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Host specificity of epiphytic macrolichens: a case study of Jageshwar forest (Uttarakhand) India

YOGESH JOSHI[1*], MANISH TRIPATHI[1], ZOYA JINNAH[1], KAPIL BISHT[3] & DALIP K. UPRETI[2]

[1]*Lichenology Division, Department of Botany, S.S.J. Campus, Kumaun University, Almora 263601, Uttarakhand, India*

[2]*Principal Scientist, Lichenology Laboratory, National Botanical Research Institute, Rana Pratap Marg, Lucknow 226001, Uttar Pradesh, India*

Abstract: We describe epiphyte-host relationships of macrolichens in the Jageshwar region of the Almora district, Uttarakhand, India. A total of 435 colonies of macrolichens – from twenty, 10 m × 10 m plots distributed across four stand types at an elevation of 1870 m in Kumaun Himalaya - yielded 8 families, with 26 genera, 44 species and 2 varieties. *Flavoparmelia caperata, Heterodermia obscurata, Parmotrema reticulatum, Parmotrema tinctorum, Punctelia subrudecta, Ramalina* and *Usnea* sp. stood out as broad-niched generalist species, since they were found in all the trees examined. *Cetrelia braunsiana* and *Pseudocyphellaria crocata* appeared to be rare members of the community, since they were encountered only once during the field survey and were found growing on a single tree. Of the 46 taxa recorded in four stand types, 63.0 % species occurred in *Quercus* stands, followed by *Pinus* (54.3 %), *Cedrus* (52.2 %) and *Juniperus* (34.8 %). In addition, our study revealed the occurrence of *Remototrachyna adducta* (Nyl.) Divakar & A. Crespo growing on the bark of *Pinus* and *Cedrus*, a new regional record for Western Himalaya, extending its distribution range within India, since this species was previously thought to be confined to the Eastern Himalaya.

Resumen: Describimos las relaciones epífita-forofito de los macrolíquenes en la región de Jageshwar del distrito Almora, Uttarakhand, India. Un total de 435 colonias de macrolíquenes – registradas en 20 parcelas de 10 m × 10 m distribuidas en cuatro tipos de rodales a una elevación de 1870 m en el Himalaya Kumaun - albergaron 8 familias con 26 géneros, 44 especies y 2 variedades. *Flavoparmelia caperata, Heterodermia obscurata, Parmotrema reticulatum, Parmotrema tinctorum, Punctelia subrudecta, Ramalina y Usnea* sp. destacaron como especies generalistas con nichos amplios, ya que fueron encontradas en todos los árboles examinados. *Cetrelia braunsiana* y *Pseudocyphellaria crocata* se revelaron como miembros raros de la comunidad, ya que fueron encontrados solamente una vez durante el trabajo de campo y fueron observados creciendo en un único árbol. De los 46 taxa registrados en cuatro tipos de rodal, 63.0 % de las especies estuvieron presentes en rodales de Quercus, seguidos por los de *Pinus* (54.3 %), *Cedrus* (52.2 %) y *Juniperus* (34.8 %). Además, nuestro estudio reveló la presencia de *Remototrachyna adducta* (Nyl.) Divakar & A. Crespo creciendo sobre la corteza de *Pinus* y *Cedrus*, un nuevo registro regional para el Himalaya Occidental, aumentando su área de distribución dentro de la India, ya que previamente se pensaba que esta especie estaba confinada al Himalaya Oriental.

Resumo: Descrevem-se as relações epífitas-hospedeiro de macro-líquenes na região de Jageshwar no distrito de Almora, Uttarakhand, na Índia. Um total de 435 colónias de macro-líquenes - de uma amostra de vinte parcelas de 10 m × 10 m distribuídas em quatro tipos de talhões a uma altitude de 1.870 m em Kumaun Himalaya - mostrou a presença de oito famílias,

