 species of ethnolichenic taxa together with the two species of Teloschistaceae (*Teloschistes flavicans* (Sw.) Norman and *Xanthoria parietina*). Crawford (2015) provided a list of 52 genera of lichens used in traditional medicine worldwide including three Teloschistaceae taxa. These reports indicate teloschistacean taxa can be exploited for their bioprospection. The present paper explores the different Teloschistaceae taxa of the world utilized in traditional medicine and biological screening. A description of the lichen taxa, its distribution in India and their utilization is provided in the enumeration.

Table 1: List of anthraquinones and depsidones in lichen family Teloschistaceae (Y. Joshi, 2001)

1-O-methylfragilin	Emodinic acid
7-chlorocitreorosein	Erythroglaucin
7-chloroemodin	Fallacinal
7-chloroemodinal	Fragilin
7-chloroemodinic acid	Isofulgidin
Atranorin	Parietin
Caloploicin	Parietinic acid
Citreorosein	Teloschistin
Emodin	Vicanicin
Emodinal	Xanthorin

Biological activities of *Teloshi-staceae* species

Several *in vitro* studies have shown that *Teloschistaceaen* species have potential biological activities either in the form of crude extract or isolated compounds. Fernández-Moriano et al. (2016) reviewed the antioxidant potentials of lichens and their isolated compounds including *Caloplaca regalis* (Vain.) Zahlbr.; *Fulgensia fulgens* (Sw.) Elekin and *Xanthoria elegans* (Link) Th. Fr. (= *Rusavskia elegans* (Link) S. Kondratyuk & Kärnefelt). Kumar et al. (2014) observed the highest antioxidant capacity in terms of β-carotene linoleic acid bleaching property in the water extract of *R. elegans* and opinioned that lichen compounds were non-toxic and may be used as natural antioxidants for stress-related problems. Anthroquinones are a potential source of the antimicrobial agent as reviewed by Malmir

Table 2: List of Teloschistaceae taxa with secondary metabolites and their distribution in India.

S.N.	*Taxa*	*Secondary metabolites*	*Distribution in India*
1	Amundsenia approximata (Lynge) Søchting, Arup & Frödén	Parietin	Uttarakhand
2	Athallia alnetorum (Giralt, Nimis & Poelt) Arup, Frödén & Søchting	Parietin	Himachal Pradesh
3	A. cerinella (Nyl.) Arup, Frödén & Søchting	Parietin	Uttarakhand
4	A. cerinelloides (Erichsen) Arup, Frödén & Søchting	Parietin	Jammu & Kashmir, Mizoram and Uttarakhand
5	A. holocarpa (Hoffm.) Arup, Frödén & Søchting	Parietin	Uttarakhand
6	A. pyracea (Ach.) Arup, Frödén & Søchting	Emodin, parietin, xanthorin, fallacinal	Himachal Pradesh, Jammu & Kashmir and Uttarakhand
7	A. vitellinula (Nyl.) Arup, Frödén & Søchting	Parietin	Madhya Pradesh, Manipur, Tamil Nadu and Uttarakhand
8	Blastenia herbidella (Arnold) Servít	Parietin	Odisha
9	B. ferruginea (Huds.) A. Massal	Parietin	Arunachal Pradesh, Himachal Pradesh, Karnataka, Maharashtra, Tamil Nadu and Uttarakhand
10	Brownliella cinnabarina (Ach.) S.Y. Kondr., Kärnefelt, A. Thell, Elix, J. Kim, A.S. Kondr. & J.-S. Hur	Parietin (major), emodin, teloschistin, fallacinal, xanthorin, parietinic	Himachal Pradesh, Karnataka, Madhya Pradesh, Meghalaya Orissa, Rajasthan, Tamil Nadu and Uttarakhand
11	Calogaya biatorina (A. Massal.) Arup, Frödén & Søchting	Parietin	Himachal Pradesh and Jammu & Kashmir
12	C. decipiens (Arnold) Arup	Parietin and yellow–orange spot at Rf 6	Jammu & Kashmir, Madhya Pradesh, Maharashtra, Rajasthan and Uttarakhand
13	C. saxicola (Hoffm.) Vondrák	Parietin	Himachal Pradesh, Jammu & Kashmir, Madhya Pradesh and Uttarakhand
14	Caloplaca abuensis Y. Joshi & Upreti	Parietin and olive green spot at Rf 4	Rajasthan and Uttarakhand
15	C. aractina (Fr.) Häyrén	Parietin	Manipur
16	C. atrosanguinea (G. Merr.) I. M. Lamb.	No lichen substance	Madhya Pradesh
17	C. aureosora Poelt & Hinteregger	Parietin	Uttarakhand

Contd...

Contd...

18	C. awasthii Y. Joshi & Upreti	Parietin and pale greenish-blue spot at Rf 4	Madhya Pradesh and Rajasthan
19	C. brebissonii (Fée) J. Sant. ex Hafellner & Poelt	Not studied	Jammu & Kashmir
20	C. cerina (Hedw.) Th. Fr.	Parietin	Jammu & Kashmir, Manipur, Tamil Nadu and Uttarakhand
21	C. cerina var. chloroleuca (SM.) Th. Fr.	Parietin	Himachal Pradesh
22	C. cerina var. muscorum (A. Massal.) Jatta	Parietin	Jammu & Kashmir
23	C. cirrochroopsis Poelt & Hinteregger	Parietin and olive spot at Rf 3	Uttarakhand
24	C. conciliascens (Nyl.) Zahlbr.	Atranorin	Uttar Pradesh
25	C. crocea (Kremp.) Hafellner & Poelt	Parietin	Tamil Nadu
26	C. cupulifera (Vain.) Zahlbr.	Parietin	Andhra Pradesh, Jharkhand, Madhya Pradesh, Orissa, Rajasthan, Tamil Nadu, Uttarakhand, Uttar Pradesh and West Bengal
27	C. diphyodes (Nyl.) Jatta	Parietin	Jammu & Kashmir
28	C. encephalartii (Kremp.) Zahlbr.	Parietin	West Bengal
29	C. festivella (Nyl.) Kieff.	Parietin	Madhya Pradesh
30	C. fraudans (Th. Fr.) H. Olivier	Parietin	Himachal Pradesh and Uttarakhand
31	C. fulvolutea (Arnold) Jatta	Parietin	Himachal Pradesh
32	C. gyrophorica Jagadeesh, Y. Joshi & G.P. Sinha	Gyrophoric acid and parietin	West Bengal
33	C. haematites (Chaub.) Zwackh	Parietin	Jammu & Kashmir
34	C. handelii (Zahlbr.) D.D. Awasthi	Parietin	Manipur
35	C. heterospora Poelt & Hinteregger	Parietin	Himachal Pradesh
36	C. himalayana Y. Joshi & Upreti	Dull yellow-beige colour at Rf 7 and yellow spot between Rf 5 and 6	Himachal Pradesh and Jammu & Kashmir
37	C. homologa (Nyl.) Hellb.	Parietin	Uttarakhand

Contd...

