

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 2021a). 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 2021b). 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

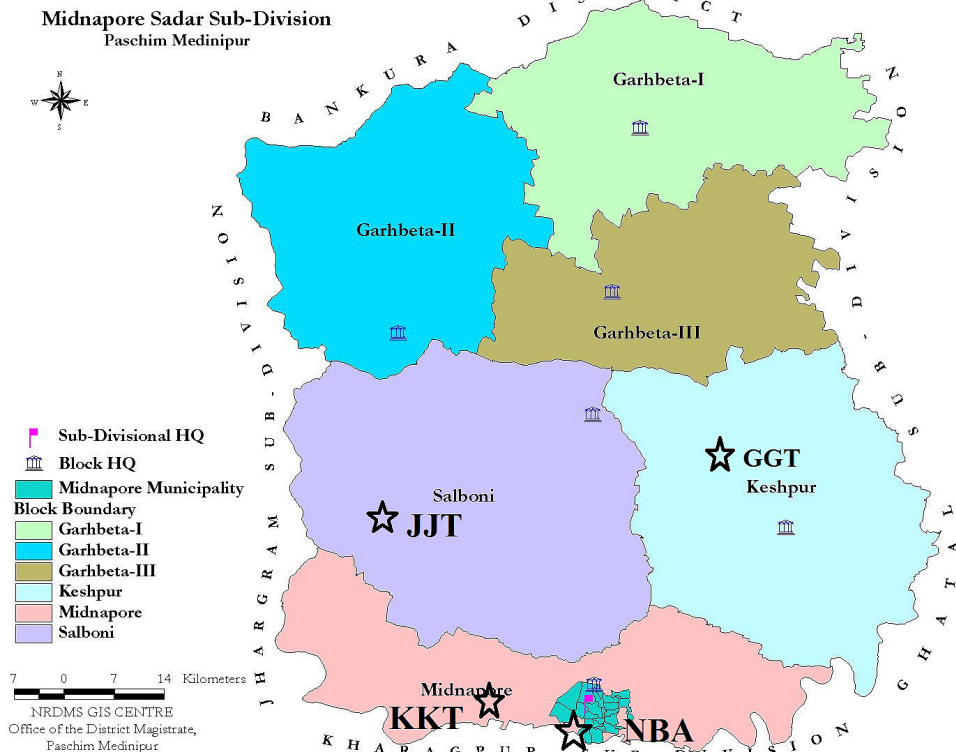


Fig. 1. Map of Midnapore Sadar sub-division with blocks

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 (WCVLP 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 | |
| <i>Allographa acharii</i> (Fée) Lücking et Kalb | Graphidaceae | Cr | + | + | + | + | Bm; Cf; Pm; Ss; Ti |
| <i>Anisomeridium terminatum</i> (Nyl.) R. C. Harris | Monoblastiaceae | Cr | + | + | - | + | Al; Ao; Lc; Sa; Sp |
| <i>Anthracothecium thwaitesii</i> (Leight.) Müll. Arg. | Pyrenulaceae | Cr | - | + | - | + | Dl; Ee; So |
| <i>Architrypethelium nitens</i> (Fée) Aptroot | Trypetheliaceae | Cr | + | - | - | - | Sr |
| <i>Arthonia medusula</i> (Pers.) Nyl. | Arthoniaceae | Cr | + | + | - | + | De; Dm3; Ds |
| <i>Arthonia translucens</i> Stirt. | Arthoniaceae | Cr | - | + | - | + | Ee; St; So |
| <i>Arthopyrenia subvelata</i> (Nyl.) R. C. Harris | Arthopyreniaceae | Cr | + | + | - | - | Sr |
| <i>Arthothelium albescens</i> Patw. et Makhija | Arthoniaceae | Cr | + | + | - | - | Sr |
| <i>Arthothelium confertum</i> (A. L. Sm.) Makhija et Patw. | Arthoniaceae | Cr | + | + | - | - | Sr |
| <i>Arthothelium erumpens</i> Müll. Arg. | Arthoniaceae | Cr | + | + | - | - | Sr |
| <i>Arthothelium pycnocarpoides</i> Müll. Arg. | Arthoniaceae | Cr | + | + | + | + | Dl; St; So |
| <i>Astrochapsa pseudophlyctis</i> (Nyl.) Parmen, Lücking et Lumbsch | Graphidaceae | Cr | + | + | - | - | Sr |
| <i>Astrothelium keralense</i> (Upreti et Ajay Singh) Aptroot et Lücking | Trypetheliaceae | Cr | + | + | - | + | Bcl; Mi; Sa; Sp |
| <i>Astrothelium pupula</i> (Ach.) Aptroot et Lücking | Trypetheliaceae | Cr | + | + | - | - | Sr |
| <i>Astrothelium vezdae</i> (Makhija et Patw.) Aptroot et Lücking | Trypetheliaceae | Cr | + | - | - | - | Sr |
| <i>Bacidia alutacea</i> (Kremp.) Zahlbr. | Ramalinaceae | Cr | - | - | + | + | Dm1; Dm3; Ds |
| <i>Bacidia convexula</i> (Müll. Arg.) Zahlbr. | Ramalinaceae | Cr | + | + | + | + | Al; Cf; Pp1; Pm |
| <i>Bacidia medialis</i> (Tuck.) Zahlbr. | Ramalinaceae | Cr | - | + | - | + | Bm; Cf; Pp2; Ss |
| <i>Bacidia millegrana</i> (Taylor) Zahlbr. | Ramalinaceae | Cr | + | - | + | + | Dl; Ee; St |
| <i>Bacidia phaeolomoides</i> (Müll. Arg.) Zahlbr. | Ramalinaceae | Cr | + | + | - | - | Sr |
