

Ecology and Distribution of Lichens in Bhadra Wildlife Sanctuary, Central Western Ghats, Karnataka, India

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ABSTRACT

This paper deals with the distribution and ecology of 152 species of lichens in different vegetation types of Bhadra wildlife sanctuary, central Western Ghats, South India. The study area covers moist and dry deciduous, semi-evergreen and montane type of vegetation. Bhadra sanctuary covers a total of 492 km² in which 67 macrolichen and 85 micro lichen species belong to 49 genera placed in 27 families were recorded. Among 152 species, 85 were crustose, 49 were foliose and 18 were fruticose. Deciduous forests represented a higher number of macrolichen (67) species followed by semi-evergreen and montane forests. Interestingly, microlichens were abundant in montane (43) and semi-evergreen (22) forest than in deciduous forest. Information of this study provided baseline data on lichen diversity in the Bhadra wildlife sanctuary, Karnataka, India.

Keywords: corticolous lichens, deciduous forest, distribution of lichens

INTRODUCTION

Bhadra Wildlife Sanctuary (BWS) is situated in the south interior part of Karnataka, Western Ghats regions distributed in parts of Chickmagalur, N.R. Pura and Tarikere taluks of Chickmagalur district and Bhadravathi taluk of Shimoga district. It lies between 75° 15' - 75° 50' E and 13° 25' - 13° 50' N latitude; the area comprises forests of Western Ghats and its adjoining areas. The sanctuary has a cool climate throughout the year and affords pleasant days during hot months (March to May). Chickmagalur is the wettest district in the Karnataka State having an annual rainfall of 2000 mm, usually distributed over 89 days. Nearly one third of rainfall is recorded during July and maximum rainfall received by southwest monsoons. Annual precipitation was recorded (200-250 cm) for the last 13 years (1994-2007). This is primarily due to high altitude, vegetation and also consequent characteristic topography of Bababudan hill tract (Raju and Hegde 1995). Vegetation of BWS is unique for its bamboo brakes, moist and dry deciduous type vegetation distributed at northern and eastern parts of the sanctuary makes it the most congenial place for lichen growth. In this ecosystem information of the lichen flora of Bhadra sanctuary forests is not available. Hence, the purpose of this paper is to offer a preliminary inventory of lichens which are distributed in BWS, providing the first contribution to knowledge of lichens, their ecology and pattern of distribution in the forest.

MATERIALS AND METHODS

A preliminary survey was carried out at different habitats by laying random 50 × 10 m transects in each chosen sites of 15 macro habitat types in BWS (Table 1). All 15 sites were taken at different altitudes ranging from 735 to 1350 masl. In each transect all substrates were thoroughly searched for the occurrence of lichens. Only representative lichen specimens were collected and packed in brown paper bags, brought in polythene bags to the laboratory. The altitude, recorded with a hand-held GPS (Garmin e-trex, USA), relative humidity (RH) (digital thermo-hygrometer, 288CTH Euro lab), temperature and microhabitat data were recorded in

each transect. Collected lichen specimens were dried for 1-2 weeks to remove all moisture content from the samples, identified on the basis of their morphology, type of fruiting bodies, anatomy and chemistry following recent literature (Walker and James 1980; Awasthi 1988; Nayaka and Upreti 2002). All lichen specimens were preserved in the herbarium of the Department of Applied Botany, Kuvempu University, Shankaraghatta, Shimoga, Karnataka and voucher specimens were submitted to the herbarium of National Botanical Research Institute, Lucknow (LWG), India. Shannon and Simpson's Diversity indices were calculated according to Magurran (1988). The relative frequency and relative density index were calculated by referring to Cottam and Curtis (1956). The Importance Value was calculated by summing the relative values for species (Species Importance Value, SIV) (Ganesh *et al.* 1996).

Table 1 Showing location number and location names at Bhadra Wildlife Sanctuary, Karnataka, India.

