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CORTICOLOUS LICHEN SPECIES DIVERSITY ON DOMINANT TREES IN SELECTED SACRED GROVES OF PASCHIM MEDINIPUR DISTRICT, WEST BENGAL, INDIA

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Sacred groves are the fairly well-protected system of community-based conservation of tree patches on account of their association with village gods, and repository of many rare and threatened elements of biodiversity. There are, however, few publications on lichens of sacred groves. The lichens have long been regarded as sensitive indicators for monitoring environmental state. The present study reports one hundred and sixteen species of lichens from forty-four genera of nineteen families in four selected sacred groves of Paschim Medinipur district, West Bengal. These lichens represent two different growth forms, i.e. crustose (105 species) and foliose (11 species). *Shorea robusta*, a dominant tree species in two sacred groves bears the highest lichen diversity with seventy-four species. To better understand the related biodiversity and climate, this work is likely to promote further studies on lichen diversity in other regions of West Bengal.

Key words: conservation, diversity, dominant species, India, sacred grove

INTRODUCTION

Lichens are an exciting symbiotic combination of green unicellular algae or cyanobacteria and fungi that flourish in a multitude of habitats and are most common in subtropical and temperate environments in India. For better development, these involve elevated humidity concentrations and can readily develop on the plant's soil, bark, and leaf, and rocks. Lichen growth forms have many characteristics. They are thalline organisms, connected in three forms to the substratum: crustose, foliose, and fruticose. Ascomycetes are the main fungal elements, for which most lichens are known as ascolichens (Tripathi and Joshi 2019). Cyanobacterial lichens make a significant contribution to the fixation of forest nitrogen (Bergman *et al*. 1992). Lichens are also used for pollution controls and in rock dating as well as many other uses including folk uses. Lichen is a very diverse group and because of their universal distribution, they play very important roles in the pioneer vegetation but they receive little attention in science when compared to various groups of plants (Coleine *et al*. 2020, Deacon 2013).

Sacred groves, the tribal community-based plant diversity repositories, are fragments of landscapes with unique ecological characteristics; protect the grounds of sacredness or religious exercise or faith (Gadgil and Vartak 1975, Sen 2019, Sen and Bhakat 2021*a*). In Paschim Medinipur district, West Bengal, India, the groves are dispersed evenly in the form of densely forested natural areas, mostly angiosperm flora with perennial water supplies in their vicinity (Sen and Bhakat 2018). As a distinctive ecosystem, it helps to preserve the soil and water. They are the treasure house of algae, fungi, lichens, bryophytes, pteridophytes and angiosperms (Sen 2014).

Overall floristic composition and physiognomy of the vegetation of sacred groves typically agree with those of the semi-evergreen forests (Parthasarathy *et al*. 2008). In undisturbed groves, the vegetation is luxuriant and includes several kinds of trees mixed with shrubs, lianas and herbs (Sen and Bhakat 2012). They are often acknowledged as "miniature biosphere reserves" (Sen and Bhakat 2021*b*). These sacred groves do not only indicate the climax vegetation but also represent ethno-environmental management and provide a relatively stable environment having a high diversity of lichens. Lichens are important components of the terrestrial biota providing early signals of forest health and potentially damaging agents for plant communities (Joshi *et al*. 2018). The soil is humus-rich and densely covered by litter generating microclimate circumstances favoured by moisture-loving lichens. Furthermore, their abundant growth has enormous environmental and economic values (Upreti *et al*. 2005). Microclimatic factors and microhabitat characteristics, such as topography, land cover and water influence the distribution of lichens (similarity other cryptogams). In sacred groves, the role of substrate, vegetation, environment and altitude were found to be important in creating several microclimate niches for the development of lichens (Ellis and Eaton 2021, Sen 2014). Hence, the present research with the objectives in some sacred groves of the district aims (a) to understand the lichen diversity in four sacred groves, (b) to learn if sacred groves may be a treasure house for the richness of lichen, and (c) to learn if there is any connection between taboos and lichen conservation.

MATERIALS AND METHODS

Study area

Four sacred groves in Midnapore Sadar subdivision of Paschim Medinipur district were selected for the current study of which GGT (Ghuchisol Ghuchisini Than; 22° 38′ 51.26″ – 22° 38′ 52.76″ North and 87° 11′ 31.73″ – 87° 20′ 32.23″ East; 35 m a.s.l.) of Keshpur block, JJT (Joypur Joysini Than; 22° 34′ 49.71″ – 22° 34′ 51.69″ North and 87° 11′ 03.51″ – 87° 11′ 05.32″ East, 57 m a.s.l.) of Salboni block, while KST (Kankabati Sitabala Than; 22° 25′ 15.12″ –

22° 25′ 15.55″ North and 87° 15′ 11.90″ – 87° 15′ 12.16″ East, 36 m a.s.l.) and NBA (Narampur Barapir Astana; 22° 24′ 36.23″ – 22° 24′ 40.32″ North and 87° 18′ 09.75″ – 87° 18′ 09.82″ East, 35 m a.s.l.) sacred groves are from Midnapore Sadar block. There are Bankura and Hooghly districts on its northern side, Jhargram on the southern side, Howrah on the northeastern side and East Midnapore on the southeastern side (Fig. 1).

