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Ecolichenology of Eastern Ghats diversity against climatic fluctuations in Kolli Hills, India

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Abstract. *Subbaiyan R, Ganesan A, Dhanuskodi S. 2023. Ecolichenology of Eastern Ghats diversity against climatic fluctuations in Kolli Hills, India. Biodiversitas 24: 625-635.* Lichens are major components of earthbound and marine environments. A lichen is a symbiotic form of algae and fungi adapted to survive in different altitudes and environmental conditions. The lichen morphology is divided into three, based on their habitat: crustose, foliose, and fruticose lichens. Eastern Ghats (EG) contribute significantly to both the endemicity and species richness of the Indian region. However, EG forests are relatively unexplored and have received less conservation consideration than the Western Ghats. Unexplored Eastern Ghats were studied to analyze the ecolichenology against climatic fluctuations. The objective of this paper is to build a stock of epiphytic lichens within the Kolli slopes. Kolli Hills are one of the ancient richest floral and faunal biodiversity hotspots of Eastern Ghats. It is assessed from the year 2018 to that 2021 with different climatic seasonal variations. The least diversity was found with the Arthonioid > Usneoid > Scaly > Ramalinoid types. Highly denser than the Parmelioid foliose and Usneoid, the Ramlinoid species was rich in numbers with healthy thallus. The population was stopped, or the least amount of thallus growth was noticed from the high rainfall season and gradual reduction in the summer. The Ramalinoid and Parmelioid lichens were found to be easy identifiers. The richness was reduced dependently and independently with nature. The health of lichens was encountered with only morphological appurtenance. Based on the lichen group, the maximum distribution was observed in Usneoid and Ramalinoid categories. The last distribution was found with Leprose and Scaly lichens. The forest wealth was described with the denser lichen patches and the shrinkages of Parmelioid lichens, especially the *Dirinaria* and *Parmoterma*, acting as a wealth analysis tool of the forest ecosystems.

Keywords: Diversity, ecolichenology, Kolli Hills, lichen, parmelioid, substrates

INTRODUCTION

Lichens are composite organisms living in a symbiotic association of algae and fungi adapted to survive in different altitudes and environmental conditions (Ganesan et al. 2015; Ayyappadasan et al. 2017; Rubavathi et al. 2022a,b). In any case, their exact recognizable proof at the species level was frequently troublesome in the early days, but the molecular scientific categorization progressed the pseudo troubles (Belguidoum et al. 2022a,b). Eastern Ghats (EG) contribute significantly to both the endemicity and species richness of the Indian region. However, EG forests are relatively unexplored and have received less conservation consideration than the Western Ghats (Nayaka et al. 2013). The objective of this paper is to build a stock of epiphytic lichens within the Kolli slopes. Kolli Hills are one of the ancient richest floral and faunal biodiversity hotspots of Eastern Ghats, located in Southern Asia of the Indian subcontinent. This area was well populated with algal and fungal species, including lichens. The diversity was enumerated with only lichen symbionts, especially of the micro and macro lichens taxa (Guillerm et al. 2020). The lichen morphology is divided into three, based on their habitat: crustose, foliose, and fruticose lichens. India has considered a rich biodiversity region, with lichen species around the planet varying from approximately 17,000 (Rubavathi et al. 2021). Victory within the advancement of the lichen thallus over miniaturized and large-scale biological scales was clearly affected by the nearness of the two primary symbionts within the environment and by the portion of selectivity and specificity that either symbiont appears for each other (Moya et al. 2021). Typically, commonly considered a versatile procedure of the mycobiont to colonize a more extensive extent of natural conditions, selecting the leading adjusted phycobiont (Muggia et al. 2013). Lichens received rationally extensive uses in long-term air pollution impact-dependent research (Hurtado et al. 2020). Not only the Lichens but their symbionts are also used in the nanoparticle synthesis and biological reduction of nanoparticles (Rubavathi et al. 2022c)