Locality number	Locality name
1	Thammadihalli
2	Shankaraghatta
3	Aladara
4	Lakkavalli
5	Sukhalahatti
6	Biranahalli
7	Gordgal
8	Hebbe
9	Bababudangiri
10	Kemmannugundi
11	Kagemane
12	Kodi
13	Gangegiri
14	Tegara gudda
15	Maduguni

Frequency and relative frequency were calculated by:

$$\text{Frequency} = \frac{\text{No. of quadrats in which species were studied}}{\text{Total number of quadrats studied}}$$

$$\text{Relative frequency} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$$

Density and relative density were calculated by:

$$\text{Density} = \frac{\text{Total no. of individual species}}{\text{Total number of quadrats studied}}$$

Relative density =

$$\frac{\text{Total No. of individuals of a species in all quadrats}}{\text{Total No. of individuals of all species in all quadrats}}$$

Abundance was calculated by:

Relative dominance =

$$\frac{\text{Total basal area of a species in all quadrats}}{\text{Total basal area of all the species in the quadrat}} \times 100$$

Importance Value Index (IVI) was calculated by:

$$\text{IVI} = \text{Relative frequency} + \text{Relative density} + \text{Relative dominance}$$

RESULTS AND DISCUSSION

A total of 152 species of lichens were distributed in all the surveyed localities of BWS, Karnataka. They belong to 49 genera representing 27 families. Corticolous lichens were found luxuriently, represented by 143 species, followed by 8 saxicolous and one terricolous lichen species. Crustose lichens were represented over 85 species followed by 49 foliose and 18 fruticose lichen species. Overall, the sanctuary harboured 94% corticolous, 56% crustose, 32% foliose and 12% fruticose lichens, respectively. Macrolichen species were abundant in deciduous forests represented by 67 species followed by semi-evergreen forests and montane vegetation (Table 2). Microlichens were distributed abundantly in montane and semi-evergreen forests at Kemmannugundi area. Among a total of 152 species surveyed, 117 lichens were from deciduous forests, 19 from semi-evergreen forests and 16 from montane vegetation.

The family-wise composition revealed that Parmeliaceae (26), Physciaceae (25), Graphidaceae (17) and Thelotremaaceae (16) exhibited a higher family importance value in BWS forest areas. Families like Cladoniaceae, Nephromataceae, Lobariaceae and Biotraceae are each represented by a single species (Table 3). *Parmotrema tinctorum* (Parmeliaceae) was represented by 38 individuals with an

Table 3 Family importance value (FIV) of lichen species distributed in Bhadra wildlife sanctuary (BWS), Karnataka, India.

Family	No. of species	No. of genera	FIV
Collemataceae	4	1	1.97
Caliciaceae	1	1	1.93
Strigulaceae	1	1	1.85
Coccocarpiaceae	2	1	1.81
Graphidaceae	17	3	1.52
Physciaceae	25	6	1.49
Opegraphaceae	4	1	1.48
Ramalinaceae	7	1	1.41
Arthopyrenaceae	1	1	1.35
Parmeliaceae	26	9	1.32
Teloschistaceae	2	2	1.31
Brigantiaceae	2	1	1.31
Phragmopeltheaceae	1	1	1.31
Cladoniaceae	1	1	1.29
Thelotremaaceae	16	4	1.25
Pyrenulaceae	6	1	1.21
Trichotheliaceae	7	1	1.20
Trypetheliaceae	5	2	1.16
Arthoniaceae	5	1	1.15
Lobariaceae	1	1	0.97
Megalosporaceae	1	1	0.97
Letrouitiaceae	4	1	0.95
Pertusariaceae	6	1	0.94
Lecanoraceae	4	1	0.78
Biatoraceae	1	1	0.63
Nephromataceae	1	1	0.58
Roccellaceae	1	1	0.58

IVI of 3.29 with relative density of 1.82 and relative frequency of 1.47 followed by *Leptogium burnetiae*, *Ramalina pacifica*, *Heterodermia incana* with IVI of 2.81, 2.56, 2.37, respectively. *Everniastrum nepalense* and *Cladonia* sp. showed lower IVI of 0.39 and 0.53, respectively (Table 4; Figs. 1, 2). *Parmotrema tinctorum* and *Leptogium burnetiae* were most common genera growing both in deciduous and semi-evergreen forests. *Parmotrema reticulatum* and *Ramalina pacifica*, *Ramalina conduplicans* and *Usnea galbini-fera* were rich in deciduous forests and semi-evergreen, montane forests were showed Thelotremaaceae and Graphidaceae members. Alpha diversity index, i.e., Shannon-Wiener and Simpson index was found to be 4.944 and 0.6031, respectively. Distribution of lichen species over the sanctuary was varied in relation to altitude in the studied area. At lower altitude i.e., around 620 m about 20 species of lichens were found at a higher altitude i.e., around 1563 m 8 species of lichens were distributed. Higher altitude contributed more number of fruticose lichens and at lower altitude found more number of foliose and crustose lichens. It was observed that higher the altitude lower the species distribution and lower the altitude higher the distribution of

Table 2 Different types of vegetation, altitude and lichen species collected from different locations of Bhadra Wildlife Sanctuary (BWS), Karnataka, Southern India.