| <i>Bacidiospora psorina</i> (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 | |
| <i>Bathelium tuberculatum</i> (Makhija et Patw.) R. C. Harris | Trypetheliaceae | Cr | + | + | - | - | Sr |
| <i>Bogoriella conothelena</i> (Nyl.) Aptroot et Lücking | Trypetheliaceae | Cr | + | - | - | - | Sr |
| <i>Bulbothrix isidiza</i> (Nyl.) Hale | Parmeliaceae | Fo | + | - | - | - | Sr |
| <i>Caloplaca herbicidella</i> (Arnold) H. Magn. | Teloschistaceae | Cr | + | - | - | - | Sr |
| <i>Caloplaca indurata</i> V. Wirth et Vězda | Teloschistaceae | Cr | + | + | - | - | Sr |
| <i>Chrysothrix candellaris</i> (L.) J. R. Laundon | Chrysothricaceae | Cr | + | + | + | + | Al; Cf; Pp2; Ti |
| <i>Coniocarpon cinnabarinum</i> DC. | Arthoniaceae | Cr | + | + | + | - | De; Dm2; Ds |
| <i>Creographa brasiliensis</i> A. Massal. | Graphidaceae | Cr | + | + | - | + | Di; St; So |
| <i>Cryptothecia bengalensis</i> Jagad. Ram, G. P. Sinha et Kr. P. Singh | Arthoniaceae | Cr | + | + | - | - | Sr |
| <i>Cryptothecia effusa</i> (Müll. Arg.) R. Sant. | Arthoniaceae | Cr | - | + | + | + | As; Hp; Pr |
| <i>Cryptothecia involuta</i> Stirt. | Arthoniaceae | Cr | + | - | - | - | Sr |
| <i>Cryptothecia multipunctata</i> Jagad. Ram, G. P. Sinha et Kr. P. Singh | Arthoniaceae | Cr | + | + | - | - | Sr |
| <i>Cryptothecia subtecta</i> Stirt. | Arthoniaceae | Cr | + | + | - | - | Sr |
| <i>Dictyonemidium proponens</i> (Nyl.) Aptroot, M. P. Nelsen et Lücking | Trypetheliaceae | Cr | + | - | - | - | Sr |
| <i>Dorygma hieroglyphicum</i> (Pers.) Staiger et Elix | Graphidaceae | Cr | + | + | - | - | Sr |
| <i>Dorygma junghuhnii</i> (Mont. et Bosch) Kalb, Staiger et Elix | Graphidaceae | Cr | + | + | - | - | Sr |
| <i>Dorygma megasporum</i> Kalb, Staiger et Elix | Graphidaceae | Cr | - | + | - | - | Sr |
| <i>Dorygma pruinosum</i> (Eschw.) Kalb, Staiger et Elix | Graphidaceae | Cr | + | + | - | - | Sr |
| <i>Dyplolabia afzelii</i> (Ach.) A. Massal. | Graphidaceae | Cr | - | + | + | + | Al; Pp2; Pm; Ti |
| <i>Glyphis cicutricosa</i> Ach. | Graphidaceae | Cr | + | - | + | + | Al; Bm; Cf; Ss |
| <i>Glyphis duriuscula</i> Stirt. | Graphidaceae | Cr | + | + | + | + | Bc2; Kh; Pa |
| <i>Glyphis scyphulifera</i> (Ach.) Staiger | Graphidaceae | Cr | + | + | - | - | Sr |
| <i>Graphina hiascens</i> (Fée) Müll. Arg. | Graphidaceae | Cr | + | + | - | - | Sr |