Contd...

38	C. holochracea (Nyl.) Zahlbr.	Parietin (major), emodin, teloschistin, fallacinal, xanthorin, parietinic	Uttarakhand and West Bengal
39	C. hueana B. de Lesd	Parietin	Madhya Pradesh
40	C. indica Y. Joshi, Jagadeesh & G.P. Sinha	Parietin	Arunachal Pradesh and West Bengal
41	C. insularis Poelt	Parietin	Jammu & Kashmir and Uttarakhand
42	C. irrubescens (Arnold) Zahlbr.	Parietin	Himachal Pradesh and Uttarakhand
43	C. jatolensis Y. Joshi & Upreti	Atranorin, grey spot at Rf 3	Uttarakhand
44	C. kashmirensis Y. Joshi & Upreti	Parietin	Jammu & Kashmir
45	C. leptopisma (Nyl.) Zahlbr.	Parietin	N. W. Himalaya
46	C. leptozona (Nyl.) Zahlbr.	Parietin	Tamil Nadu
47	C. lithophila H. Magn.	Parietin	Uttarakhand
48	C. litoricola Brodo	Parietin	Andhra Pradesh
49	C. lypera Poelt & Hinteregger	Parietin	Uttarakhand
50	C. maura Poelt & Hinteregger	Parietin	Sikkim
51	C. malaensis (Räsänen) D. D. Awasthi	Parietin	Uttarakhand and Karnataka
52	C. ochroplaca Poelt & Hinteregger	Parietin	Himachal Pradesh, Jammu & Kashmir and Uttarakhand
53	C. orissensis (Räsänen) D.D. Awasthi	Parietin	Orissa
54	C. pachycheila Poelt & Hinteregger	Parietin	Jammu & Kashmir and Uttarakhand
55	C. pelodella (Nyl.) Hasse	Parietin	Tamil Nadu
56	C. phloginopsis Poelt & Hinteregger	Parietin	Himachal Pradesh
57	C. poliotera (Nyl.) Steiner	Parietin	Tamil Nadu
58	C. pseudisteroides Y. Joshi & Upreti	Parietin and atranorin	Madhya Pradesh
59	C. rinodinopsis Poelt & Hinter.	Parietin	Uttarakhand
60	C. ruderum (Malbr.) J.R. Laundon	Parietin	Jammu & Kashmir

Contd...

Contd...

61	C. subbassiae Y. Joshi & Upreti	Parietin, pale yellow spot at Rf 5 and olive green spot between Rf 2–3	Madhya Pradesh and Uttarakhand
62	C. subdulosa (Nyl.) Zahlbr.	Parietin	Karnataka
63	C. subleptozona Y. Joshi & Upreti	Atranorin, triterpenes at Rf class 3 and 7	Himachal Pradesh, Rajasthan and Uttarakhand
64	C. transcaspica (Nyl.) Zahlbr.	No chemicals	Himachal Pradesh
65	C. triloculans Zahlbr.	TLC not done	Uttarakhand
66	C. tropica Y. Joshi & Upreti	Parietin and olive spot at Rf 4	Madhya Pradesh, Maharashtra and Uttar Pradesh
67	Flavoplaca citrina (Hoffm.) Arup, Frödén & Søchting	Parietin	Jammu & Kashmir, Madhya Pradesh, Maharashtra, Tamil Nadu and Uttarakhand
68	F. flavocitrina (Nyl.) Arup, Frödén & Søchting	Parietin and olive green spot at Rf 4	Himachal Pradesh, Jammu & Kashmir and Uttarakhand
69	Flavoplacagranulosa (Nyl.) Arup, Frödén & Søchting	TLC not done	Uttarakhand
70	Gallowayella awasthiana S.Y. Kondr. & Upreti	Parietin, fallacinal, emodin, teloschistin and parietinic	Jammu & Kashmir and Uttarakhand
71	G. fulva (Hoffm.) S.Y. Kondr., Fedorenko, S. Stenroos, Kärnefelt, Elix, J.-S. Hur & A. Thell	Parietin, fallacinal, emodin, teloschistin and parietinic acid	Jammu & Kashmir
72	Golubkovaea trachyphylla (Tuck.) S.Y. Kondr., Kärnefelt, Elix, A. Thell, J. Kim, M.-H. Jeong, N.-N. Yu, A.S. Kondr. & J.-S. Hur	Parietin	Himachal Pradesh
73	Gyalolechia bassiae (Ach.) Søchting, Frödén & Arup ex Ahti	Parietin, fragilin	Andaman & Nicobar Islands, Arunachal Pradesh, Assam, Himachal Pradesh, Jammu & Kashmir, Madhya Pradesh, Orissa, Rajasthan, Sikkim, Tamil Nadu, Uttarakhand and Uttar Pradesh

Contd...

Contd...