Locations in BWS	Altitude (m)	Vegetation type	No. of lichen species recorded
Aldhara	732	Dry deciduous	11
Bababudangiri.	1563	Montane	8
Gangegiri	800	Semi-evergreen	10
Hebbe	674	Semi-evergreen	9
Kemmannugundi	1387	Montane	8
Kagemanegiri	900	Moist deciduous	7
Kodi	778	Moist deciduous	13
Lakkavalli	625	Moist deciduous	20
Gordgal	802	Moist deciduous	6
Madhuguni	890	Moist deciduous	8
Shankaraghatta	638	Dry deciduous	12
Biranahalli	706	Dry deciduous	9
Sukhalahatti	802	Moist deciduous	12
Tegaragudda	974	Moist deciduous	8
Thammadihalli	621	Dry deciduous	11

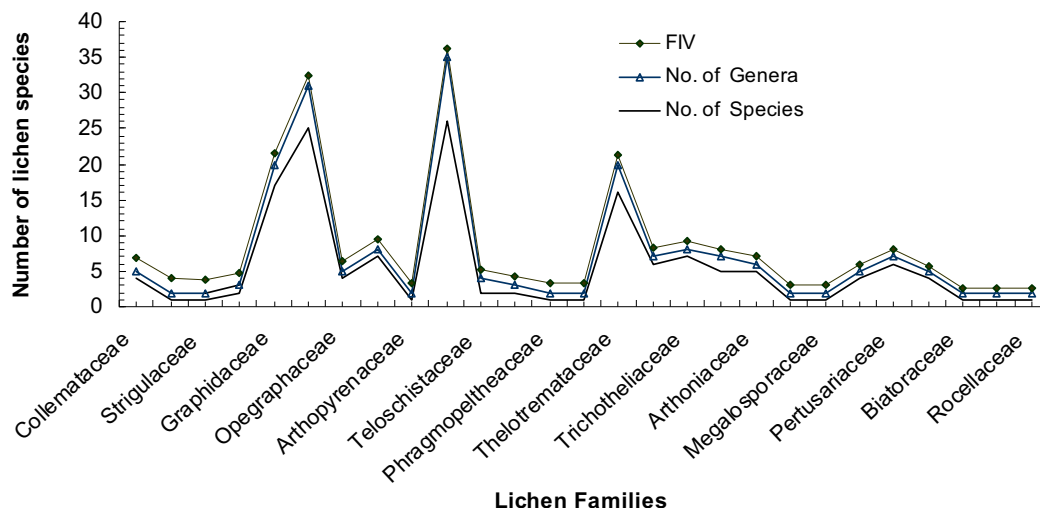


Fig. 1 Relation between number of lichen species and Family Importance Value in Bhadra Wildlife Sanctuary, Karnataka, India.

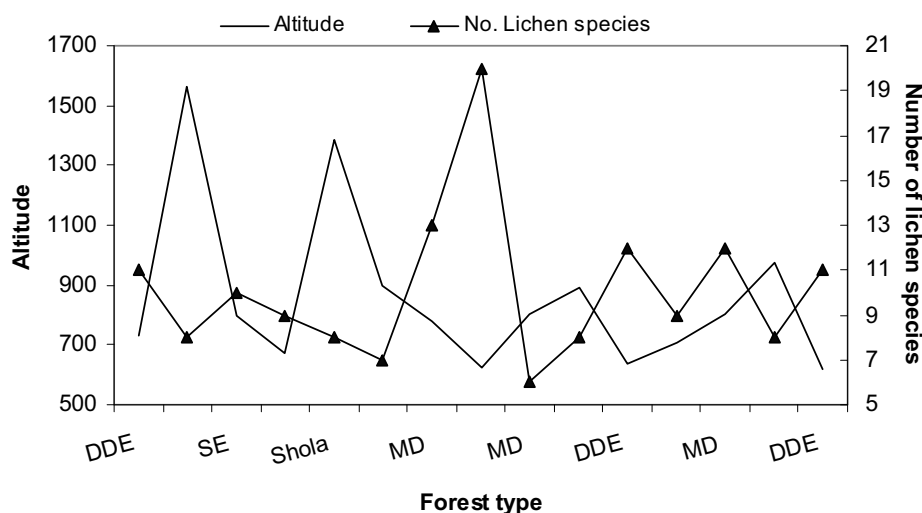


Fig. 2 Number of lichen species distributed in relation to altitude in Bhadra Wildlife Sanctuary, Karnataka, India. DDE: dry deciduous forest; SE: semi-evergreen; MD: moist deciduous.