Regional diversity in terms of physiographic, agro-climatic characteristics and social composition etc. is found in this district. Geomorphologically, the district is divided into three regions as Chhota Nagpur flanks, Rahr plain and alluvial plain. Semi-aquatic vegetation areas of marshy lands are dominating the east replacing the dense semi-evergreen forest. Barren lateritic, non-arable lands, which gradually changes with highly productive alluvial soil areas are found in the central and the eastern part of the district. Most of the inhabitants are tribals (Anon. 2011).

The region has a tropical climate. Hard rock uplands, lateritic areas, and flat alluvial and deltaic plains with fairly fertile soils are very common. The

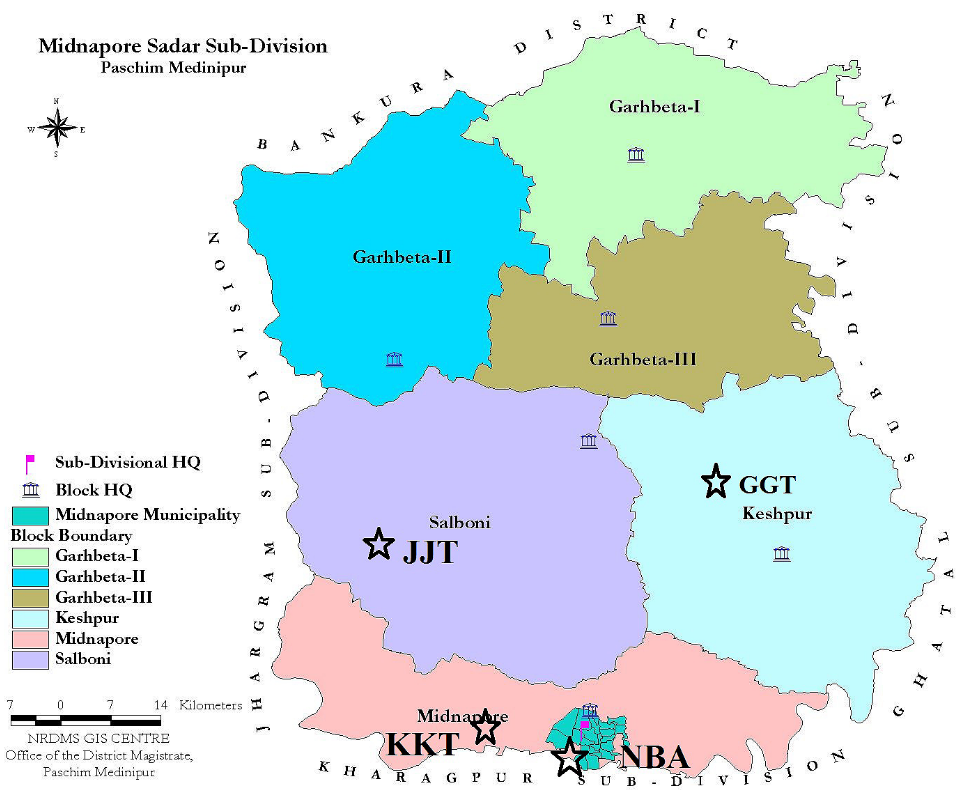

Fig. 1. Map of Midnapore Sadar sub-division with blocks

area characterised by an annual rainfall of 1400–1500 mm, but remained highly erratic for the last few years. The mean temperature of the area is between a maximum of 44 °C during peak summer and a minimum of 10 °C during the coldest days of winter.

Methodology

Different species of lichens were collected from thirty-two different dominant species of dicotyledonous trees from four selected sacred groves (an area of more than 1.5 hectares). Intensive sampling of lichens was carried out from January 2015 to February 2020. Lichens were collected along with substratum using a sharp knife. The specimens were procured very precisely without damaging the thallus. Various species of lichen were also encountered through the collection of fallen branches and twigs on the ground. The specimens were cleaned carefully by removing debris, sundried and deposited in the laboratory herbaria of the Department of Botany, Vidyasagar University, Midnapore, India. Later, the species of lichens were identified up to species level using a light compound binocular microscope and also identified with the help of standard techniques such as spot tests, UV-light and thin layer chromatography (TLC) (Elix and Ernst-Russel 1993, Orange *et al*. 2001). Some of the lichen species were identified and confirmed by the help of National Botanical Research Institute, Lucknow. The identification of each species of lichen was done using relevant keys, published literature and technical monographs (Huneck and Yoshimura 1996, Kondratyuk *et al*. 2020, Rout *et al*. 2010, Sen 2014, 2018, Singh and Kumar 2012, Singh and Sinha 2010, Vinayaka *et al*. 2010). Scientific names of lichens and plants were checked with the Index Fungorum (http://www.indexfungorum.org) and World Checklist of Vascular Plant (WCVP 2021) websites and confirmed only accepted names.

Abbreviations: m a.s.l. = metre above sea level, NTFPs = Non Timber Forest Products.

RESULTS

The results revealed the presence of a total of 116 species of corticolous lichens belonging to 54 genera and 20 families (Table 1). The sacred groves JJT and GGT had more lichen species (89 and 88 species, respectively). These two sacred groves once in their prime glory were on the way to degradation due to rising human impacts. Another two sacred groves NBA and KST contained a lesser amount of lichen species, 40 and 25, respectively (Table 1, Fig. 2).