The Index-based Atmospheric Purity research is attributing thus the indices of the trepidation of the lichen flora distinct from unrealistic conditions (Case 1980). Their priority and prosperity were studied with the alpha indices and beta diversity indexes, along with their altitude ranges. Earlier, this area was considered for the population density, and species richness was documented (Shyam et al. 2011). So far, the Indian subcontinent has been discovered with only 3,005 lichenized and lichenicolous fungal taxa (Rajaprabu and Ponmurugan 2022a,b). One of the major biodiversity hotspots of the Eastern Ghats (Sirumalai) was determined with only 96 species, the exact opposite

direction of the Western Ghats, Megamalai (Tiger reserve and Wildlife sanctuary), was reported with 101 species (Rajaprabu et al. 2021; Rajaprabu and Ponmurugan 2022a,b).

Randomized trophic communications were crucial in governing a species' retort to climate changes and challenges with biotic and abiotic conditions (Schweiger 2008). For epiphytic lichens, an interface between the thallus establishment and successful development was responses to grazers, structure, and shaping of the lichens' communities through an influencing impact on the rejuvenation role (Asplund and Gauslaa 2008). The density of lichens is reassessed based on the morpho chemotic features and its updated taxonomic keys. The impact of the susceptibility of lichen species to abiotic and biotic changes was influenced by the ability of the thallus accumulation within challenging environments through physiological adhesiveness (Kodnik et al. 2015; Moya et al. 2021). Most corticolous and saxicolous taxa were reported with multiple species rich in nature (Belguidoum et al. 2022a,b). Regular monitoring was more important to the habitat environment's climatic and biotic factors. The valid impacts of climate change on the growth of epiphytic lichen are threatened by enormous forest land reduction, destruction, and deprivation, specifically in clement and boreal areas, the noticeable changes of climatic evolution (Ellis 2013). Substrata are very important to the habitat growth influenced by the symptomatic and asymptomatic pathogens and other strange elements in the survival areas of the lichens. Secondary metabolite production was unique in these lichenized fungi. It is merely the mevalonic acid pathway overruling other acid pathways in lichens. The study was conducted with the connection and continuation of the lichens (Shyam et al. 2011).

MATERIALS AND METHODS

Study area

Kollimalai (Mountains of Death) is a hill station about 1,300 m above sea level in the center of Trichy and Namakkal Districts, the center of the Deccan plateaus of South India, located in the middle of South Asia's premier state of Tamil Nadu, as a bridge connecting the eastern hills and the Western Ghats, Kollimalai is a mystical region inhabited by Siddhas and tribals, with a total area of 637.19 km². The Latitude ranges between 11.248514°N and Longitude: 78.338707°E. This study, which describes the lichen growth, metabolism, and habitat characteristics of the Kolli hill, which is a habitat for different types of plants (1,500 angiosperms, ~70 cryptogams) and animals, has been calculated from March 2019 to April 2021 based on climate, growth intervals, and its natural metabolism (Figure 1).