Table 4 Top 20 species of lichens in Bhadra wildlife sanctuary (BWS), Karnataka based on their IVI and abundance.

Species	Family	G	I	II	III	D	F	Ab	RD	RF	IVI
<i>Parmotrema tinctorum</i> (Despr. ex Nyl.) Hale	Parmeliaceae	F	15	15	38	2.53	1	2.53	1.82	1.47	3.29
<i>Leptogium burnetiae</i> Dodge	Collemaataceae	F	15	13	32	2.13	0.86	2.46	1.53	1.27	2.81
<i>Ramalina pacifica</i> Asahina	Ramalinaceae	Fr	15	12	29	1.93	0.8	2.42	1.39	1.17	2.56
<i>Heterodermia incana</i> (H.Magn.) D.D. Awasthi	Physciaceae	F	15	11	27	1.8	0.73	2.45	1.29	1.08	2.37
<i>Parmotrema stuppeum</i> (Taylor) Hale	Parmeliaceae	F	15	14	18	1.2	0.93	1.29	0.86	1.37	2.23
<i>Heterodermia albidiflava</i> (Kurok.) D.D. Awasthi	Physciaceae	F	15	10	25	1.66	0.66	2.5	1.2	0.98	2.18
<i>Leptogium chloromelum</i> (Sw.) Nyl.	Collemaataceae	F	15	10	25	1.67	0.66	2.5	1.2	0.98	2.18
<i>Graphina junghunii</i> (Mont & v.d.Bosh) Mull. Arg.	Graphidaceae	C	15	11	23	1.53	0.73	2.09	1.1	1.08	2.18
<i>Graphis grammatis</i> Fee	Graphidaceae	C	15	12	20	1.33	0.8	1.67	0.96	1.17	2.13
<i>Heterodermia angustiloba</i> (Mull. Arg.) D.D. Awasthi	Physciaceae	F	15	12	19	1.26	0.8	1.58	0.91	1.17	2.08
<i>Pyxine cocoes</i> (Sw.) Nyl.	Physciaceae	F	15	10	23	1.53	0.66	2.3	1.1	0.98	2.08
<i>Graphina nylanderii</i> Patw. & Kulk.	Graphidaceae	C	15	12	19	1.26	0.8	1.58	0.91	1.17	2.08
<i>Opegrapha leptoterodes</i> Nyl.	Opegraphaceae	C	15	10	23	1.53	0.67	2.3	1.1	0.98	2.08
<i>Graphis longiramea</i> Mull. Arg.	Graphidaceae	C	15	11	19	1.26	0.73	1.73	0.91	1.08	1.99
<i>Heterodermia diademata</i> (Taylor) D.D. Awasthi	Physciaceae	F	15	9	23	1.53	0.6	2.56	1.1	0.88	1.98
<i>Thelotrema canarensis</i> Patw. & Kulk.	Thelotremataceae	C	15	10	21	1.4	0.66	2.1	1.01	0.98	1.98
<i>Coccocarpia erythroxyli</i> (Spreng.) Swinsc. & Krog	Coccocarpiaceae	F	15	9	22	1.46	0.6	2.44	1.05	0.88	1.93
<i>Cyphelium sessile</i> (Pers.) Trevisan	Caliciaceae	C	15	9	22	1.46	0.6	2.44	1.05	0.88	1.93
<i>Heterodermia dissecta</i> (Kurok.) D.D. Awasthi	Physciaceae	F	15	9	21	1.4	0.6	2.33	1.01	0.88	1.89
<i>Ramalina arabum</i> (Ach.)	Ramalinaceae	F	15	9	20	1.33	0.6	2.22	0.96	0.88	1.84
Rest of all other species						0.8206	0.4061	2.1126	0.5913	0.5995	1.192

I- total number of transect studied, II- number of transect in which species were occurred, III- number of individuals, Ab- abundance, C- crustose, D- density, F- frequency, F- foliose, Fr- fruticose, G- growth form, IVI- important value index, RD- relative density, RF- relative frequency

number of species in these forests. A list of 25 species commonly occurred frequently along different types of forests are given in Annex 1.