The lichen flora on trees of the sacred grove studied was of tropical type (Table 1). Among the tree species, *Shorea robusta* was found to provide suitable habitat for the rich growth of lichens (74 species, 63.79%). The other 15 lichen

Table 1

Occurrence of lichens in selected flagship trees in sacred groves of West Midnapore district, West Bengal, India (abbreviations: Cr = crustose, Fo = foliose, + = present, – = absent). For host plant names see Table 3.

Lichen species	Family	Habit	Studied sacred groves				Substratum/ host plant
			GGT	JJT	KST	NBA	
Allographa acharii (Fée) Lücking et Kalb	Graphidaceae	Cr	+	+	+	+	Bm; Cf; Pm; Ss; Ti
Anisomeridium terminatum (Nyl.) R. C. Harris	Monoblastiaceae	Cr	+	+	–	+	Al; Ao; Lc; Sa; Sp
Anthracothecium thwaitesii (Leight.) Müll. Arg.	Pyrenulaceae	Cr	–	+	–	+	Dl; Ee; So
Architrypethelium nitens (Fée) Aptroot	Trypetheliaceae	Cr	+	–	–	–	Sr
Arthonia medusula (Pers.) Nyl.	Arthoniaceae	Cr	+	+	–	+	De; Dm3; Ds
Arthonia translucens Stirt.	Arthoniaceae	Cr	–	+	–	+	Ee; St; So
Arthopyrenia subvelata (Nyl.) R. C. Harris	Arthopyreniaceae	Cr	+	+	–	–	Sr
Arthothelium albescens Patw. et Makhija	Arthoniaceae	Cr	+	+	–	–	Sr
Arthothelium confertum (A. L. Sm.) Makhija et Patw.	Arthoniaceae	Cr	+	+	–	–	Sr
Arthothelium erumpens Müll. Arg.	Arthoniaceae	Cr	+	+	–	–	Sr
Arthothelium pycnocarpoides Müll. Arg.	Arthoniaceae	Cr	+	+	+	+	Dl; St; So
Astrochapsa pseudophlyctis (Nyl.) Parnmen, Lücking et Lumbsch	Graphidaceae	Cr	+	+	–	–	Sr
Astrothelium keralense (Upreti et Ajay Singh) Aptroot et Lücking	Trypetheliaceae	Cr	+	+	–	+	Bc1; Mi; Sa; Sp
Astrothelium pupula (Ach.) Aptroot et Lücking	Trypetheliaceae	Cr	+	+	–	–	Sr
Astrothelium vezdae (Makhija et Patw.) Aptroot et Lücking	Trypetheliaceae	Cr	+	–	–	–	Sr
Bacidia alutacea (Kremp.) Zahlbr.	Ramalinaceae	Cr	–	–	+	+	Dm1; Dm3; Ds
Bacidia convexula (Müll. Arg.) Zahlbr.	Ramalinaceae	Cr	+	+	+	+	Al; Cf; Pp1; Pm
Bacidia medialis (Tuck.) Zahlbr.	Ramalinaceae	Cr	–	+	–	+	Bm; Cf; Pp2; Ss
Bacidia millegrana (Taylor) Zahlbr.	Ramalinaceae	Cr	+	–	+	+	Dl; Ee; St
Bacidia phaeolomoides (Müll. Arg.) Zahlbr.	Ramalinaceae	Cr	+	+	–	–	Sr
Bacidiospora psorina (Nyl. ex Hue) Kalb	Ramalinaceae	Cr	–	+	–	+	Al; Pm; Ss; Ti

Table 1 (continued)

Lichen species	Family	Habit	Studied sacred groves				Substratum/ host plant
			GGT	JJT	KST	NBA	
Bathelium tuberculosum (Makhija et Patw.) R. C. Harris	Trypetheliaceae	Cr	+	+	–	–	Sr
Bogoriella conothelena (Nyl.) Aptroot et Lücking	Trypetheliaceae	Cr	+	–	–	–	Sr
Bulbothrix isidiza (Nyl.) Hale	Parmeliaceae	Fo	+	–	–	–	Sr
Caloplaca herbidella (Arnold) H. Magn.	Teloschistaceae	Cr	+	–	–	–	Sr
Caloplaca indurata V. Wirth et Vězda	Teloschistaceae	Cr	+	+	–	–	Sr
Chrysothrix candelaris (L.) J. R. Laundon	Chrysothricaceae	Cr	+	+	+	+	Al; Cf; Pp2; Ti
Coniocarpon cinnabarinum DC.	Arthoniaceae	Cr	+	+	+	–	De; Dm2; Ds
Creographa brasiliensis A. Massal.	Graphidaceae	Cr	+	+	–	+	Dl; St; So
Cryptothecia bengalensis Jagad. Ram, G. P. Sinha et Kr. P. Singh	Arthoniaceae	Cr	+	+	–	–	Sr
Cryptothecia effusa (Müll. Arg.) R. Sant.	Arthoniaceae	Cr	–	+	+	+	As; Hp; Pr
Cryptothecia involuta Stirt.	Arthoniaceae	Cr	+	–	–	–	Sr
Cryptothecia multipunctata Jagad. Ram, G. P. Sinha et Kr. P. Singh	Arthoniaceae	Cr	+	+	–	–	Sr
Cryptothecia subtecta Stirt.	Arthoniaceae	Cr	+	+	–	–	Sr
Dictyomeridium proponens (Nyl.) Aptroot, M. P. Nelsen et Lücking	Trypetheliaceae	Cr	+	–	–	–	Sr
Diorygma hieroglyphicum (Pers.) Staiger et Kalb	Graphidaceae	Cr	+	+	–	–	Sr
Diorygma junghuhnii (Mont. et Bosch) Kalb, Staiger et Elix	Graphidaceae	Cr	+	+	–	–	Sr
Diorygma megasporum Kalb, Staiger et Elix	Graphidaceae	Cr	–	+	–	–	Sr
Diorygma pruinosum (Eschw.) Kalb, Staiger et Elix	Graphidaceae	Cr	+	+	–	–	Sr
Dyplolabia afzelii (Ach.) A. Massal.	Graphidaceae	Cr	–	+	+	+	Al; Pp2; Pm; Ti
Glyphis cicatricosa Ach.	Graphidaceae	Cr	+	–	+	+	Al; Bm; Cf; Ss
Glyphis duriuscula Stirt.	Graphidaceae	Cr	+	+	+	+	Bc2; Kh; Pa
Glyphis scyphulifera (Ach.) Staiger	Graphidaceae	Cr	+	+	–	–	Sr
Graphina hiascens (Fée) Müll. Arg.	Graphidaceae	Cr	+	+	–	–	Sr