[*]*Corresponding Author*; e-mail: dryogeshcalo@gmail.com

com 26 géneros, 44 espécies e 2 variedades. A *Flavoparmelia caperata, Heterodermia obscurata, Parmotrema reticulatum, Parmotrema tinctorum, Punctelia subrudecta, Ramalina e Usnea* sp. destacaram-se como espécies generalistas num nicho amplo, uma vez que foram encontradas em todas as árvores analisadas. A *Cetrelia braunsiana* e a *Pseudocyphellaria crocata* pareciam ser membros raras da comunidade, uma vez que só foram encontradas apenas uma vez durante o levantamento de campo e crescendo numa única árvore. Dos 46 táxon registados nos quatro tipos de talhões, 63,0 % das espécies ocorreram em talhões de Quercus, seguido por Pinus (54,3 %), *Cedrus* (52,2 %) e *Juniperus* (34,8 %). Além disso, o nosso estudo revelou a ocorrência de *Remototrachyna adducta* (Nyl.) Divakar & A. Crespo crescente na casca de *Pinus* e *Cedrus*, um novo registo regional para os Himalayas ocidentais, estendendo sua área de distribuição na Índia, uma vez que inicialmente se pensava que esta espécie estava confinada aos Himalaias Orientais.

Key words: Epiphytes, stand, forest, macrolichens, Kumaun Himalaya, Uttarakhand.

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Introduction

In forested areas the diversity of lichens is variable, with supporting host trees providing space for different type of lichens. Some lichens show preference for certain trees, mostly based on the nature of the bark as well as micro climatic and chemical conditions (Barkman 1958). Understanding host preferences is an important aspect of lichen ecology, since these organisms play an important role in forest ecosystems, as they contribute to forest biodiversity (Dettki & Esseen 1998; Kuusinen & Siitonen 1998; Lesica *et al.* 1991; Pharo *et al.* 1999), are used as forage by many animals (Rosentreter *et al*. 1997; Zabel & Waters 1997), provide nesting material for birds (Hayward & Rosentreter 1994; Starkey & Hagar 1999), constitute preferred habitat for many invertebrates (Pettersson *et al*. 1995) and are involved in nutrient cycling (Boucher & Nash 1990; Esseen *et al*. 1996; Knops *et al*. 1991; Pike 1978). Knowledge of the degree of host specificity of lichens is also useful in estimating their diversity and conservation. There are several publications available on the lichen-phorophyte relationships from Europe and other countries (Christopher 2012; Cobanoglu & Sevgi 2009; Mežaka *et al*. 2008; Ozturk *et al*. 2010; Wannebo-Nilsen *et al*. 2010); however, only scant information is available for Indian lichens (Dudgeon 1923; Sequiera & Kumar 2008; Satya *et al*. 2005; Upreti 1996; Upreti & Chatterjee 1999).

As indicated by Gadgil (1996), Negi & Gadgil (1996, 1997), and Negi (1999, 2000), floristic inventories in India - particularly of lower plants - suffer from a lack of uniform field methods; hence, proper methodology for documenting floristic diversity with ecological correlates should be a prerequisite for inventorying, periodic monitoring, and conservation of bio-resources. While there have been systematic studies on macrolichens for several decades, investigations of their community ecology have only recently begun in India (Awasthi 1988; Negi 1999; Negi & Gadgil 1996; Negi & Upreti 2000). This has led us to work on lichen-phorophyte relationship in Jageshwar, with certain questions in mind:

1. What is the diversity of epiphytic macrolichens in Jageshwar?
2. Does the species composition differ between different stand types?
3. Which phorophytes are most important for the lichen flora in the area? Answers to these questions are important since community studies have now shifted from larger spatial scales to locally manageable landscapes because land use decisions and management policies are most often implemented at local scales (Nagendra & Gadgil 1999; Negi 1999; Ricklefs & Schluter 1993).

Materials and methods

Study site

Jageshwar, an isolated and small village, spread over an area of about 2 km^2 along both banks of the Jataganga river (79° 36'E, 29° 36'N), is situated at 1870 m above mean sea level and 37 km north east of Almora on main road to Pithoragarh. Because of its high religious impor-

tance (ca. 150 shrines of various Gods and Goddesses), the village is facing heavy anthropogenic pressure and is under legal protection of Archaeological Survey of India. Hence we wanted to check the lichen diversity of the study area, so that in near future these baseline data can be used for climate change and environmental studies. One of the main characteristics of Jageshwar forest is the high frequency of *Cedrus deodara* that forms large areas of pure stands. About 95 % of the total area is covered by *C. deodara* trees, with a few pure stands of *Quercus leucotricophora*, *Pinus roxburghii* and *Juniperus communis* also present. *Aesculus indica* and *Taxus baccata* are also found in the study area, but do not form stands and have a discontinuous distribution, hence they were excluded from the study. The individual trees in the study area are often very old, with thick trunks that measure 425 cm in diameter or more.