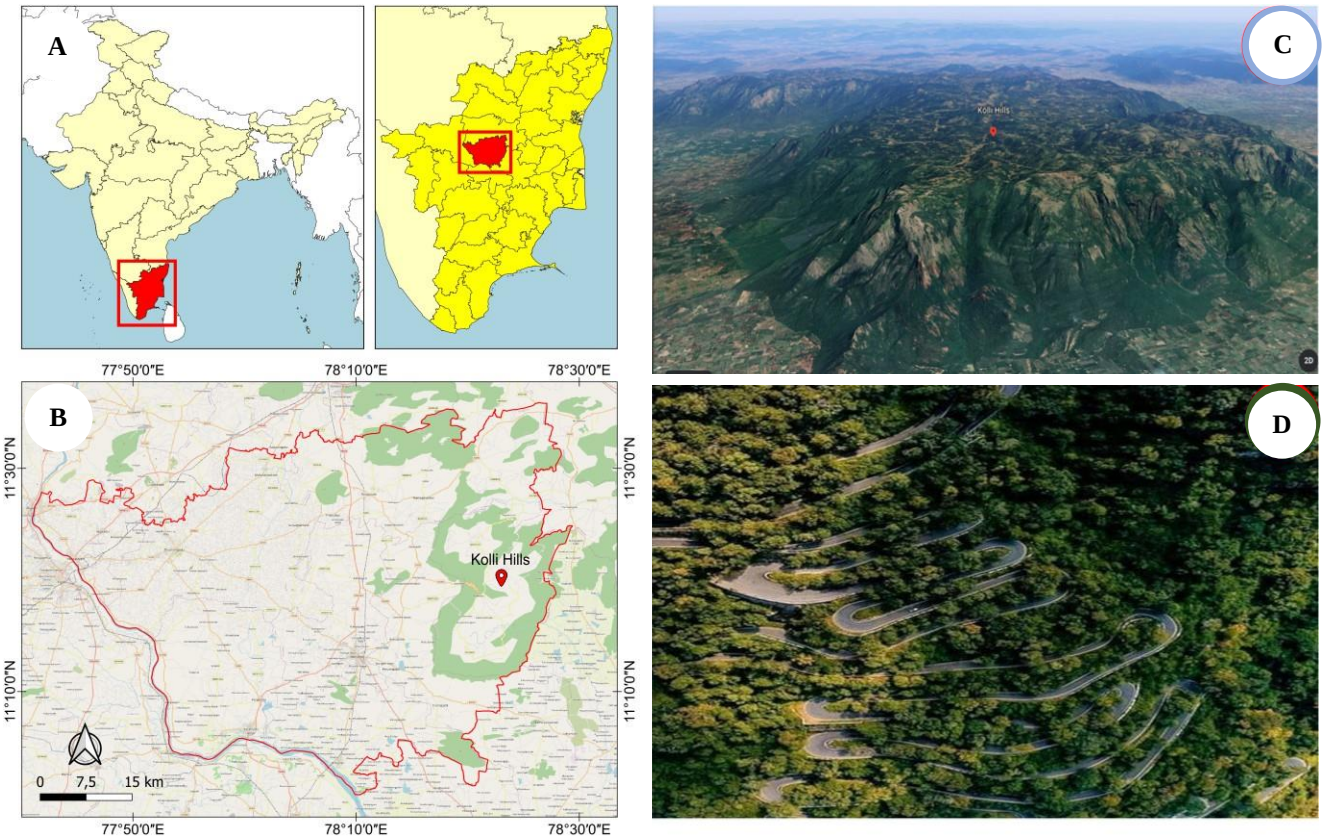

Figure 1. The map showing about the study area of Kolli Hills in Eastern Ghats, Tamil Nadu, India. A. India map, B. Kolli Hills, Namakkal District, C. 3D view of Kolli Hills, and D. Roadmap of the Kolli Hills, Tamil Nadu

Data collection and identification of the Kolli Hills lichens

The fresh samples were collected from the field for serialized identification from 2018-2021 for every four seasons. Samples were identified up to the genus level using the Published identification manuals and Keys for Indian, Nepal, and Srilankan lichen floral data (Singh and Sinha 2010). Seven classes were segregated for the altitude ranges from the mid-level of the study area. Among the 650 meters, every 100 meters were classified for a class. The samples are classified based on morphological texture and reproductive structures. The plot allotment with 5 x 5 meters even. Lichen's distribution and data analysis were followed by Saipunkaew et al. (2005).