Table 1 (continued)

Lichen species	Family	Habit	Studied sacred groves				Substratum/ host plant
			GGT	JJT	KST	NBA	
Graphina platycarpa (Eschw.) Zahlbr.	Graphidaceae	Cr	+	+	–	–	Sr
Graphis albidofarinacea Adaw. et Makhija	Graphidaceae	Cr	+	–	–	–	Sr
Graphis albissima Müll. Arg.	Graphidaceae	Cr	–	+	–	–	Sr
Graphis caesiella Vain.	Graphidaceae	Cr	–	+	+	+	Dl; Ee; St; So
Graphis chlorotica A. Massal.	Graphidaceae	Cr	–	–	–	–	Dl; Ee; So
Graphis cincta (Pers.) Aptroot	Graphidaceae	Cr	+	+	–	–	Sr
Graphis distincta Makhija et Adaw.	Graphidaceae	Cr	–	+	–	+	As; Hp; Pr
Graphis filiformis Adaw. et Makhija	Graphidaceae	Cr	+	+	–	–	Sr
Graphis furcata Fée	Graphidaceae	Cr	+	+	–	–	Sr
Graphis glaucescens Fée	Graphidaceae	Cr	+	–	+	+	Dl; Ee; So
Graphis handelii Zahlbr.	Graphidaceae	Cr	+	–	–	–	Sr
Graphis insulana (Müll. Arg.) Lücking et Sipman	Graphidaceae	Cr	+	+	–	–	Sr
Graphis japonica (Müll. Arg.) A. W. Archer et Lücking	Graphidaceae	Cr	+		+	+	Bm; Cf; Pp2; Ti
Graphis librata C. Knight	Graphidaceae	Cr	+	+	–	–	Sr
Graphis perticosa (Kremp.) A. W. Archer	Graphidaceae	Cr	–	+	–	–	Sr
Graphis pinicola Zahlbr.	Graphidaceae	Cr	+	+	+	+	Al; Pp2; Ss; Ti
Graphis pyrrhocheiloides Zahlbr.	Graphidaceae	Cr	+	–	–	–	Sr
Graphis scripta (L.) Ach.	Graphidaceae	Cr	+	+	–	–	Sr
Graphis streblocarpa (Bél.) Nyl.	Graphidaceae	Cr	–	+	+	+	As; Hp; Pr
Graphis subasahinae Nagarkar et Patw.	Graphidaceae	Cr	+	+	+	+	Cf; Pp1; Pp2; Ti
Graphis tenella Ach.	Graphidaceae	Cr	+	+	–	–	Sr
Gyalolechia bassiae (Ach.) Søchting, Frödén et Arup ex Ahti	Teloschistaceae	Cr	+	+	–	–	Sr
Haematomma wattii (Stirt.) Zahlbr.	Haematommataceae	Cr	+	–	–	–	Sr

Table 1 (continued)