74	G. flavorubescens (Huds.) Søchting, Frödén & Arup	Parietin	Himachal Pradesh, Karnataka, Manipur, Nagaland and Uttarakhand
75	Huneckia pollinii (A. Massal.) S.Y. Kondr., Elix, Kärnefelt, A. Thell, J. Kim, A.S. Kondratiuk & J.-S. Hur	Parietin	Karnataka and Orissa
76	Ioplaca pindarensis (Räs.) Poelt & Hinteregger	Parietin	Arunachal Pradesh, Himachal Pradesh, Jammu & Kashmir, Sikkim, Uttarakhand and West Bengal
77	I. sphalera Poelt	Parietin	Eastern Himalaya
78	Klauderuiella aurantia (Pers.) S.Y. Kondr. & J.-S. Hur	Parietin	Western Himalaya
79	K. flavescens (Huds.) S.Y. Kondr. & J.-S. Hur	Parietin	Jammu & Kashmir and Himachal Pradesh
80	Laundonia flavovirescens (Wulfen) S.Y. Kondr., L. Lőkös & J.-S. Hur	Parietin	Himachal Pradesh, Jammu & Kashmir, Nagaland, Tamil Nadu and Uttarakhand
81	Lazarenkoiopsis ussuriensis (Oxner, S.Y. Kondr. & Elix) S.Y. Kondr., L. Lőkös & J.-S. Hur	Parietin	Himachal Pradesh
82	Leproplaca chrysodeta (Vain.) J. R. Laundon	Parietin	Himachal Pradesh and West Bengal
83	L. cirrochroa (Ach.) Arup, Frödén & Søchting	Parietin	Jammu & Kashmir and Madhya Pradesh
84	L. obliterans (Nyl.) Arup, Frödén & Søchting	Parietin	Jammu & Kashmir, Rajasthan and Uttarakhand
85	Massjukiella candelaria (L.) S.Y. Kondr., Fedorenko, S. Stenroos, Kärnefelt, Elix, J.-S. Hur & A. Thell	Parietin (major), fallacinal, emodin, teloschistin and parietinic	Himachal Pradesh, Jammu & Kashmir and Uttarakhand
86	M. polycarpa (Hoffm.) S.Y. Kondr., Fedorenko, S. Stenroos, Kärnefelt, Elix, J.-S. Hur & A. Thell	Parietin (major), fallacinal, emodin, teloschistin and parietinic	Jammu & Kashmir
87	Mikhtomia gordejevii (Tomin) S.Y. Kondr., Kärnefelt, Elix, A. Thell, J. Kim, A.S. Kondratiuk & J.-S. Hur	Parietin, anthraquinones of fragilin and parietin chemosyndromes, as well as gyrophoric acid	Uttarakhand

Contd...

Contd...

88	Olegblumia demissa Flot. ex S.Y. Kondr., Lőkös, Jung Kim, A.S. Kondr., S.O. Oh & J.-S. Hur	Parietin	Himachal Pradesh
89	Oxneria huculica S.Y. Kondr.	Parietin (major), fallacinal (major), emdin, teloschistin (major) and parietinic	Jammu & Kashmir and Himachal Pradesh
90	O. ulophyllodes (Räsänen) S.Y. Kondr. & Kärnefelt	Parietin, fallacinal, emodin, teloschistin and parietinic	Himachal Pradesh, Jammu & Kashmir and Uttarakhand
91	Pachypeltis intrudens (H. Magn.) Søchting, Frödén & Arup	Parietin	Himachal Pradesh
92	Polycauliona inconspecta (Arup) Arup, Frödén & Søchting	Parietin (major) and small amounts of emodin, teloschistin, parietinic acid	Maharashtra
93	Pyrenodesmia chalybaea (Fr.) A. Massal.	Atranorin	Madhya Pradesh
94	P. variabilis (Pers.) A. Massal.	No lichen substance	Himachal Pradesh, Jammu & Kashmir and Uttarakhand
95	Rufoplaca arenaria (Pers.) Arup, Søchting & Frödén	Parietin	Himachal Pradesh, Jammu & Kashmir and Uttarakhand
96	R. scotoplaca (Nyl.) Arup, Søchting & Frödén	Parietin	Manipur and Sikkim
97	Rusavskia elegans (Link) S. Y. Kondr. & Kärnefelt	Parietin (major), fallacinal, emodin, teloschistin and parietinic	Himachal Pradesh, Jammu & Kashmir, Sikkim and Uttarakhand
98	R. granulifera (Giralt, Nimis & Poelt) S.Y. Kondr.	Parietin (major), fallacinal, emodin, teloschistin and parietinic	Uttarakhand
99	R. indica S.Y. Kondr. & Upreti	Chemistry not studied	Andaman Islands, Jammu & Kashmir, Himachal Pradesh and Uttarakhand
100	R. sorediata (Vain.) S.Y. Kondr. & Kärnefelt	Parietin (major), fallacinal, emodin, teloschistin and parietinic	Andaman Islands, Himachal Pradesh, Jammu & Kashmir and Uttarakhand

Contd...

Contd...

101	R. upretii S.Y. Kondr., G.K. Mishra & S. Nayaka	Not studied	Uttarakhand
102	Scythioria phlogina (Ach.) S.Y. Kondr., Kärnefelt, Elix, A. Thell & J.-S. Hur	Parietin	Uttarakhand
103	Squamulea parviloba (Wetmore) Arup, Søchting & Frödén	Parietin	Himachal Pradesh, Tamil Nadu and Uttarakhand
104	S. squamosa (B. de Lesd.) Arup, Søchting & Frödén	Parietin	Uttarakhand
105	S. subsoluta (Nyl.) Arup, Søchting & Frödén	Parietin	Himachal Pradesh, Madhya Pradesh, Tamil Nadu and Uttarakhand
106	Teloschistes flavicans (Swartz) Norman	Parietin (major), teloschistin, fallacinal, parietinic acid, erythroglaucin and emodin. Depsidones: caloploicin (major), vicanicin, isofulgidin	Karnataka, Kerala and Tamil Nadu
107	Upretia amarkantakana (Y. Joshi & Upreti) S.Y. Kondr. & A. Thell	Parietin present in apothecial disc and an olive green spot at Rf class 4	Madhya Pradesh
108	Wetmoreana appressa (Wetmore & Kärnefelt) Arup, Frödén & Søchting	Parietin	Jammu & Kashmir
109	Xanthaptychia contortuplicata (Ach.) S.Y. Kondr. & Ravera	Parietin (major), fallacinal, teloschistin, and parietinic acid (all minor), and emodin (minor)	Himachal Pradesh, Jammu & Kashmir and Uttarakhand
110	Xanthoria parietina (L.) Th. Fr.	Parietin (major), fallacinal, emodin, teloschistin and parietinic	Himachal Pradesh, Jammu & Kashmir and Tamil Nadu
111	Zeroviella esfahanensis S.Y. Kondr., B. Zarei–Darki & J.-S. Hur	Parietin (major), teloschistin, fallacinal, parietinic acid and emodin (traces)	Himachal Pradesh, Jammu & Kashmir and Uttarakhand

et al. (2017) and Fouillaud et al. (2016). Manojlovic et al. (2000, 2005) studied isolated anthraquinones from *Xanthoria* species possessing antifungal activity. Parietin, an anthraquinone isolated from methanol extracts of *Caloplaca cerina* (Ehrh. ex Hedwig) Th. Fr. displayed a significant antifungal activity. Further, Manojlovic et al. (2008) claimed that methanol extract and fractions of three species of *Caloplaca* (*C. lacteal* (A. Massal.) Zahlbr.; *Flavoplaca citrina* (Hoffm.) Arup, Frödén & Søchting; *Variospora dolomiticola* (Hue) Arup, Søchting & Frödén) collected from Serbia showed broad-spectrum antifungal and antibacterial properties against some human and plant pathogens. The fraction with methylene chloride and pure anthraquinone derivatives substantially increased the level of antimicrobial activity. In another study usnic acid isolated from *Teloschistes chrysophthalmus* (L.) Th. Fr. exhibited antiviral activity against the arenaviruses Junin and Tacaribe (Fazio et al., 2007).