Climatic data were obtained from the Standard observatory, Kolli Hills, in Tamil Nadu. The climatic conditions were considered for the cool to dry season triggered by the natural flow of the atmospheric air from both northeast and Southwest monsoons from the Asian continents, with 12-25°C from the end to the beginning of the annual year (November to February). During the hot seasons (from March to May), the temperature was high at up to 45°C and less at 40°C; the rain was compartmented from southwest ranges from the end of September to January. In the below 500 m, rainfall was considered average, 600 to 1,000 mm per annum of rainfall was considered as a medium, and rainfall increased up to 1,200 mm per annum was considered high. The temperature ranges from -4°C to 45°C was calculated for the temperate density towards lichens distributions. The mountain's forehead areas are very cooler and in a wet state with high humidity for a long time for an annual period. The selected lichen groups were encountered from 2018 to the end of the financial year 2021 (Visser and Molenaar 1995; Saipunkaew et al. 2005). At each location, lichen samples were taken from at least five randomly chosen trees or rocks. Identification of the lichen samples was performed by microchemical methods such as K-Test, C-Test, KC test, and PD color test using test chemicals on the Lichen thallus followed by Thin layer Chromatography. Microchemical tests were done to determine the order, genus, and Species level lichen taxonomy (Upreti and Sanjeeva 2004; Rubavathi et al. 2022a).

RESULTS AND DISCUSSION

Results

Lichens are very sensitive and high-stress, tolerant symbiotic organisms from cold mountains to hot deserts. They were used for various purposes, including modern biological pollution determination tools and many biological applications. The particular study area was one of the richer reports of proven floral and faunal distribution with cryptogams, including lichen (Ponmurugan et al. 2016). The Kolli Hills were richer in lichen diversity and reported 56 lichens from the end of the 20th Century. Altitude dependence distribution resulted for the most population from the ranges between 900 to 1150 m above MSL; only the maximum distribution was found in the following types such as Lecanoroid, Parmelioid, Graphidaceous, and Leprose types are found in all ranges. The following types of lichens are very sensitive to pollution and other anthropogenic activities: Pertisarioid, Usneoid, Ramalinoid, Arthonioid, and Cyanolichens. The most sensitive lichens types, Scaly and Cyanolichens, are highly sensitive and naturally found in the study area's tropical and high humidity areas. The least diversity was found with the Arthonioid > Usneoid > Scaly > Ramalinoid types. The richness of lichens was grouped based on their external appearance related to the classical cataloging position. There are seven larger groups found to be assessed by their richness (Table 1). The highest peak of the slope was 1,380 m above MSL. It was found that large numbers of crustose and Leprose colonies are frond from Lecanorid, Usneoid (Hairy), Ramalinoid (Straps), and Parmelioid (Leafy) lichens are found. The lowest height of the little mountain was only 755 m MSL; here, the density was less, and all types were very poor. Comparatively, the moderate altitude ranges (900 to 1,100) were the best adaptative areas for the lichen species' growth and helped them complete their life cycle.

Based on the substrata, the most abundant diversity was noticed from the saxicolous habitat's crustose-typed parmelioid lichens. Based on the substrate specificity, the corticolous was more-richer than other habitats. The mono species peculiarity was noticed from the dense forests of the Kolli Hills. The open grasslands and mountainous rocky areas are found with mixed species of both Crustose and foliose types. The terrestrial lichens such as Evernia, Pseudevernia, and Cladonia were more abundant in the shady pine forests and sub-tropical areas. The Lecanora and Graphidaceous lichens are found in all types of areas, including the thorny boundaries of the forest and commercial farming lands. The vegetation of the lichens was very hard to tabulate. But the group's density was easily notable during the data collection. Comparatively, the arthonioid, lecanoroid, Graphidaceous, and Pertusarioid types were found with equal distribution from the middle ranges of the mountain altitude with the Usneoid (*Usnea* and *Alectoria*), Ramalinoid (*Pseudevernia, Ramalina, Telochistes* and *Evernia*), Cyanolichens (*Leptogium* and *Collema*) on the higher altitude ranges. Noteworthy, the lichens distribution was found from the baselines of the reachable heights with higher foliose types density was unreachable heights (nearly 20-40 meters from the land surface). Highly denser than the Parmelioid foliose and Usneoid, and the Ramlinoid species was rich in numbers with healthy thallus (Figure 2). Based on the substrata, the most abundant diversity was noticed from the saxicolous habitat's crustose typed lecanoroid lichens. Powdery lichens were found with maximal distribution and unlimited growth in all seasonal years (exempted in summer). The major characterization and covariation of epiphytic lichens were reported to continental ranges on latitudinal gradient separation. Those were proposed to eliminate the irregular population and generation gaps of the foliose Parmelioid thallus. The scales were rich in the denser shady areas, but the richness and density in the open land areas were less (Hurtado et al. 2020; Belguidoum et al. 2022a,b).