Sampling and data analysis

Sampling was done in May - June 2013. According to coverage area of these forests, 20 quadrats (5 quadrats per stand type), each 10 m x 10 m in size, were laid out randomly for sampling of the epiphytic macrolichen flora. An exhaustive search and representative collection of all colonies of macrolichens were carried out in each stand. A contiguous patch with an area of 1 cm^2 covering individuals of recognizable taxonomic units (RTUs) identified based on morphological differences was defined as a colony of that taxon, irrespective of association with individuals of other taxa. The specimens were examined morphologically, anatomically and chemically based on published floras (Awasthi 2007; Divakar & Upreti 2005; Orange *et al.* 2001). Collected specimens are deposited at the herbarium of Kumaun University (ALM). The scientific names are given based on Singh & Sinha (2010).

Results and discussion

Four different host tree stands were recorded from 20 quadrats, with sampling for epiphytic macrolichens performed on 93 trees (Table 1). A total of 8 families with 26 genera, 44 species and 2 varieties from 432 colonies sampled over 2 km^2 constituted the epiphytic macrolichen community of Jageshwar. On average, 23.5 species were found on each stand, with the number varying from 16 species on *Juniperus* to 29 on *Quercus* (Table 1).

Quercus and *Pinus* were the most species-rich phorophytes, hosting about 29 and 25 species, respectively. *Cedrus* had the third most taxa (24), followed by *Juniperus* (16). Fifty two percent of the species, 57.7 % of the genera and 62.5 % of the families were confined to *Cedrus*; 63.0 % of the species, 61.5 % of the genera and 75.0 % of the families to *Quercus*; 54.3 % of the species, 57.7 % of the genera and 50.0 % of the families to *Pinus*; and 34.8 % of the species, 46.2 % of the genera, and 50.0 % of the families were confined to *Juniperus*. If RTUs are considered, *Cedrus* and *Quecus* were excellent host to lichens, followed by *Pinus* and *Juniperus* (Table 1). The nine lichen species found on *Juniperus* represent a fairly high number, since this phorophyte is scarce in this forest community. Additional study of this phorophyte may lead to numbers comparable to those for *Quercus, Pinus* and *Cedrus*.

The most common lichen species (>30 records on trees) were *Parmotrema reticulatum, P. tinctorum* and *Usnea*; however, *Flavoparmelia caperata, Heterodermia obscurata, P. reticulatum, P. tinctorum, Punctelia subrudecta, Ramalina* and *Usnea* sp. were broad-niched generalist species occurring frequently in all trees, and constituted 15.2 % of the generalist species. About 19 species of macrolichens were found to have a narrow niche and were considered host-specific (Table 1). For example, *Pseudocyphellaria crocata* and *Cetrelia braunsiana* were found only on *Cedrus deodara*. In addition, these two species were encountered only once during the study period, hence they can be considered rare members of the community in the study site. The species richness of epiphytic macrolichen species varied among tree species, and was highest for *Pinus* (170), followed by *Quercus* (149), *Cedrus* (88), and *Juniperus* (25) (Table 1).

Thirty nine species of lichens with green alga as a photobiont, and 3 species with blue-green alga as a photobiont, were common to all the stands; however, the abundance and frequency of green-algal lichens were far greater than blue-green. Therefore, the green-algal lichens were considered to have a broader niche with respect to their habitat preference.

Remototrachyna adducta, which was found growing on the bark of *Pinus* and *Cedrus*, is reported as new to Western Himalaya (Joshi *et al.* 2014). Previously the species was reported only from Eastern Himalaya (Divakar & Upreti 2005; Singh & Sinha 2010). In addition, we observed pruinosity (i.e. powdery mass of calcium oxalate crystals on thallus surface) in some specimens of *Parmotrema tinctorum* and *Bulbothrix meizospora*, which has not been reported previously by workers

Table 1. Host specificity of epiphytic macrolichen species in Jageshwar forest, Almora district, Uttarakhand (Number of tree trunks for species is given in brackets).