Table 1 (continued)

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

Table 1 (continued)

| Lichen species | Family | Habit | Studied sacred groves | | | | Substratum/ host plant |
|--|------------------|-------|-----------------------|-----|-----|-----|---------------------------|
| | | | GGT | JJT | KST | NBA | |
| <i>Herpothallon isidiatum</i> Jagad. Ram et G. P. Sinha | Arthoniaceae | Cr | - | + | - | + | As; Hp; Pr |
| <i>Heterodermia albidiflora</i> (Kurok.) D. D. Awasthi | Physciaceae | Fo | + | + | + | + | Al; Cf; Pp1; Ti |
| <i>Heterodermia diademata</i> (Taylor) D. D. Awasthi | Physciaceae | Fo | + | + | - | - | Sr |
| <i>Heterodermia obscurata</i> (Nyl.) Trevis. | Physciaceae | Fo | + | + | + | + | Bm; Pp1; Pm; Ti |
| <i>Heterodermia pseudospeciosa</i> (Kurok.) W. L. Culb. | Physciaceae | Fo | + | - | - | - | Sr |
| <i>Laurera aurentiacea</i> Makhija et Patw. | Trypetheliaceae | Cr | + | - | + | - | Bc2; Ga; Gu; Pa |
| <i>Laurera kundarensis</i> Upreti et Ajay Singh | Trypetheliaceae | Cr | + | + | - | - | Sr |
| <i>Lecanora cinerofusca</i> H. Magn. | Lecanoraceae | Cr | - | + | - | - | Sr |
| <i>Lecanora iseara</i> Räsänen | Lecanoraceae | Cr | - | + | - | + | As; Hp; Pr |
| <i>Letorreuina exaltatum</i> (Mont. et Bosch) Staiger | Graphidaceae | Cr | + | - | - | - | Sr |
| <i>Lepra multipuncta</i> (Turner) Hafellner | Pertusariaceae | Cr | + | - | - | - | Sr |
| <i>Leptogium austroamericanum</i> (Malme) C. W. Dodge | Collemaaceae | Fo | + | + | - | - | Sr |
| <i>Letrouititia domingensis</i> (Pers.) Hafellner et Bellem. | Letrouititiaceae | Cr | - | + | - | + | Al; Bm; Cf; Pp1 |
| <i>Letrouititia leprolyta</i> (Nyl.) Hafellner | Letrouititiaceae | Cr | + | - | + | + | As; Hp; Pr |
| <i>Letrouititia transgressa</i> (Malme) Hafellner et Bellem. | Letrouititiaceae | Cr | + | + | - | - | Sr |
| <i>Malmidea granifera</i> (Ach.) Kalb, Rivas Plata et Lumbsch | Malmideaceae | Cr | + | + | - | - | Sr |
| <i>Marcellaria benguelensis</i> (Müll. Arg.) Aptroot, Nelsen et Parmen | Trypetheliaceae | Cr | - | + | + | + | Dl; St; So |
| <i>Marcellaria cumingii</i> (Mont.) Aptroot, Nelsen et Parmen | Trypetheliaceae | Cr | + | + | + | + | Al; Bm; Pp2; Ti |
| <i>Myelochroa xantholepis</i> (Mont. et Bosch) Elix et Hale | Parmeliaceae | Fo | - | + | - | - | Sr |
| <i>Myriotrema norsictideum</i> (Patw. et Nagarkar) D. D. Awasthi | Graphidaceae | Cr | + | + | - | - | Sr |
| <i>Nigrotohelium tropicum</i> (Ach.) Lücking, M. P. Nelsen et Aptroot | Trypetheliaceae | Cr | + | - | - | - | Sr |
| <i>Pallidogramme chrysoenteron</i> (Mont.) Staiger, Kalb et Lücking | Graphidaceae | Cr | - | + | - | - | Sr |
| <i>Parmotrema andinum</i> (Müll. Arg.) Hale | Parmeliaceae | Fo | + | + | - | - | Sr |

Table 1 (continued)

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

Table 1 (continued)