Figure 2. Thallus density of the *Corticolous* lichen during different seasons in Kolli Hills, Tamil Nadu, India

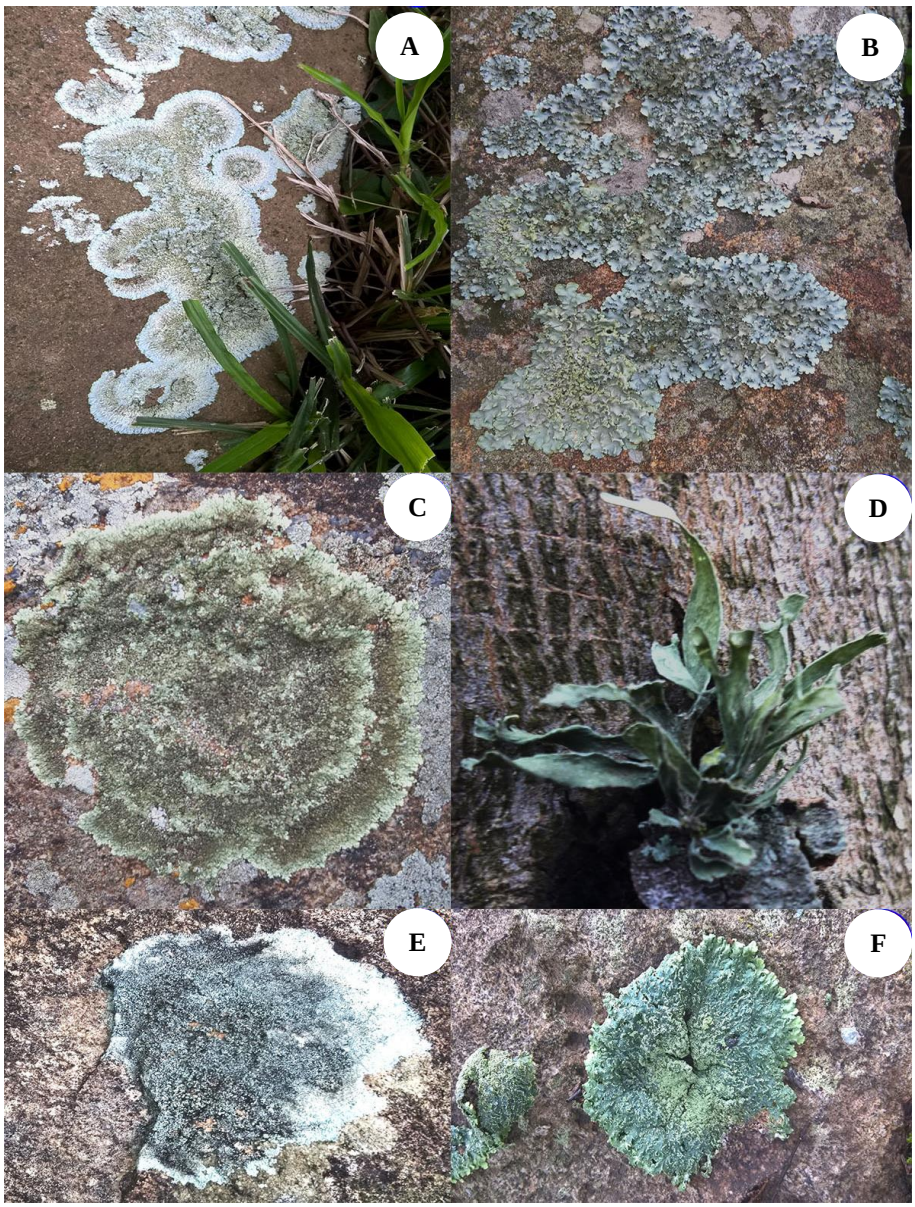

Figure 3. Growth richness of lichens from various substrates in Kolli Hills, India. A. Parmelioid (*Dirinaria*) on saxicolous, B. Parmelioid (*Parmotrema* and *Parmelinella*) lichens wealth during Monsoon, C. Year rings of the parmelioid lichens, D. Ramalinoind type on *Corticolous*, E. Pertusarioid on the top of Kolli Hills (1,350 m above MSL), and F. *Heterodermia* lichen grown from the cave of the rocky area, in Kolli Hills

The selected lichen-type verities samples were considered for the seasonal stress population, and the divergence was observed from March 2018 to April 2021. The atmospheric air was a natural Nitrogen producer, and the lichen was absorbed from the air. During the winter, a large amount of NO_2 was collected, and the thallus size gradually increased. Conversely, during the summer season, the lack of nutrition in thalli was observed, and the mycobiont shared the food material with their Photobiont. Therefore, the diverse population gradually increased from the beginning of the selected year. The population was stopped, or the least amount of thallus growth was noticed from the high rainfall season and gradual reduction in the summer. The Ramalinoid and Parmelioid lichens were found to be easy identifiers, represented in Figure 3. The growth rate was considered a year of the growth of the second branch in *Ramalina* and the secondary growth of thallus formation. Most living substrata were adopted to adhere to the thalli in winter and summer. But in the other seasons, the thalli were distributed by natural and other calamities.

Seasonal diversity and population of lichens in Kolli Hills, Tamil Nadu