Lichenized fungal species	Family	Algal partner	Host tree genus				Total number of colonies of lichens
			Pinus (32)	*Cedrus* (26)	*Juniperus* (8)	*Quercus* (27)	
Bulbothrix isidiza (Nyl.) Hale	Parmeliaceae	Green	(1)	(0)	(1)	(2)	4
B. meizospora (Nyl.) Hale	Parmeliaceae	Green	(0)	(0)	(0)	(2)	2
B. setschwanensis (Zahlbr.) Hale	Parmeliaceae	Green	(0)	(0)	(0)	(4)	4
Candelaria concolor (Dicks.) Stein	Candelariaceae	Green	(0)	(0)	(0)	(5)	5
Canomaculina subtinctoria (Zahlbr.) Elix	Parmeliaceae	Green	(1)	(0)	(0)	(0)	1
Canoparmelia aptata (Kremp.) Elix & Hale	Parmeliaceae	Green	(0)	(0)	(0)	(1)	1
C. ecaperata (Müll. Arg.) Elix & Hale	Parmeliaceae	Green	(1)	(1)	(0)	(0)	2
C. texana (Tuck.) Elix & Hale	Parmeliaceae	Green	(15)	(5)	(1)	(5)	26
Cetrelia braunsiana (Müll. Arg.) W.L. Culb. & C.L. Culb.	Parmeliaceae	Green	(0)	(1)	(0)	(0)	1
Cladonia sp.	Cladoniaceae	Green	(10)	(3)	(0)	(0)	13
Collema sp.	Collemataceae	Blue green	(0)	(0)	(1)	(0)	1
Dirinaria sp.	Physciaceae	Green	(0)	(1)	(0)	(0)	1
Flavoparmelia caperata (L.) Hale	Parmeliaceae	Green	(25)	(4)	(4)	(4)	37
Heterodermia diademata (Taylor) D.D. Awasthi	Physciaceae	Green	(3)	(2)	(0)	(4)	9
H. firmula (Nyl.) Trevis.	Physciaceae	Green	(0)	(0)	(0)	(2)	2
H. incana (Stirton) D.D. Awasthi	Physciaceae	Green	(1)	(0)	(1)	(0)	2
H. japonica (Sato) Swinsc. & Krog	Physciaceae	Green	(4)	(1)	(0)	(0)	5
H. obscurata (Nyl.) Trevis.	Physciaceae	Green	(6)	(5)	(1)	(6)	18
H. pseudospeciosa (Kurok.) W.L. Culb.	Physciaceae	Green	(3)	(8)	(0)	(0)	11
Hyperphyscia adglutinata (Flörke) H. Mayerhofer & Poelt	Physciaceae	Green	(0)	(0)	(0)	(1)	1
Hypotrachyna exsecta (Taylor) Hale	Parmeliaceae	Green	(1)	(0)	(0)	(0)	1
H. osseoalba (Vain.) Y.S. Park & Hale	Parmeliaceae	Green	(6)	(1)	(0)	(0)	7
Leptogium sp.	Collemataceae	Blue green	(0)	(0)	(1)	(1)	2
Myelochroa aurulenta (Tuck.) Elix & Hale	Parmeliaceae	Green	(3)	(0)	(2)	(16)	21

Contd...

Table 1. Continued.