Wei et al. (2008) studied cultured mycobiont of 100 Korean and Chinese lichen-forming fungi for their antifungal activity against *Colletotrichum acutatum,* the causal agent of anthracnose on hot pepper. Among them, Korean *Caloplaca flavorubescens* (Huds.) J.R. Laundon (= *Gyalolechia flavorubescens* (Huds.) Søchting, Frödén & Arup) and *R. elegans* exhibited significant antifungal activity with inhibition zone of 40.76 ± 1.58 and 34.31 ± 0.58 mm diameter respectively. Bhattarai et al. (2008) screened antioxidant properties of methanol-water (90:10 v/v) extracts of five Antarctic lichen species including *Caloplaca* through thin layer chromatography which showed strong discoloration of DPPH. Basile et al. (2015) investigated the antibacterial, antifungal, and antiproliferative activities of the acetone extract of *Xanthoria parietina* and found main secondary metabolite, parietin.

The crude extract of *R. elegans* and *X. parietina* have shown excellent anti-bacterial activity. Karagöz et al. (2009) and Karagöz and Aslan (2005) evaluated the aqueous and the ethanolic extract of *X. parietina* for antiviral activity against human parainfluenza virus type 2(HPIV-2) and cytotoxic activity towards Vero cells. Yamamoto et al. (1998) demonstrated that the methanol extract of cultured tissue of this *Oxneria fallax* (Arnold) S.Y. Kondr. & Kärnefelt inhibited Epstein-Barr virus activation induced teleocidin B-4 and superoxide dismutase-like activity. Felczykowska et al. (2017) demonstrated significant antibacterial and anticancer activities in the mycobiont culture of *Caloplaca pusilla* (A. Massal.) Zahlbr. (= *Calogaya pusilla* (A. Massal.) Arup, Frödén & Søchting) and *X. parietina* collected in Poland. They opinioned that mycobiont culture could be an alternative to poor biomass yielding lichens. Quahiba et al. (2018) evaluated the hypoglycemic and antioxidant effect of the methanolic extract of *X. parietina* on rats diabetes induced by streptozotocin (40 mg/g). The study resulted in rendering hyperglycemic condition in rats and a marked improvement in the antioxidant state in the liver with a decrease in the malondialdehyde concentration of 25.91% and an increase in the reduced glutathione rate of 23.62%, an increase in the superoxide dismutase activity of 23.53% and catalase activity of 49.10%. Methanolic extract of *R. elegans* collected from Iceland exhibited cancer chemopreventive and cytotoxic activity (Ingólfsdóttir et al. 2000).

Biological activities of other lichen species due to the presence of common secondary metabolites of Teloschistaceae

The secondary metabolites found in species of *Teloschistaceae* are also available in other lichens. Some of these isolated metabolites or lichens due to the presence of such metabolites have shown significant biological activities. For examples, benzene and methanolic fractions of *Laurera benguelensis* (Müll. Arg.) Zahlbr. (Trypetheliaceae) having parietin, emodin, teloschistin and citreorosein exhibited weak antioxidant activity, while chloroform exacted showed the strongest activity (Manojlovic et al. 2010a). Further, the same lichen's extracts showed effective antimicrobial activities against the bacteria—*Escherichia coli*, *Bacillus subtilisi* and *Staphylococcus aureus,* and the fungi *Candida albicans, Mucor mucedo*, and *Trichoderma harzianum.* The inhibition zones ranged from 3.5 to 10.3 mm against bacteria and from 4.0 to 14.0 mm against fungi (Manojlovic et al. 2010b). Parietin isolated from *Ramalina celastri* (Spreng.) Krog & Swinscow demonstrated antiviral activity against the arenaviruses Junin and Tacaribe (Fazio et al., 2007). Similarly, anthraquinones isolated from lichens *Nephroma laevigatum* Ach. and *Heterodermia obscurata* (Nyl.) Trevis. showed significant antiviral activities (Cohen et al. 1996).

Other bioprospecting potential of Teloschistaceaen lichens

It can be noted that *R. elegans* was part of the space experiment wherein it was showing to space condition in the BIOPAN-5 facility of the European Space Agency for 16 days. BIOPAN-5 is located on the outer shell of the earth-orbiting FOTON-M2 Russian satellite. All the exposed lichens exposed nearly the same photosynthetic activities as earlier exposure and no ultrastructural changes were detected in most of the algal and fungal cells. These findings indicate that lichens can survive in space after full exposure to massive UV and cosmic radiation, conditions proved to be lethal to bacteria and other microorganisms (Sancho et al. 2007). Later, *R. elegans* was included in Lichen and Fungi Experiment (LIFE) on the International Space Station (ISS) and exposed to space condition for 559 days. After returning to earth surface, an impressive 71% of the lichen remained viable (Brandt et al. 2016).

Lichens being sensitive to air pollution and bioaccumulation of pollutants, they are used in biomonitoring studies. Several studies are available in this regards, but here only a few examples are cited to explain the potentials of Teloschistaceaen species. In Italy, epiphytic foliose lichen species belonging to the genera *Xanthoria* were mostly employed as bioaccumulators (Nimis et al. 2000). *R. elegans* and *X. parietina* are pollution sensitive species in India, but they are common and tolerant species in temperate countries. The indicator value of *R. elegans* can be marked as "tolerant" (Shukla et al. 2014). The diversity, abundance and frequency of lichens are greatly influenced by the level of pollution. It is found that the frequency of *X. parietina* and *C. holocarpa* (Hoffm.) A.E. Wade (= *Athallia holocarpa* (Hoffm.) Arup, Frödén & Søchting) increases with increasing vehicular and agricultural activities (Shukla et al. 2014).