Lichen species	Family	Habit	Studied sacred groves				Substratum/ host plant
			GGT	JJT	KST	NBA	
Herpothallon isidiatum Jagad. Ram et G. P. Sinha	Arthoniaceae	Cr	–	+	–	+	As; Hp; Pr
Heterodermia albidiflava (Kurok.) D. D. Awasthi	Physciaceae	Fo	+	+	+	+	Al; Cf; Pp1; Ti
Heterodermia diademata (Taylor) D. D. Awasthi	Physciaceae	Fo	+	+	–	–	Sr
Heterodermia obscurata (Nyl.) Trevis.	Physciaceae	Fo	+	+	+	+	Bm; Pp1; Pm; Ti
Heterodermia pseudospeciosa (Kurok.) W. L. Culb.	Physciaceae	Fo	+	–	–	–	Sr
Laurera aurentiaca Makhija et Patw.	Trypetheliaceae	Cr	+	–	+	–	Bc2; Ga; Gu; Pa
Laurera kundarensis Upreti et Ajay Singh	Trypetheliaceae	Cr	+	+	–	–	Sr
Lecanora cinereofusca H. Magn.	Lecanoraceae	Cr	–	+	–	–	Sr
Lecanora iseana Räsänen	Lecanoraceae	Cr	–	+	–	+	As; Hp; Pr
Leiorreuma exaltatum (Mont. et Bosch) Staiger	Graphidaceae	Cr	+	–	–	–	Sr
Lepra multipuncta (Turner) Hafellner	Pertusariaceae	Cr	+	–	–	–	Sr
Leptogium austroamericanum (Malme) C. W. Dodge	Collemataceae	Fo	+	+	–	–	Sr
Letrouitia domingensis (Pers.) Hafellner et Bellem.	Letrouitiaceae	Cr	–	+	–	+	Al; Bm; Cf; Pp1
Letrouitia leprolyta (Nyl.) Hafellner	Letrouitiaceae	Cr	+	–	+	+	As; Hp; Pr
Letrouitia transgressa (Malme) Hafellner et Bellem.	Letrouitiaceae	Cr	+	+	–	–	Sr
Malmidea granifera (Ach.) Kalb, Rivas Plata et Lumbsch	Malmideaceae	Cr	+	+	–	–	Sr
Marcelaria benguelensis (Müll. Arg.) Aptroot, Nelsen et Parnmen	Trypetheliaceae	Cr	–	+	+	+	Dl; St; So
Marcelaria cumingii (Mont.) Aptroot, Nelsen et Parnmen	Trypetheliaceae	Cr	+	+	+	+	Al; Bm; Pp2; Ti
Myelochroa xantholepis (Mont. et Bosch) Elix et Hale	Parmeliaceae	Fo	–	+	–	–	Sr
Myriotrema norstictideum (Patw. et Nagarkar) D. D. Awasthi	Graphidaceae	Cr	+	+	–	–	Sr
Nigrovothelium tropicum (Ach.) Lücking, M. P. Nelsen et Aptroot	Trypetheliaceae	Cr	+	–	–	–	Sr
Pallidogramme chrysenteron (Mont.) Staiger, Kalb et Lücking	Graphidaceae	Cr	–	+	–	–	Sr
Parmotrema andinum (Müll. Arg.) Hale	Parmeliaceae	Fo	+	+	–	–	Sr

Table 1 (continued)

Lichen species	Family	Habit	Studied sacred groves				Substratum/ host plant
			GGT	JJT	KST	NBA	
Parmotrema ravum (Krog et Swinscow) Sérus.	Parmeliaceae	Fo	+	+	–	–	Sr
Parmotrema tinctorum (Despr. ex Nyl.) Hale	Parmeliaceae	Fo	+	+	–	–	Sr
Pertusaria melastomella Nyl.	Pertusariaceae	Cr	+	+	–	–	Sr
Pertusaria quassiae (Fée) Nyl.	Pertusariaceae	Cr	–	+	–	–	Sr
Platythecium grammitis (Fée) Staiger	Graphidaceae	Cr	+	+	–	–	Sr
Pseudopyrenula subnudata Müll. Arg.	Trypetheliaceae	Cr		+	–	–	Sr
Pseudoschismatomma rufescens (Pers.) Ertz et Tehler	Roccellaceae	Cr	+	+	–	–	Sr
Pyrenula acutalis R. C. Harris	Pyrenulaceae	Cr	+	–	–	–	Sr
Pyrenula anomala (Ach.) Vain.	Pyrenulaceae	Cr	–	+	–	–	Sr
Pyrenula citriformis R. C. Harris	Pyrenulaceae	Cr	+	–	–	–	Sr
Pyrenula introducta (Stirt.) Zahlbr.	Pyrenulaceae	Cr	+	+	+	+	Al; Bm; Ss; Ti
Pyrenula leucotrypa (Nyl.) Upreti	Pyrenulaceae	Cr	+	+	–	–	Sr
Pyrenula mamillana (Ach.) Trevis.	Pyrenulaceae	Cr	–	+	–	–	Sr
Pyrenula sublaevigata (Patw. et Makhija) Upreti	Pyrenulaceae	Cr	+	+	–	–	Sr
Pyrenula subnitida Müll. Arg.	Pyrenulaceae	Cr	+	+	+	+	Al; Pm; Ss; Ti
Pyrenula thelomorpha Tuck.	Pyrenulaceae	Cr	–	+	+	+	As; Hp; Pr
Pyxine coccifera (Fée) Nyl.	Caliciaceae	Fo	–	+	–	–	Sr
Ramboldia russula (Ach.) Kalb, Lumbsch et Elix	Ramboldiaceae	Cr	+	–	–	–	Sr
Reimnitzia santensis (Tuck.) Kalb	Graphidaceae	Cr	+	+	–	–	Sr
Sarcographa tricosa (Ach.) Müll. Arg.	Graphidaceae	Cr	+	+	+	+	Bm; Cf; Ss; Ti
Trypethelium eluteriae Spreng.	Trypetheliaceae	Cr	+	+	–	+	Ao; Lc; Mi; Sa
Trypethelium endosulphureum Makhija et Patw.	Trypetheliaceae	Cr	+	+	–	–	Sr

Table 1 (continued)

Lichen species	Family	Habit	Studied sacred groves				Substratum/ host plant
			GGT	JJT	KST	NBA	
Trypethelium platystomum Mont.	Trypetheliaceae	Cr	+	–	+	+	Ee; St; So
Tylophoron protrudens Nyl.	Arthoniaceae	Cr	+	+	–	–	Sr
Variospora aurantia (Pers.) Arup, Frödén et Søchting	Teloschistaceae	Cr	–	+	–	–	Sr