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

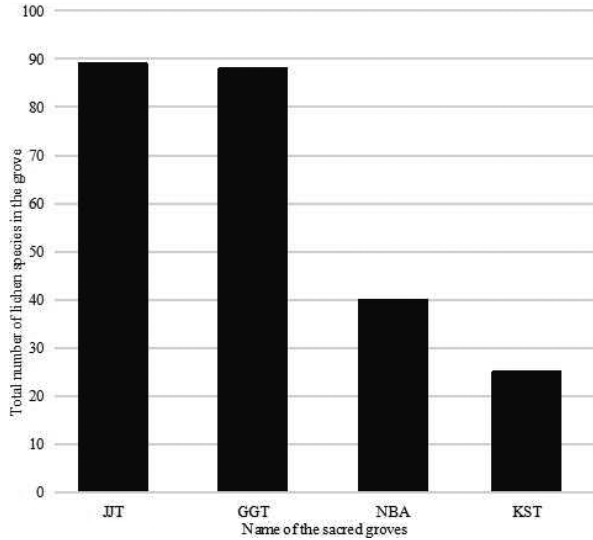


Fig. 2. Total number of lichen species in the sacred groves

containing trees in descending orders (≥ 5 species) were *Tamarindus indica* (13 species, 11.21%), *Albizia lebbek* (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. | <i>Arthonia</i> | 2 | 14 |
| | <i>Arthothelium</i> | 4 | |
| | <i>Coniocarpon</i> | 1 | |
| | <i>Cryptothecia</i> | 5 | |
| | <i>Herpothallon</i> | 1 | |
| | <i>Tylophoron</i> | 1 | |
| Arthopyreniaceae W. Watson | <i>Arthopyrenia</i> | 1 | 1 |
| Caliciaceae Chevall. | <i>Pyxine</i> | 1 | 1 |
| Chrysothricaceae Zahlbr. | <i>Chrysothrix</i> | 1 | 1 |
| Collemataceae Zenker | <i>Leptogium</i> | 1 | 1 |
| Graphidaceae Dumort. | <i>Allographa</i> | 1 | 39 |
| | <i>Astrochapsa</i> | 1 | |
| | <i>Creographa</i> | 1 | |
| | <i>Diorygma</i> | 4 | |
| | <i>Dyplolabia</i> | 1 | |
| | <i>Glyphis</i> | 3 | |
| | <i>Graphina</i> | 2 | |
| | <i>Graphis</i> | 20 | |
| | <i>Leiorreuma</i> | 1 | |
| | <i>Myriotrema</i> | 1 | |
| | <i>Pallidogramme</i> | 1 | |
| | <i>Platythecium</i> | 1 | |
| | <i>Reimmitzia</i> | 1 | |
| | <i>Sarcographa</i> | 1 | |
| | Haematommataceae Hafellner | <i>Haematomma</i> | |
| Lecanoraceae Körb. | <i>Lecanora</i> | 2 | 2 |
| Letrouitiaceae Bellem. et Hafellner | <i>Letrouitia</i> | 3 | 3 |
| Malmideaceae Kalb, Rivas Plata et Lumbsch | <i>Malmidea</i> | 1 | 1 |
| Monoblastiaceae W. Watson | <i>Anisomeridium</i> | 1 | 1 |
| Parmeliaceae F. Berchtold et J. Presl | <i>Bulbothrix</i> | 1 | 5 |
| | <i>Myelochroa</i> | 1 | |
| | <i>Parmotrema</i> | 3 | |
| Pertusariaceae Körb. ex Körb. | <i>Lepora</i> | 1 | 3 |
| | <i>Pertusaria</i> | 2 | |

Table 2 (continued)