Vannini et al. (2015, 2018) concluded that lichens, especially *X. parietina* are suitable organisms for monitoring unwanted biological effects from the application of glyphosate-based herbicides, as well as for detecting the accumulation of this compound in the biota, thus screening for its environmental fate. They utilized *X. parietina* for studying the toxicity of diclofenac on the photosynthetic apparatus. Yenisoy-Karakaş and Tuncel (2004) utilized *X. parietina* for checking the distribution pattern of pollutants in Aegean region of Turkey and found that the range of the concentrations for most of the elements on a local scale was an order of magnitude lower than for the element concentrations on a regional scale. Hissler et al. (2008) assessed the trace metal atmospheric contamination in one of the oldest European industrial sites of steel production situated in the southern part of the Grand-Duchy of Luxembourg using *X. parietina*. It is found that the concentrations of elements decreased with increasing distance from the historical and actual steel-work areas. The study enabled them to distinguish between three principal sources: the historical steel production (old tailings corresponding to blast-furnace residues), the present steel production (industrial sites with arc electric furnace units) and the regional background (baseline) components. Scerbo et al. (2002) by using *X. parietina* studied trace element contamination and air quality assessment in Pisa Province of Italy and detected the highest levels of Zn, Pb, Cr, and Ni contamination, which well correlated with air quality and metal concentrations in lichens. Domeňo et al. (2006) quantified the 12 airborne PAHs in *X. parietina* samples with concentration ranging from 25 to 40 ng g^{-1}. In India, Shukla et al. (2007) estimated the heavy metal concentration in *R. elegans* collected from Badrinath area.

The Teloschistacean species having yellow thallus and apothecia have an ability to grow both on exposed and sheltered rocks. The dark orange pigment present on the upper cortex of the thallus acts as a filter and protects the lichens from high UV radiation. Therefore, these lichens can be important compounds for developing of UV protective creams and cosmetics products (Shukla et al. 2014, Solbaug et al. 1996, Nybakken et al. 2004).

Traditional uses and biological activities of Teloschistaceae species found in India

1. **Massjukiella candelaria** (L.) S.Y. Kondr., Fedorenko, S. Stenroos, Kärnefelt, Elix, Hur & A. Thell, in Fedorenko, Stenroos, Thell, Kärnefelt, Elix, Hur & Kondratyuk, Biblthca Lichenol. 108: 60 (2012).

Thallus foliose to subfoliose, up to 15.0 mm in diameter and 5–10 mm high, upper surface wrinkled yellow to light orange, sorediate, soredia granular, blastidious, produced marginally to sub-marginally or at the lobe tips, medulla white. Apothecia rare, sessile or substipitate, disc orange, concave to plane, spores polaribilocular, ellipsoid, 11–15 × 5–7 µm. Chemistry: Upper surface K+ purple, C–, KC–, Pd–; Parietin (major), fallacinal, emodin, teloschistin and parietinic acid, chemosyndrome A present in TLC.

Distribution

The taxon is restricted in temperate to alpine areas in the western Himalayas in India, though it is widely distributed in bipolar-alpine regions of North Africa, Europe, North America, Asia (Himalayan Mts.), southernmost Antarctica, New Zealand and South America (Lindblom 1997). It is a very variable taxon occurring generally on sun-exposed and nutrient-rich substrata such as bark, rock, and detritus.

Uses

In Europe, lichen is boiled with milk to treat jaundice along with *X. parietina* (Tonning 1769). Anar et al. (2016) carried out antigenotoxic and antioxidant activities of *M. candelaria.* They concluded that *M. candelaria* could be a safe natural antioxidant and anticancer agents, and indispensable in human, animal and plant diseases treatment.

2. Oxneria huculica S.Y. Kondr., Flora Lischaĭnikiv Ukraïni (Kiev) 2(3): 435 (2010).

Thallus foliose, up to 30 mm wide, upper side yellowish-orange or orange, smooth to shiny, sorediate, soredia marginal, medulla white, reticulate, not well developed, with short to elongate irregular hyphae. Apothecia rare, disc orange, spores polaribilocular, ellipsoid, 10–17 × 5–9 µm. Chemistry: Upper surface K+ purple, KC–, C–, Pd–; Parietin, fallacinal, emodin, teloschistin and parietinic acid, chemosyndrome A3 present in TLC.

Distribution

It is common and widespread species growing on barks, rarely on rock or detritus, temperate regions around the globe with extensions into boreal regions in the open to semi-open, often more or less dry areas. Outside country, it is reported from Africa, Asia, Europe, North & Central America (Lindblom 1997).

Uses

The methanol extract of cultured tissue of *O. fallax* inhibited Epstein-Barr virus activation induced teleocidin B-4 and superoxide dismutase-like activities (Yamamoto et al. 1998). Similarly, *O. fallax* anthraquinones showed broad spectrum antifungal activity selective activity again some phytopathogenic bacterial species (Manojlovic et al. 2000).

3. ***Rusavskia elegans*** (Link) S. Kondratyuk & Kärnefelt, *Ukr. Botan. Journ.* 60: 434 (2003).

Thallus foliose, adnate, effigurate, upper side yellow to orange, mostly coarse, irregularly pruinose, medulla white, reticulate, consisting of loosely interwoven hyphae in bundles. Apothecia numerous, often crowded to sparse, disc orange to deep red-brown, spores polaribilocular, ellipsoid, 11–18 × 5–10 µm. Chemistry: Upper surface K+ purple, KC–, C–, Pd–; Parietin (major), fallacinal, emodin, teloschistin, parietinic acid, chemosyndrome A present in TLC.

Distribution

The taxon is widely distributed in upper temperate, alpine to frigid zones all over the world and is highly polymorphic with broad ecological amplitude (Lindblom 1997). It grows on various kinds of rocks, both acidic and calciferous. In India, it is found growing in temperate and alpine regions of Central and Western Himalayas.

Uses

Methanolic extract of this lichen collected from Iceland exhibited cancer chemopreventive and cytotoxic activity (Ingólfsdóttir et al. 2000). Nybakken et al. (2004) studied arctic *R. elegans* against UV-B radiation and resulted parietin deficient *R. elegans* thalli cultivated under various filters showed that UV-B was essential for the induction of parietin synthesis. Hasan et al. (2012) used *R. elegans* extract for DNA damage and oxidative stress of mitomycin C in human lymphocytes and the results indicated that lichen extract is a potential source of natural antigen toxicants.