Among 8 lichenogeographic regions of India, Western Ghats secures first position in terms of higher lichen diversity with 800 species and occupy second in terms of ende-

mism with 140 species (Singh and Sinha 1997). Species known so far from Indian subcontinent are about 50% belonging to the crustose forms, most of which have not been collected a second time. A great majority of these were corticolous Pyrenocarpus, Graphidaceae and Thelotrema-taceous lichens which are widely distributed in tropical countries (Awasthi 1977). Generally, lichen flora shows strong correlation with the climatic conditions and arboreal elements of the flora of the regions. Inventory of the present study showed that the distribution of lichens mutually varied with climatic conditions in the deciduous forest had higher number of macrolichens, where as montane forests consisted high number of microlichens.

The present study recorded a rich diversity of lichens with a total of 152 species representing 49 genera in BWS. Tropical dry evergreen forest of Guindy National Park, Chennai, in India showed distribution of 31 lichens from 26 genera (Balaji and Hariharan 2004). The studies conducted at Garwal Himalaya region reported 85 species from 15 genera among 13 families (Negi 2000). Most areas of BWS are dominated by moist and dry deciduous forests as these types of vegetation supports luxuriant growth of macrolichens. The macrolichen species growing very common in these forests are *Dirinaria*, *Pyxine*, *Lecanora*, *Heterodermia*, *Parmotrema*, *Usnea*, *Ramalina* and several other species.

The distribution pattern of lichen communities depends on micro climatic conditions such as light, water relations and insolation (Canters *et al.* 1991; Wolseley and Hudson 1997a). Negi (2000) found that over 64% of lichen species occurred on the woody component in two landscapes of Chopta-Tungnath and Nanda Devi Biosphere reserve in India. A higher diversity in evergreen forests is associated with an increase in crustose species and lower foliose species. In dry deciduous forests the diversity of crustose and foliose lichens varied due to fire disturbance and forest history (Wolseley and Hudson 1997b).

BWS represents a higher number of corticolous lichens (94.07%) and high altitude locations contain low percentage of lichens compared with plain areas. This is true in a study where a total of 76 species of macrolichens were recorded at high altitude region from 16 transects at Nanda Devi Biosphere in northern part of India and suggested that deforestation, fuel wood collection, grazing and forest fires are the major threat to lichen diversity in the region (Negi and Gadgil 1996). Pinakiyo *et al.* (2008) reported the diversity and distribution of corticolous lichens (133 species) in north east India. The forests of BWS have abundant growth of lichens due to prevailing favorable tropical climatic conditions. It is understood that the forests of high altitude areas often receive high precipitation, frequent fog and optimal temperature that leads to the formation of crustose lichens whereas forests of low altitude areas have deciduous forests which are exposed to variable climatic conditions with high temperature during summer resulting in the growth of foliose and fruticose lichens.

This is the first report of the occurrence and distribution of lichen species in BWS. Lichen flora of BWS is remarkably rich and diverse with a representation of 152 species. This documentation is further useful for understanding the distribution of bioresources of lower plants in the area. The baseline information on lichens in BWS will be useful for conservation policy making and biomonitoring studies keeping in view global warming and climatic change.

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Annex 1 Distribution of top 25 lichen species in the sanctuary