Diversity was analyzed for the data collection and analysis for the 12 seasons. Among them, the year 2020-2021 (seasons 10 and 11) had populated with a large amount of groups density in their plot area with 78 and 79, respectively. Dominance (D) of the lichen samples was richer in Season 1, with 0.1424 units in 2018-2019 and less in Season 7 (0.1151) in 2019-2020. PCA of lichen distribution concerning the reasons was indicated in Figure 5. The thallus development was the measured basis of the year-ting formation and the apothecial development in the selected lichen groups. The size of the thalli was also considered for the Seasonal analysis. Most of the fast grower thali were Fruticose (*Usena*, *Ramalina*, and *Leucodermia*) and Leprose (*Chrysothrix and Lepraria*) in the Monsoon and Winter Seasons. The Least amount of growth was observed from both Arthonia, Graphidaceous (*Graphis*, *Diorygma*, *Phaeographis*, *Glyphis*, and more), Pertusarioid, and Lecanorid samples found less, were represented in Figure 4. All the Seasons are found with ten types of lichen distribution were analysed using Principal component analysis. Principal component analysis (PCA) of the samples of the *P. furfuracea* lichen was found in all types of agriculture and forests, and the pond shola on the denser in all other areas was in accordance with Kodnik et al. (2015). In this, the seasonal differences of the polycyclic aromatic hydrocarbons content in the lichen transplants were assessed as it is largely unknown. The seasonal differences existing in the PAHs loads should be taken into account when we are planning a biomonitoring survey and assessment of the distribution pattern. Several physical-chemical and biological factors like Lichen growth forms, age, lipid content that may influence the bioaccumulation capacity of lichen were determined in Kodnik et al. (2015).

Based on Fisher's alpha diversity, the samples were more in the 3.759 in season 1 of 2018-2019, and moderate rate with seasons 2, 4, and 6 with 3.483, 3.427, and 3.427, respectively (Table 2).