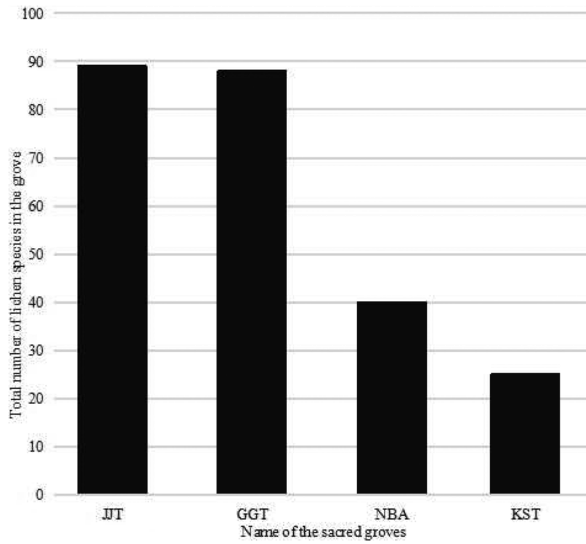

Fig. 2. Total number of lichen species in the sacred groves

containing trees in descending orders (≥ 5 species) were *Tamarindus indica* (13 species, 11.21%), *Albizia lebbeck* (11 species, 9.48%), *Cassia fistula* (10 species, 8.62%), *Butea monosperma* and *Schleichera oleosa* (9 species each, 7.76%), *Dimocarpus longan* and *Senna siamea* (8 species each, 6.90%), *Alstonia scholaris*, *Erioglossum edule*, *Holarrhena pubescens*, *Plumeria rubra*, *Pongamia pinnata* and *Sapindus trifoliatus* (7 species each, 6.03%), *Pterocarpus marsupium* (6 species, 5.17%), *Peltophorum pterocarpum* (5 species, 4.31%), whereas 2 tree species contained 3 and 8 species comprised 2 lichen species. Another 6 tree species each carried single lichen species (Table 3, Fig. 3).

The studied 7 well-represented host tree families of 32 tree species in lichen species quantity were: Dipterocarpaceae 74 (1 tree, 63.79%), Fabaceae 69 (8 trees, 59.48%), Sapindaceae 31 (4 trees, 26.72%), Apocynaceae 21 (3 trees, 18.10%), Anacardiaceae 12 (6 trees, 10.34%), Ebenaceae 9 (5 trees, 7.76%) and Malvaceae 7 (5 trees, 6.03%) (Table 4, Fig. 4).

The study revealed the occurrence of 20 families of lichens represented by 54 genera and 116 species. Graphidaceae (39 species) was the most dominant family, followed successively by Trypetheliaceae (17 species); Arthoniaceae (14 species); Pyrenulaceae (10 spe-

Table 2
Enumeration of family, genus and species of lichens

Family	Genus	Number of species	
		Genus-wise	Family-wise
Arthoniaceae Reichenb. ex Reichenb.	*Arthonia*	2	14
	Arthothelium	4	
	Coniocarpon	1	
	Cryptothecia	5	
	Herpothallon	1	
	Tylophoron	1	
Arthopyreniaceae W. Watson	*Arthopyrenia*	1	1
Caliciaceae Chevall.	*Pyxine*	1	1
Chrysothricaceae Zahlbr.	*Chrysothrix*	1	1
Collemataceae Zenker	*Leptogium*	1	1
Graphidaceae Dumort.	*Allographa*	1	39
	Astrochapsa	1	
	Creographa	1	
	Diorygma	4	
	Dyplolabia	1	
	Glyphis	3	
	Graphina	2	
	Graphis	20	
	Leiorreuma	1	
	Myriotrema	1	
	Pallidogramme	1	
	Platythecium	1	
	Reimnitzia	1	
	Sarcographa	1	
Haematommataceae Hafellner	*Haematomma*	1	1
Lecanoraceae Körb.	*Lecanora*	2	2
Letrouitiaceae Bellem. et Hafellner	*Letrouitia*	3	3
Malmideaceae Kalb, Rivas Plata et Lumbsch	*Malmidea*	1	1
Monoblastiaceae W. Watson	*Anisomeridium*	1	1
Parmeliaceae F. Berchtold et J. Presl	*Bulbothrix*	1	5
	Myelochroa	1	
	Parmotrema	3	
Pertusariaceae Körb. ex Körb.	*Lepra*	1	3
	Pertusaria	2	

Table 2 (continued)

Family	Genus	Number of species	
		Genus-wise	Family-wise
Physciaceae Zahlbr.	*Heterodermia*	4	4
Pyrenulaceae Rabenh.	*Anthracothecium*	1	10
	Pyrenula	9	
Ramalinaceae C. Agardh	*Bacidia*	5	6
	Bacidiospora	1	
Ramboldiaceae S. Stenroos, Miądl. et Lutzoni	*Ramboldia*	1	1
Roccellaceae Chevall.	*Pseudoschis-matomma*	1	1
Teloschistaceae Zahlbr.	*Caloplaca*	2	4
	Gyalolechia	1	
	Variospora	1	
Trypetheliaceae Zenker	*Architrypethelium*	1	17
	Astrothelium	3	
	Bathelium	2	
	Bogoriella	1	
	Dictyomeridium	1	
	Laurera	2	
	Marcelaria	2	
	Nigrovothelium	1	
	Pseudopyrenula	1	
	Trypethelium	3	
Total: 20	54	116	116

Table 4
Families of host tree species of lichen

Family	Total tree species	Total lichen species
Dipterocarpaceae	1	74
Fabaceae	8	69
Sapindaceae	4	31
Apocynaceae	3	21
Anacardiaceae	6	12
Ebenaceae	5	9
Malvaceae	5	7

Table 3
Total number of lichen species hosted by each flagship tree species. NLH = number of lichen species hosted, Abbr. = abbreviation.