4. ***Teloschistes flavicans*** (Swartz) Norman, Nytt Mag. Natur. 7: 229 (1853) [1852].

Thallus fruticose to subfruticose, upper surface pale yellow to orange to reddish-orange; sorediate, soredia basically farinose to granular, yellow to whitish. Apothecia absent in Indian specimens. Chemistry: Thallus K+ purple, C-, KC-, Pd-: Anthraquinones: parietin (major), teloschistin, fallacinal, parietinic acid, erythroglaucin and emodin; Depsidones: caloploicin (major), vicanicin, isofulgidin; chemosyndrome A+2 present in TLC.

Distribution

The taxon is widely distributed in warm subtropical to temperate regions of the world where there is a fairly high amount of precipitation. In India the species has been reported from Karnataka, Kerala and Tamil Nadu, at an altitude of 1265-2250 m, growing over *Rhododendron*, *Eucalyptus*, coniferous trees and sometimes on the soil in association with *Heterodermia leucomela* ssp. *boryi* (Fée) Swinsc. & Krog, and members of Parmeliaceae.

Uses

In China, it is used as an antibacterial agent (Wang and Qian 2013). Shivanna & Garampalli (2015) studied the fungitoxic effect of *T. flavicans* as a bio-fungicide. Pereira et al. (2010) carried out the anti-inflammatory *and* antiedematogenic activity but concluded that they are not effective on sub-chronic inflammation. Maulidiyah et al. (2018) studied antifungal potential against *Aspergillus flavus* and successfully isolated a bioactive compound from lichen *T. flavicans*.

5. ***Xanthoria parietina*** (L.) Th. Fr., *Lichenes Arctoi*: 69 (1860).

Thallus foliose, up to 10 cm in diameter, upper surface smooth to wrinkled, wax-yellow to nugget-bronze yellow, medulla white, lower surface scattered hapters attached with a terminal foot. Apothecia 1–8 mm in diameter, disc usually darker than the thallus, concave-plane or folded, spores polaribilocular, ellipsoid, 11–18 × 5–10 µm. Chemistry: Upper surface K+ purple, C–, KC–, Pd–; Parietin (major), fallacinal, emodin, teloschistin, parietinic acid chemosyndrome A present in TLC.

Distribution

The species is found generally growing over various phorophytes in Central and Western Himalayas, but sometimes on rocks too. Outside India, it is reported from Australia, Pacific Islands, Antarctica, Africa, Europe, South America and North & Central America (Lindblom 1997).

Uses

X. parietina is one of the lichens mentioned in Pharmacopoeia Universalis of 1846 (Vartia 1973). As the lichen appears yellow it is used in Finish folklore and other European countries for the treatment of Jaundice (Doctrine of signature) (Llano 1951) and in intermittent fevers (Lindley 1838, 1849). It is also used in preparation for washing hair (Nadkarni 1976) and boiled with milk to treat jaundice along with *M. candelaria* (Tonning 1769). Used for treating diarrhea, dysentery (Luyken 1809, Willemet 1787), hepatitis (Gioanetto 1993) and as a quinine replacement for malaria (Lebail 1853, Schneider 1904). The extract of the lichen has exhibited antibacterial activity against *A. faecalis* (Bustinza 1952). The methanol extract of cultured tissue of this lichen exhibited inhibition of Epstein-Barr virus activation induced teleocidin B-4 and superoxide dismutase-like activity (Yamamoto et al. 1998). Also, the methanolic extract of this lichen collected from Iceland exhibited cancer chemopreventive and cytotoxic activity (Ingólfsdóttir et al. 2000).

ACKNOWLEDGEMENTS

We are thankful to the Director, CSIR-National Botanical Research Institute, Lucknow for providing facilities and Department of Science and Technology, New Delhi (INT/UKR/P-19/2015) for providing the fund.

REFERENCES

Anar M, Aslan A, Agar G and Ozgencli (2016). Antigenotoxic and antioxidant activity of lichens Anaptychia ciliaris, Bryoria fuscescens, Parmotrema chinensa and Xanthoria candelaria: An in vitro Study. Medicinal & Aromatic Plants 5:2 http://dx.doi.org/10.4172/2167-0412.1000233.

Asahina Y and Shibata S (1954). Chemistry of lichen substances. Japan Society for the Promotion of Science, Tokyo.

Basile A, Rigano D and Loppi S (2015). Antiproliferative, antibacterial and antifungal activity of the lichen Xanthoria parietina and its secondary metabolite parietin. International Journal of Molecular Sciences 16(4): 7861-7875. doi:10.3390/ijms16047861

Bhattarai HD, Paudel B, Hong SG, Lee HK and Yim JH (2008). Thin layer chromatography analysis of antioxidant constituents of lichens from Antarctica. J Nat Med. 62(4):481-4. doi: 10.1007/s11418-008-0257-9.

Boustie J and Grube M (2005). Lichens – a promising source of bioactive secondary metabolites. Plant Genetic Resources 3(2): 273-287.

Brandt, Annette P, Eva dV, Jean P, Onofri S, Ott S (2016). Characterisation of growth and ultrastructural effects of the Xanthoria elegans photobiont after 1.5 years of space exposure on the International Space Station. Origins of Life and Evolution of Biospheres 46(2-3): 311-321.

Brij L and Upreti DK (1995). Ethnobotanical notes on three Indian lichens. Lichenologist 27(1): 77-79.

Brij L (1988). Traditional remedies for bone-fracture among the tribals of Madhya Pradesh. India. Aryavaidyan 1: 190-195.

Brij L (1990). Ethnobotanical studies of the Baiga tribe of Madhya Pradesh. Ph.D. Thesis. Meerut University, Meerut.

Bustinza F (1952). Antibacterial substances from lichens. Economic Botany 64(4): 402-406.

Chandra S and Singh A (1971). A lichen crude drug (Chharila) from India. Jour. Rese. Ind. Med. 6(4): 209-215.

Cohen PA, Hudson JB and Towers GH (1996). Antiviral activities of anthraquinones, bianthrones and hypericin derivatives from lichens. Experientia 52(2): 180-3.

Domeňo C, Blasco M, Sanchez C and Nerin C (2006). A fast extraction technique for extracting polycyclic aromatic hydrocarbons (PAHs) from lichen samples used as biomonitors of air pollution: dynamic sonication versus other methods. Anal Chim Acta 569: 103-112.