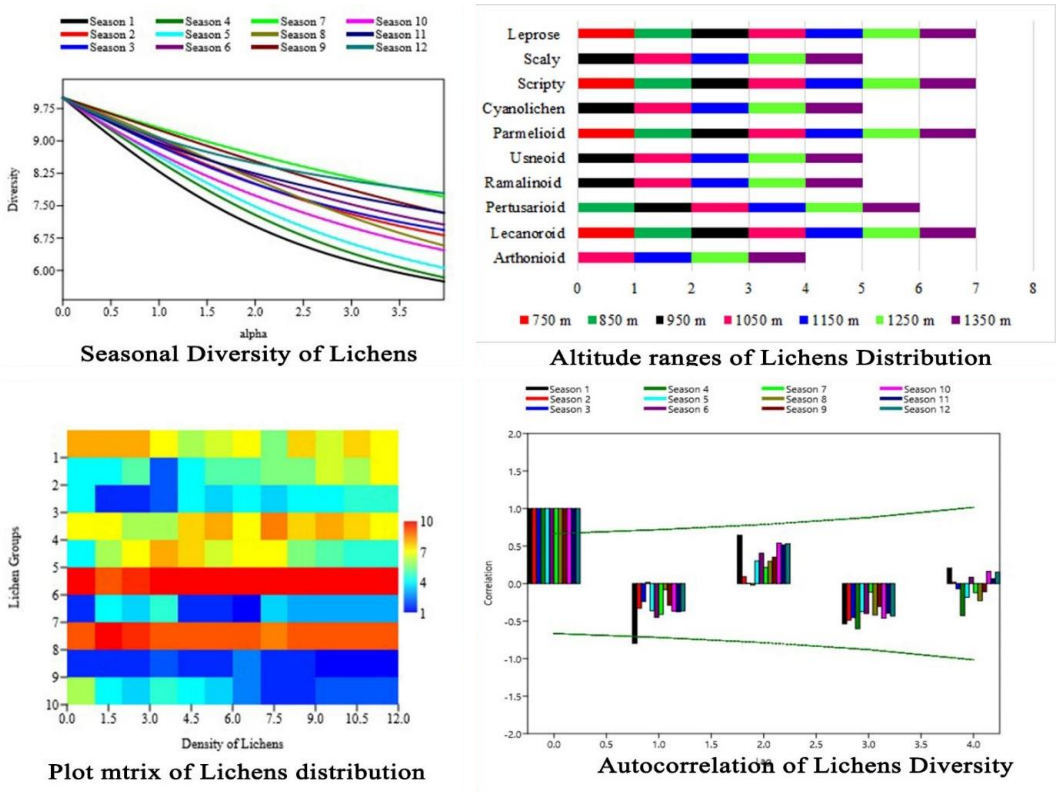

Figure 4. Resultants for various test using Past3 for Kolli Hills lichen diversity in Tamil Nadu, India

Table 1. Thallus types and their peculiarities are found in Kolli Hills, India

Name of the Group	External appearance	Specificity	Substrata	Genera
Arthonioid (Dust patch)		Thallus crustose, rudimentary, immersed, and or superficially grown, well developed. Prothallus is present with dark colors, thalli are found in white-pale yellow-green colors, and apothecia may be present with bright colors. Pycnidia present in apothecia, photobionts are trentepohlioid or coccal green algae.	Corticolous, saxicolous, Follicolous, lignicolous	*Arthonia, Arthothelium, Bacidia, Stirtonia, Synarthonia,*
Lecanoroid (Buttons)		Thallus crustose, white-pale yellow-green, brown, orange, red-colored, apothecia incomplete with bowl, wrinkled half rounded shaped, Orange-red-brown-black colored	Corticolous, saxicolous, lignicolous	*Amandinea, Buelia, Caloplaca, Haematomma, Lecanora, Lecidea Neobrowniella, Ocellularia etc.,*
Pertusarioid (Pimples)		Thallus crustose, white-pale yellow-green colored, apothecia complete with pimple-like appeared, wrinkled with completely rounded, White-pale-brown-black colored.	Corticolous, saxicolous	*Pertusaria, Pyrenula, Porina, Porpida*
Usneoid (Hairy)		Thallus is well developed, branched, fruticose typed; isidia and/or soredia may be present or absent. Green–grey–red mixed colors.	Corticolous, Saxicolous, Terricolous	*Usnea, Telochistes, Alectoria, Bryoria*