Name of the tree species	Abbr..	Family	NLH
Albizia lebbeck (L.) Benth.	Al	Fabaceae	11
Alstonia scholaris (L.) R. Br.	As	Apocynaceae	7
Anacardium occidentale L.	Ao	Anacardiaceae	2
Bombax ceiba L.	Bc2	Malvaceae	2
Buchanania cochinchinensis (Lour.) M. R. Almeida	Bc1	Anacardiaceae	1
Butea monosperma (Lam.) Taub.	Bm	Fabaceae	9
Cassia fistula L.	Cf	Fabaceae	10
Dimocarpus longan Lour.	Dl	Sapindaceae	8
Diospyros exsculpta Buch.-Ham.	De	Ebenaceae	2
Diospyros malabarica (Desr.) Kostel.	Dm1	Ebenaceae	1
Diospyros melanoxylon Roxb.	Dm3	Ebenaceae	2
Diospyros montana Roxb.	Dm2	Ebenaceae	1
Diospyros sylvatica Roxb.	Ds	Ebenaceae	3
Erioglossum edule (Aiton) Blume	Ee	Sapindaceae	7
Grewia asiatica L.	Ga	Malvaceae	1
Guazuma ulmifolia Lam.	Gu	Malvaceae	1
Holarrhena pubescens Wall. ex G. Don	Hp	Apocynaceae	7
Kleinhovia hospita L.	Kh	Malvaceae	1
Lannea coromandelica (Houtt.) Merr.	Lc	Anacardiaceae	2
Mangifera indica L.	Mi	Anacardiaceae	2
Peltophorum pterocarpum (DC.) K. Heyne	Pp1	Fabaceae	5
Plumeria rubra L.	Pr	Apocynaceae	7
Pongamia pinnata (L.) Pierre	Pp2	Fabaceae	7
Pterocarpus marsupium Roxb.	Pm	Fabaceae	6
Pterospermum acerifolium (L.) Willd.	Pa	Malvaceae	2
Sapindus trifoliatus L.	St	Sapindaceae	7
Schleichera oleosa (Lour.) Merr.	So	Sapindaceae	9
Semecarpus anacardium L. f.	Sa	Anacardiaceae	3
Senna siamea (Lam.) H. S. Irwin et Barneby	Ss	Fabaceae	8
Shorea robusta Gaertn.	Sr	Dipterocarpaceae	74
Spondias pinnata (L. f.) Kurz.	Sp	Anacardiaceae	2
Tamarindus indica L.	Ti	Fabaceae	13

cies); Ramalinaceae (6 species); Parmeliaceae (5 species); Physciaceae and Teloschistaceae (4 species each); Letrouitiaceae and Pertusariaceae (3 species each), and Lecanoraceae (2 species) (Table 2). Another set of 9 families contained only single species, each namely Arthopyreniaceae, Caliciaceae, Chrysothricaceae, Collemataceae, Haematommataceae, Malmideaceae, Monoblastiaceae, Ramboldiaceae and Roccellaceae (Table 2, Fig. 5).

Among the various growth forms, crustose was the dominant (105 species, 90.52%) over foliose (11 species, 9.48%) (Table 1, Fig. 6). All studied lichens on the trees of the sacred groves were corticolous in habitat (Table 1).

The 18 dominant lichen genera with descending species number (≥ 2 species) were *Graphis* (20 species); *Pyrenula* (9 species); *Bacidia* and *Cryptothecia* (5 species each); *Arthothelium*, *Diorygma* and *Heterodermia* (4 species each); *Astrothelium*, *Glyphis*, *Letrouitia*, *Parmotrema* and *Trypethelium* (3 species each); and 8 genera *Arthonia*, *Bathelium*, *Caloplaca*, *Graphina*, *Laurera*, *Lecanora*, *Marcelaria* and *Pertusaria* contained 2 species each. Remaining 34 genera namely *Allographa*, *Anisomeridium*, *Anthracothecium*, *Architrypethelium*, *Arthopyrenia*, *Astrochapsa*, *Bacidiospora*, *Bogoriella*, *Bulbothrix*, *Chrysothrix*, *Coniocarpon*, *Creographa*, *Dictyomeridium*, *Dyplolabia*, *Gyalolechia*, *Haematomma*, *Herpothallon*, *Leiorreuma*, *Lepra*, *Leptogium*, *Malmidea*, *Myelochroa*, *Myriotrema*, *Nigrovothelium*, *Pallidogramme*, *Platythecium*, *Pseudopyrenula*, *Pseudoschismatomma*, *Pyxine*, *Ramboldia*, *Reimnitzia*, *Sarcographa*, *Tylophoron* and *Variospora* contained only single species (Table 2).

The lichen flora of these sacred groves was represented by two growths forms, crustose and foliose. Of the total lichen species, 105 species belonged to the crustose group and 11 species were foliose (Table 1).