| Family | Genus | Number of species | |
|--|---------------------------|-------------------|-------------|
| | | Genus-wise | Family-wise |
| Physciaceae Zahlbr. | <i>Heterodermia</i> | 4 | 4 |
| Pyrenulaceae Rabenh. | <i>Anthracothecium</i> | 1 | 10 |
| | <i>Pyrenula</i> | 9 | |
| Ramalinaceae C. Agardh | <i>Bacidia</i> | 5 | 6 |
| | <i>Bacidiospora</i> | 1 | |
| Ramboldiaceae S. Stenroos, Miqdl. et Lutzoni | <i>Ramboldia</i> | 1 | 1 |
| Roccellaceae Chevall. | <i>Pseudoschismatomma</i> | 1 | 1 |
| Teloschistaceae Zahlbr. | <i>Caloplaca</i> | 2 | 4 |
| | <i>Gyalolechia</i> | 1 | |
| | <i>Variospora</i> | 1 | |
| Trypetheliaceae Zenker | <i>Architrypethelium</i> | 1 | 17 |
| | <i>Astrothelium</i> | 3 | |
| | <i>Bathelium</i> | 2 | |
| | <i>Bogoriella</i> | 1 | |
| | <i>Dictyomeridium</i> | 1 | |
| | <i>Laurera</i> | 2 | |
| | <i>Marcelaria</i> | 2 | |
| | <i>Nigrovothelium</i> | 1 | |
| | <i>Pseudopyrenula</i> | 1 | |
| | <i>Trypethelium</i> | 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 |
|---|--------|------------------|-----|
| <i>Albizia lebbbeck</i> (L.) Benth. | Al | Fabaceae | 11 |
| <i>Alstonia scholaris</i> (L.) R. Br. | As | Apocynaceae | 7 |
| <i>Anacardium occidentale</i> L. | Ao | Anacardiaceae | 2 |
| <i>Bombax ceiba</i> L. | Bc2 | Malvaceae | 2 |
| <i>Buchanania cochinchinensis</i> (Lour.) M. R. Almeida | Bc1 | Anacardiaceae | 1 |
| <i>Butea monosperma</i> (Lam.) Taub. | Bm | Fabaceae | 9 |
| <i>Cassia fistula</i> L. | Cf | Fabaceae | 10 |
| <i>Dimocarpus longan</i> Lour. | Dl | Sapindaceae | 8 |
| <i>Diospyros exsculpta</i> Buch.-Ham. | De | Ebenaceae | 2 |
| <i>Diospyros malabarica</i> (Desr.) Kostel. | Dm1 | Ebenaceae | 1 |
| <i>Diospyros melanoxylon</i> Roxb. | Dm3 | Ebenaceae | 2 |
| <i>Diospyros montana</i> Roxb. | Dm2 | Ebenaceae | 1 |
| <i>Diospyros sylvatica</i> Roxb. | Ds | Ebenaceae | 3 |
| <i>Erioglossum edule</i> (Aiton) Blume | Ee | Sapindaceae | 7 |
| <i>Grewia asiatica</i> L. | Ga | Malvaceae | 1 |
| <i>Guazuma ulmifolia</i> Lam. | Gu | Malvaceae | 1 |
| <i>Holarrhena pubescens</i> Wall. ex G. Don | Hp | Apocynaceae | 7 |
| <i>Kleinhovia hospita</i> L. | Kh | Malvaceae | 1 |
| <i>Lannea coromandelica</i> (Houtt.) Merr. | Lc | Anacardiaceae | 2 |
| <i>Mangifera indica</i> L. | Mi | Anacardiaceae | 2 |
| <i>Peltophorum pterocarpum</i> (DC.) K. Heyne | Pp1 | Fabaceae | 5 |
| <i>Plumeria rubra</i> L. | Pr | Apocynaceae | 7 |
| <i>Pongamia pinnata</i> (L.) Pierre | Pp2 | Fabaceae | 7 |
| <i>Pterocarpus marsupium</i> Roxb. | Pm | Fabaceae | 6 |
| <i>Pterospermum acerifolium</i> (L.) Willd. | Pa | Malvaceae | 2 |
| <i>Sapindus trifoliatus</i> L. | St | Sapindaceae | 7 |
| <i>Schleichera oleosa</i> (Lour.) Merr. | So | Sapindaceae | 9 |
| <i>Semecarpus anacardium</i> L. f. | Sa | Anacardiaceae | 3 |
| <i>Senna siamea</i> (Lam.) H. S. Irwin et Barneby | Ss | Fabaceae | 8 |
| <i>Shorea robusta</i> Gaertn. | Sr | Dipterocarpaceae | 74 |
| <i>Spondias pinnata</i> (L. f.) Kurz. | Sp | Anacardiaceae | 2 |
| <i>Tamarindus indica</i> 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*, *Marcellaria* and *Pertusaria* contained 2 species each. Remaining 34 genera namely *Allographa*, *Anisomeridium*, *Anthracotheicum*, *Architrypethelium*, *Arthopyrenia*, *Astrochapsa*, *Bacidiospora*, *Bogoriella*, *Bulbothrix*, *Chrysothrix*, *Coniocarpon*, *Creographa*, *Dictyomeridium*, *Dyplolabia*, *Gyalolechia*, *Haematomma*, *Herpothallon*, *Leiorreuma*, *Lepora*, *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 growth 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 fol-

lows: 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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