1. *Bulbothrix isidiza* (Nyl.) Hale (Parmeliaceae) Semi-evergreen forests of Hebhe 674 m. Specimen No. KU00036
2. *Coccocarpia erythroxyli* (Spreng.) Swinsc. and Krog (Coccocarpiaceae) Shola forests of Bababudangiri, 1563 m. Specimen No. KU000721
3. *Cyphelium sessile* (Pers.) Trevisan (Caliciaceae) Semi-evergreen forests of Hebhe and way to Gangegiri 800 and 674 m. Specimen No. KU20661
4. *Graphina junghunii* (Mont and v. d. Bosh) Mull. Arg. (Graphidaceae) Semi-evergreen forests of Hebhe 674 m. Specimen No. KU20588
5. *Graphina nylanderii* Patw. and Kulk. (Graphidaceae) Semi-evergreen and Shola forests of Kemmannugundi and Gangegiri, 800 and 1387 m. Specimen No. KU20221
6. *Graphis grammatis* Fee (Graphidaceae) Semi-evergreen and Deciduous forests of Kemmannugundi and Shankaraghatta 635 and 1387 m. Specimen No. KU20403
7. *Graphis longiramea* Mull. Arg. (Graphidaceae) semi-evergreen forests of Gangegiri, 800 m. Specimen No. KU20558
8. *Heterodermia albidiflava* (Kurok.) D.D.Awasthi (Physciaceae) Moist and Dry Deciduous forests of Maduguni and Biranahalli 890 and 706 m. Specimen No. KU00054
9. *Heterodermia angustiloba* (Mull. Arg.) D.D.Awasthi (Physciaceae) Moist deciduous forests of Kagamanegiri and Sukalhatti, 900 and 802 m. Specimen No. KU00110
10. *Heterodermia diademata* (Taylor) D.D.Awasthi (Physciaceae) Moist and dry deciduous forests of Maduguni and Biranahalli, 890 and 706 m. Specimen No. KU00043
11. *Heterodermia dissecta* (Kurok.) D.D.Awasthi (Physciaceae) Dry and moist deciduous forests of Maduguni and Shankaraghatta, 890 and 638 m. Specimen No. KU00058
12. *Heterodermia incana* (H. Magn.) D.D.Awasthi (Physciaceae) Moist and dry deciduous forests of Gordgal, Tegaragudda, Shankaraghatta and Kagamanegiri, 802, 974, 638 and 900 m. Specimen No. KU00053
13. *Leptogium burnetiae* Dodge (Colemataceae): Semi-evergreen and moist deciduous forests of Hebhe and Kodi, 674 and 778 m. Specimen No. KU00166
14. *Leptogium chloromelum* (Sw.) Nyl. (Physciaceae) Shola and semi-evergreen forests of Kemmannugundi and Hebhe, 1387 and 674 m. Specimen No. KU00169
15. *Opegrapha leptoterodes* Nyl. (Opegraphaceae) Shola forests of Bababudangiri, 1563 m. Specimen No. KU20331
16. *Parmotrema cristiferum* (Taylor) Hale (Parmeliaceae) Moist and Dry deciduous forests of Lakkavalli, Shankaraghatta, 625 and 750 m. Specimen No. KU00274
17. *Parmotrema hababianum* (Gyeln.) Hale (Parmeliaceae) Moist deciduous forests of Lakkavalli and Kodi, 625 and 750 m. Specimen No. KU00157
18. *Parmotrema stuppeum* (Taylor) Hale (Parmeliaceae) Shola and dry, moist deciduous forests of Kemmannugundi, Shankaraghatta, Madhuguni 1387, 638 and 890 m. Specimen No. KU00409
19. *Parmotrema tinctorum* (Despr. ex Nyl.) Hale (Parmeliaceae): dry and moist deciduous forests of Aldhara and Lakkavalli, 732 and 625 m. Specimen No. KU00272.
20. *Pyxine cocoes* (Sw.) Nyl. (Physciaceae) Moist and dry deciduous forests of Kagamanegiri, Thammadihalli, Shankaraghatta, 900, 621 and 638 m. Specimen No. KU00221
21. *Ramalina arabum* (Ach.) (Ramalinaceae) dry deciduous and semi-evergreen forests of Shankaraghatta, way to Gangegiri 638 and 800 m. Specimen No. KU00352
22. *Ramalina conduplicans* Vain. (Ramalinaceae) Deciduous forests of Shankaraghatta, 638 m. Specimen No. KU00314
23. *Ramalina pacifica* Asahina (Ramalinaceae): Shola and dry deciduous forests of Kemmannugundi and Shankaraghatta 1387 and 638 m, Specimen No. KU00350
24. *Thelotrema canarense* Patw. and Kulk. (Thelotremataceae) Semi-evergreen and shola forests of Gangegiri and Kemmannugundi, 800 and 1387 m. Specimen No. KU20551
25. *Usnea galbinifera* Asahina. (Parmeliaceae) Deciduous forests of Tegaragudda and Shankaraghatta, 950 and 650 m. Specimen No. KU00341

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