Lichenized fungal species	Family	Algal partner	Host tree genus				Total number of colonies of lichens
			Pinus (32)	*Cedrus* (26)	*Juniperus* (8)	*Quercus* (27)	
Parmelinella wallichiana (Taylor) Elix & Hale	Parmeliaceae	Green	(2)	(1)	(0)	(0)	3
Parmelinopsis horrescens (Taylor) Elix & Hale	Parmeliaceae	Green	(2)	(0)	(0)	(0)	2
Parmotrema crinitum (Ach.) Choisy	Parmeliaceae	Green	(0)	(2)	(1)	(10)	13
P. hababianum (Gyeln.) Hale	Parmeliaceae	Green	(0)	(0)	(0)	(11)	11
P. praesorediosum (Nyl.) Hale	Parmeliaceae	Green	(0)	(0)	(0)	(1)	1
P. reticulatum (Taylor) Choisy	Parmeliaceae	Green	(24)	(12)	(4)	(17)	57
P. saccatilobum (Taylor) Hale	Parmeliaceae	Green	(2)	(1)	(1)	(0)	4
P. tinctorum (Despr. ex Nyl.) Hale	Parmeliaceae	Green	(14)	(13)	(2)	(3)	32
Phaeophyscia hispidula (Ach.) Essl.	Physciaceae	Green	(0)	(0)	(0)	(3)	3
P. hispidula var. *exornatula* (Zahlbr.) Moberg	Physciaceae	Green	(0)	(0)	(0)	(1)	1
P. orbicularis (Neck.) Moberg	Physciaceae	Green	(0)	(0)	(1)	(2)	3
Phyllopsora sp.	Biatoracaae	Green	(0)	(0)	(0)	(1)	1
Physcia dilatata Nyl.	Physciaceae	Green	(0)	(0)	(0)	(17)	17
Pseudocyphellaria crocata (L.) Vain.	Lobariaceae	Blue green	(0)	(1)	(0)	(0)	1
Punctelia rudecta (Ach.) Krog.	Parmeliaceae	Green	(5)	(6)	(0)	(1)	12
P. subrudecta (Nyl.) Krog	Parmeliaceae	Green	(3)	(2)	(1)	(15)	21
Pyxine berteriana var. *himalaica* D.D. Awasthi	Physciaceae	Green	(0)	(0)	(0)	(2)	2
P. subcinerea Stirt.	Physciaceae	Green	(0)	(1)	(0)	(1)	2
Ramalina sp.	Ramalinaceae	Green	(4)	(2)	(1)	(11)	18
Remototrachyna adducta (Nyl.) Divakar & A. Crespo	Parmeliaceae	Green	(1)	(2)	(0)	(0)	3
R. infirma (Kurok.) Divakar & A. Crespo	Parmeliaceae	Green	(11)	(3)	(0)	(0)	14
Usnea sp.	Parmeliaceae	Green	(22)	(10)	(2)	(3)	37
Total	8		170	88	25	152	435

from India as well as across the world (Divakar & Upreti 2005).

Forests are habitats with complex ecological gradients that provide habitat for a rich assemblage of epiphytic angiosperms (Mondragon *et al.* 2015) as well as various cryptogams, such as lichens. Lichen communities change as a forest changes. The number of species, as well as other higher ranks of taxonomic organization in a site (e.g. species richness or alpha diversity), and their compositional change across different habitat types (species turnover or beta-diversity) within a landscape, are important measures of biodiversity that have wide applications, such as environmental monitoring and conservation evaluation (Negi 1999; Pressey *et al.* 1994).

Previous floristic studies in India, particularly on lower plants, have lacked objective-oriented field methods, partly hindering the progress of long-term monitoring of biological diversity and its conservation (Gadgil 1996; Negi & Gadgil 1997; Negi 1999). In the present study, a methodological approach was adopted that would facilitate comparable studies and periodic monitoring of such taxa in near future. Although the findings presented here are from a relatively small area (about 2 km^2), the study points the way towards site-specific representative inventorying and monitoring of the diversity of macrolichens in Jageshwar.

The macrolichen flora of Jageshwar has, through this investigation, become better known than previously, but cannot be considered as well known. The habitats vary greatly and any new locality that is investigated thoroughly adds to the knowledge of the macrolichen flora. However, we can state that the macrolichen flora of Jageshwar is rich, although perhaps not as rich as that found in some other localities of Uttarakhand. Upreti & Chatterjee (1999) recorded the distribution of lichens on *Quercus* and *Pinus* trees in different forests of Pithoragarh district. *Q. semicarpifolia* exhibited the maximum occurrence of lichens, represented by 24 species in the Nainsingh Top area. The Barabey forest area exhibited 9 species of lichens on *Q. leucotricophora*, while the Chandak forest area, having pure stands of *Pinus roxburghii*, had 21 epiphytic lichen species. Similarly, in their study on lichens of Almora district, Upreti & Chatterjee (2000) reported that *Pinus roxburghii* trees of the Karbala region, exhibited the occurrence of 19 species of lichens, while *Q. leucotricophora* and *Betula alnoides* forests in the Loharkhet-Dhakuri region showed occurrence of 68 species of lichens. However, the Dhakuri, Khati and Dwali regions, which are dominated by *Q. semicarpifolia* trees, harbor 23 species of lichens, while *Betula utilis* trees in the Dwali-Kafni forest area harbored 20 species of lichens. The disparity of richness in the Jageshwar forest may be attributed to the fact that, although the forest is managed by the local people for cutting and lopping, there is no control over grazing of the undergrowth or collection of dry fuel wood.

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