Fazio AT, Adler MT, Bertoni MD, Sepúlveda CS, Damonte EB and Maier MS (2007). Lichen secondary metabolites from the cultured lichen mycobionts of Teloschistes chrysophthalmus and Ramalina celastri and their antiviral activities. Z Naturforsch C. 62(7-8): 543-549.

Felczykowska A, Pastuszak-Skrzypczak A, Pawlik A, Bogucka K, Herman-Antosiewicz A and Guzow-Krzeminska B (2017). Antibacterial and anticancer activities of acetone extracts from in vitro cultured lichen-forming fungi. BMC Complementary and Alternative Medicine 17(1): 300. doi: 10.1186/s12906-017-1819-8.

Fernández-Moriano C, Gómez-Serranillos MP and Crespo A (2016). Antioxidant potential of lichen species and their secondary metabolites. A systematic review. Pharm Biol. 54(1): 1-17. doi: 10.3109/13880209.2014.1003354.

Fouillaud M, Venkatachalam M, Girard-Valenciennes E, Caro Y and Dufossé L (2016). Anthraquinones and derivatives from marine-derived fungi: Structural diversity and selected biological activities. Mar Drugs 14(4): 1-64. doi: 10.3390/md14040064.

Gioanetto F (1993). Aspetti etnofarmacologici e nutrizionali dei licheni. Notiziario [Societa` Lichenologica Italiana] 5: 29–37.

Gonza´lez-Tejero MR, Martı´nez-Lirola MJ, Casares-Porcel M and Molero-Mesa J (1995). Three lichens used in popular medicine in eastern Andalucia (Spain). Econ Bot 49:96–98

Hale ME (1983). The biology of lichens. 3rd Edition. Edward Arnold Ltd. London.

Hasan T, Elanur A and Ali A (2012). Xanthoria elegans (Link) (lichen) extract counteracts DNA damage and oxidative stress of mitomycin C in human lymphocytes. Cytotechnology (2012) 64: 679–686

Hissler C, Stille P, Krein A, Geagea ML, Perrone T, Probst JL and Hoffmann L (2008). Identifying the origins of local atmospheric deposition in the steel industry basin of Luxembourg using the chemical and isotopic composition of the lichen Xanthoria parietina. Sci Total Environ. 405(1-3): 338-44. doi: 10.1016/j.scitotenv.2008.05.029.

Huneck S and Yoshimura Y (1996). *Identification of lichen substances.* Springer, Berlin, Heidelberg, New York.

Ingólfsdóttir K, Lee SK, Bhat KPL, Lee K, Chai HB, Kristinsson H, Song LL, Gills J, Gudmundsdóttir JT, Greenwood M, Jang MS and Pezzuto JM (2000). Evaluation of selected lichens from Iceland for Cancer chemopreventive and cytotoxic activity. Pharma Biol. 38(4): 313-317.

Joshi Y (2008). Morphotaxonomic studies on lichen family Teloschistaceae from India. Ph.D. thesis Kumaon University. Kumar, K. and Upreti, D.K. 2001. Parmelia spp. (Lichens) in ancient medicinal plantlore of India. Economic Botany 55(3): 458-459.

Karagöz A and Aslan A (2005). Antiviral and cytotoxic activity of some lichen extracts. Biologia Bratislava 60: 281–86.

Karagöz A, Doğruöz N, Zeybek Z and Aslan A (2009). Antibacterial activity of some lichen extracts. J Med Plants Res 3: 1034–1039.

Kumar J, Dhar P, Tayade AB, Gupta D, Chaurasia OP, Upreti DK, Arora R and Srivastava RB (2014). Antioxidant capacities, phenolic profile and cytotoxic effects of saxicolous lichens from Trans-Himalayan cold desert of Ladakh. PLoS ONE 9(6): e98696. https://doi.org/10.1371/journal.pone.0098696.

Lebail JBEF (1853). Des lichens, conside´re´s sous le point de vue e´conomique, me´dical, et physiologique (nutrition). M.D. thesis, Faculte´ de Me´decine de Paris, France.

Lindblom L. (1997). The genus Xanthoria (Fr.) Th. Fr. in North America. J. Hattori Bot. Lab. 83: 75-172.

Lindley J (1838). Flora Medica. Longman, London.

Lindley J (1849). Medical and economical botany. Bradbury and Evans, London.

Llano GA (1948). Economic uses of lichen. Economic Botany 2: 26.

Llano GA (1951). Economic uses of lichen. Ann. Rep. Smithis. Insti. Volume 385-422.

Luyken JA (1809). Tentamen historiae lichenum in genere cui accedunt primae lineae distributionis novae. Henry Dieterich, Gottingen.

Malmir M, Serrano R and Silva O (2017). Anthraquinones as potential antimicrobial agents - A review. In Antimicrobial Research: Novel Bioknowledge and Educational Programs (A. Méndez-Vilas, Ed.). Formatex Research Center, Badajoz, Spain. pp. 55-61.

Manojlovic NT, Solujic S, Sukdolak S and Krstic LJ (2000). Isolation and antimicrobial activity of anthraquinones from some species of lichen genus Xanthoria. J Serb Chem Soc 65: 555–560.

Manojlovic NT, Solujic S, Sukdolak S and Milosev M (2005). Antifungal activity of Rubia tinctorum, Rhamnus frangula and Caloplaca cerina. Fitoterapia 76: 244–246.

Manojlovic NT, Vasiljevic PJ, Gritsanapan W, Supabphol R and Manojlovic I (2010a). Phytochemical and antioxidant studies of Laurera benguelensis growing in Thailand. Biol Res 43:169–176.

Manojlovic NT, Vasiljevic PJ and Marković ZS (2010b). Antimicrobial activity of extracts and various fractions of chloroform extract from the lichen Laurera benguelensis. J Biol Res Thessaloniki 13: 27–34.

Manojlovic NT, Solujic S, Sukdolok S and Krstic LJ (2000). Isolation and antimicrobial activity of anthraquinones from some species of the lichen genus Xanthoria. J. Serb. Chem. Soc. 65(8): 555-560.

Manojlovic, Nedeljko, Novakovic M., Stević V. and Solujic S (2008). Antimicrobial metabolites from three Serbian Caloplaca. Pharmaceutical Biology 43: 718-722. 10.1080/13880200500387257.