DISCUSSION

The corticolous lichen flora of the sacred groves studied revealed the occurrence of 116 species within 20 families belonging to 54 genera. The dominant family and genus were Graphidaceae (33.62%) and *Graphis* (17.24%) (Table 2). Due to the presence of *Shorea robusta* (Dipterocarpaceae) in both sacred groves, JJT and GGT contained higher levels of lichen species. On a particular tree, the rich lichen flora relied on a wide range of interrelated factors. The microclimate shown by different species of encountering tree, including the mature substratum, defined the growth of lichen. Certain important factors influencing the growth of lichens on the tree were the age, smoothness, roughness and spongy nature of the bark, along with pH, nutrient status, buffer ability and water holding capacity (Satya *et al*. 2005). The explanation for *Shorea robusta*'s rich lichen flora would be attributed to the variability in bark consistency in various parts of the tree. There were four different niches for the lichens to colonise within a single tree of *Shorea robusta*, these are as follows: At the base, the bark is rough, hard, and wrinkled, and it is sometimes covered with soil or dust. The cracks are significantly narrower and the bark becomes slightly less rough around the trunk base, 3–6 feet above ground. The bark on the major branches over 6 feet, as well as lesser branches and twigs, remains smooth and soft (Satya *et al*. 2005). In JJT and GGT, the ecological requirements of the foliose lichens belonging to the families Parmeliaceae and Physciaceae were well known. These lichens, with green algae as photobiont, occur where twigs, branches and trunks of trees were found in areas with canopy openings resulting in good light conditions and frequent winds (Tripathi and Joshi 2019). The proliferation of these lichens on tree trunks was a cause for concern because they were more photophilic and signified drier circumstances (Kumar 2010). These findings were consistent with other sacred grove studies (Dudani *et al*. 2015, Joshi *et al*. 2018, Upadhyay *et al*. 2018).

By contrast, the family Graphidaceae characterised by the wetter portions of sacred groves with darker canopies (Dudani *et al*. 2015). Lichen species of the Graphidaceae and Pyrenulaceae were markers of warm and humid conditions, reminding them of those occurring in Eastern India (Vinayaka *et al*. 2010). The species of the Thelotremataceae were great bioindicators of undisturbed forests, typical of tropical rainforests (Rivas Plata *et al*. 2008). In the wet evergreen forests, the lichens Graphidaceae, Pyrenulaceae and Thelotremataceae were also found to dominate (Rivas Plata *et al*. 2008, Rout *et al*. 2010).

Over the past three decades, almost all the claims about nature conservation on this planet had been about biological diversity and how it could be maintained (Margules and Pressey 2000). Lichens were not exempt from such investigations and several studies attested to the contemporary importance of lichens and their habitats (Lücking *et al*. 2019). Ganderton and Coker (2005) state "in terms of biogeography, conservation could be seen as one more element in the dynamic interactions between species and their natural environment". Such a strategy would also be helpful to conserve a suitable range of taxa and habitats against prevailing environmental and ecological changes. As a result of human activities, many aspects of our environment were changing locally or globally. These included temperature, carbon dioxide, rainfall, UV radiation, ozone, nitrification, and acidification and would directly affect the populations of lichen (Galloway 1996). Conservation measures, such as the creation of protected areas, now need to take into account shifts in environmental factors and human-induced events, such as rapid climate change that can alter the environmental conditions of a protected area in such a way that the protected area is no longer able to support taxa or habitats (Mackey *et al*. 2008, Muggia *et al*. 2018). Lichens had undergone some dramatic shifts in the terrestrial ecosystems of the earth throughout their long evolutionary history and are likely to be far better equipped to thrive and see any potential episodes of anthropogenic mass extinction with their special symbiotic systems.

In 2005, UNESCO designated the sacred grove, a social institution that allowed the management of biotic resources through the involvement of peoples, as a heritage site for biodiversity (Wild *et al*. 2008). In addition to harvesting controls, in harvesting traditional plants, there had been taboos that had influenced the social behaviour of people in society. Colding and Folke (2001) showed several taboos associated with sacred groves like regulating resource access and withdrawal, regulating the withdrawal of vulnerable life-history stages of species, total protection to species and restrictions in access and use of resources in time and space. The current study is a prelude to more such and much-needed exploratory surveys critical to the conservation of this global small-scale biodiversity hotspot in Paschim Medinipur district of West Bengal in India.

CONCLUSIONS

Sacred groves are religiously protected areas that provide a comprehensive and rich ecological niche serving as repositories of genetic diversity. Moreover, the groves are threatened by immense direct and indirect pressures. These challenges may be linked to growing tourism opportunities, higher demands for NTFPs, fuel-wood collection, a decline in religious faiths along with a decline in the current generation's dedication to such sacred natural areas, and finally, the heavy burden of developmental interventions is ready to tackle. Sacred groves' microclimatic conditions play an important role in lichen ecology. The main factors responsible for optimal growth of lichens are the availability of water, sunshine, mild climate, unpolluted environment, adequate wind condition and form of the substratum. It has become evident from the present study that the sacred grove abounds in a good number of lichens in its rich ecosystems, which are declining due to different factors. Administrators' little attention to the declining state of holy places and groves adds another dimension. Such gene pool reserves can serve as symbols of *in situ* conservation in the present times through a good mix of research measures and efforts to raise awareness with the active involvement of the local community and government.

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