Maulidiyah M, Hasan A, Irna WO, Nurdin IFA, Kusmalawati T, Imran, Watoni AH, Azis T and Darmawan A (2018). Antifungal potential against Aspergillus flavus: Secondary metabolite compound from unique organism of Lichen Teloschistes flavicans. Int. Res. J. Pharm. 9(8):30- 35 http://dx.doi.org/10.7897/2230-8407.098160.

Müller K (2001). Pharmaceutically relevant metabolites from lichens. Appl. Microbiol. Biotechnol 56: 9-16.

Nadkarni KM (1976). Indian materia medica. South Asia Books, India.

Nayaka S, Upreti DK and Khare R (2010). Medicinal lichens of India. In P.C. Trivedi (ed.). Drugs from Plants. Avishkar Publishers Distributors, Jaipur. pp. 1-38.

Nimis PL, Lazzarin A, Lazzarin G and Skert N (2000). Biomonitoring of trace elements with lichens in Veneto (NE Italy). Sci Total Environ 255: 97–111

Nybakken L, Solhaug KA, Bilger W and Gauslaa Y (2004). The lichens Xanthoria elegans and Cetraria islandica maintain a high protection against UV-B radiation in Arctic habitats. Oecologia 140: 211–216

Ouahiba B, Karima Y, Narimen B, Razika L and Karim A (2018). Preventive effect of Xanthoria parietina polyphenols on the complications of diabetes in white rat. Pak J Pharm Sci. 31(1 Suppl.): 317-324.

Pereira EC, Silva NH, Santos RA, Sudário APP, Silva AAR and Maia MBdeS (2010). Determination of Teloschistes flavicans (sw) norm anti-inflammatory activity. Pharmacognosy Res. 2(4): 205–210.

Saklani A and Upreti DK (1992). Folk use of lichens in Sikkim. J. Ethnopharmacology 37: 229-233.

Sancho LG, de la Torre R, Horneck G, Ascaso C, de Los Rios A, Pintado A, Wierzchos J and Schuster M (2005). Lichens survive in space: results from the 2005 LICHENS experiment. Astrobiology 7(3): 443-54.

Scerbo R, Ristori T, Possenti L, Lampugnani L, Barale R and Barghigiani C (2002). Lichen (Xanthoria parietina) biomonitoring of trace element contamination and air quality assessment in Pisa Province (Tuscany, Italy). Sci Total Environ. 286(1-3): 27-40.

Schneider A (1904). A guide to the study of lichens. Knight and Miller, Boston.

Shivanna R, Garampalli RH (2015). Evaluation of fungistatic potential of lichen extracts against Fusarium solani (Mart.) Sacc. causing Rhizome rot disease in Ginger. Journal of Applied Pharmaceutical Science 5 (10): 067-072.

Shukla V (2007). Lichens as bioindicator of air pollution. Final technical report. Science and Society Division, Department of Science and Technology, New Delhi. Project No. SSD/SS/063/2003.

Shukla V, Upreti DK and Bajpai R (2014). Lichens to biomonitor the environment. Springer, New Delhi.

Solhaug KA and Gauslaa Y (1996). Parietin, a photoprotective secondary product of the lichen *Xanthoria parietina*. *Oecologia* 108: 412-418.

Stuart D Crawford (2015). *Lichens Used in Traditional Medicine*. B. Rankovic´ (ed.), Lichen Secondary Metabolites. Springer International Publishing Switzerland. pp-27-80.

Tonning H (1769). Rariora Norvegiæ. In: Linnaeus C (ed) Amoenitates Academicæ. Sumtu & literis Laurentii Salvii, Holmiæ, pp 466–496.

Upreti DK, Bajpai R, Nayaka S and Singh BN (2015). Ethnolichenological studies in India: Future prospects. In: Jain AK (Ed) *Emerging Dimensions in Indian Ethnobotany*, Scientific publishers, Jaipur, pp 195-233.

Upreti DK and Chatterjee S (2007). Significance of lichens and their secondary metabolites: A review. In: *Fungi multifaceted microbes* (Eds. Ganguli B.N. and Deshmukh, S.K.) Anamaya Publishers, New Delhi. pp 169-188.

Upreti DK, Divakar PK and Nayaka S (2005). Commercial and ethnic use of lichens in India. *Economic Botany* 59(3): 269-273.

Vannini A, Guarnieri M, Bačkor M, Bilová I and Loppi S (2015). Uptake and toxicity of glyphosate in the lichen *Xanthoria parietina* (L.) Th. Fr. *Ecotoxicol Environ Saf*. 122: 193-7. doi: 10.1016/j.ecoenv.2015.07.030.

Vannini A, Paoli L, Vichi M, Bačkor M, Bačkorová M and Loppi S (2018). Toxicity of Diclofenac in the Fern Azolla filiculoides and the Lichen Xanthoria parietina. Bull Environ Contam Toxicol. 100(3): 430-437. doi: 10.1007/s00128-017-2266-4.

Vartia KO (1973). Antibiotics in lichens. In: The Lichens (Eds. Ahmadjian, V. and Hale, M.E.). Academic Press. New York and London. pp 547-561.

Wang LS and Qian ZG (2013). Zhong guo yao yong di yi tu jian= Illustrated medicinal lichens of China. Yunnan ke ji chu ban she, China.

Wei X, Jeon HS, Han KS, Koh YJ and Hur JS (2008). Antifungal activity of lichen-forming fungi against Colletotrichum acutatum on hot pepper. Plant Pathol J 24:202–206.

Willemet R (1787). Liche´nographie E´ conomique, ou Histoire des Lichens Utiles dans la Me´decine et dans les Arts. In: Hoffmann GF et al (eds) Me´moires sur l'utilite´ des lichens dans la me´decine et dans les arts. Chez Piestre et Delamollie`re, Lyon, pp 1–48.

Yamamoto Y, Kinoshita Y, Matsubara H, Kinoshita K, Koyama K, Takahashi K, Kurokawa T, Yoshimura I (1998). Screening of biological activities and isolation of biological-active compounds from lichens. Recent Res. Devel. in Phytochem. 2: 23-34.

Yenisoy-Karakaş S and Tuncel SG (2004). Geographic patterns of elemental deposition in the Aegean region of Turkey indicated by the lichen, Xanthoria parietina (L.) Th. Fr. Sci Total Environ. 329(1-3):43-60.