Ramalinoid (Straps)		Thallus bunchy shrub shaped, fruticose typed, full or often flattened, Grey – green – Orange – yellow. Highly sensitive and growing in non-polluted areas. Up to 10 cm long, apothecia may / not be present, grown with the other types such as crustose, foliose including leprose. Tropical and subtropical areas suit their growth.	Corticolous, Saxicolous,	*Ramalina, Evernia, Pseudevernia, Leucodermia, Telochistes, Rocella*
Parmelioid (Leafy)		Thallus foliose, flattened, completely shaped, isidia, soredia, apothecia, cilia, and rhizines may or/not be present. Pollution, UV tolerated, stable to extreme temperate conditions Chlorobionts are the major photo-synthesizer. Spot tests will give fluorescent colors—a faster-growing type- stable in all seasons.	Corticolous, Saxicolous, Terricolous, Plasticolous	*Parmotrema, Dirinaria, Pyxine, Parmelia, Parmelinella,*
Cyanolichen (Bluegreenish)		Thallus foliose, grey to dark black colored, high amount of water accumulates in the thalli; Cyanobiont (Blue-green alga) is the major source for the thalli. Mosses and ferns are very close neighboring green plants of the thallus habitat.	Corticolous, Muscicolous, Saxicolous	*Collema, Leptogium, Pshyma*
Graphidaceous (Scripts)		Thallus crustose, different colored thalli, stable in all environments, very slow growing type, apothecia transformation like concave and open type perithecia. More numbers of perithecia were found in 1 cm thalli. Few of them were found with the prothallus border lines. Spot tests give immediate color representations.	Corticolous, Saxicolous	*Diorygma, Graphis, Graphina, Glyphis*

Scaly type (Tubularly)		Thallus squamulose, tubular stalk will be found, and a scale-like part will be found on the base. Thallus is loosely attached, photobionts are green alga, and Apothecia will be present with light to dark and fluorescent colors. Cup-shaped, button-shaped, and bowl-shaped apothecia are found on the primary thallus's edge.	Terricolous, saxicolous, corticolous.	*Clasonia, Phyllospora, Leprocaulon,*
Leprose type (Powdery)		Thallus leprose found on high-radiated open areas. Fluorescent in bright colors on both naturally disturbed and undisturbed areas. The chemical spot test gives Bright red colors. Photobionts are green algal species.	Saxicolous, corticolous, lichenicolous	*Chrysothrix, Lepraria*

Table 2. Diversity indices of Kolli Hills, India

Diversity indices	The seasonal Year 2018-2019				The seasonal Year 2019-2020				The seasonal Year 2020-2021			
	Season 1	**Season 2**	**Season 3**	**Season 4**	**Season 5**	**Season 6**	**Season 7**	**Season 8**	**Season 9**	**Season 10**	**Season 11**	**Season 12**
Groups_S	10	10	10	10	10	10	10	10	10	10	10	10
Individuals	50	58	64	60	62	60	63	69	73	79	78	77
Dominance_D	0.1424	0.1249	0.125	0.1372	0.1337	0.1222	0.1151	0.1233	0.1173	0.1293	0.1213	0.1179
Simpson_1-D	0.8576	0.8751	0.875	0.8628	0.8663	0.8778	0.8849	0.8767	0.8827	0.8707	0.8787	0.8821
Shannon_H	2.115	2.19	2.184	2.144	2.157	2.199	2.23	2.206	2.225	2.164	2.192	2.205
Evenness_e^H/S	0.829	0.8934	0.8884	0.853	0.8643	0.902	0.9304	0.9079	0.9251	0.8705	0.8953	0.9068
Brillouin	1.842	1.937	1.949	1.9	1.918	1.952	1.989	1.981	2.008	1.964	1.989	1.999
Menhinick	1.414	1.313	1.25	1.291	1.27	1.291	1.26	1.204	1.17	1.125	1.132	1.14
Margalef	2.301	2.217	2.164	2.198	2.181	2.198	2.172	2.126	2.098	2.06	2.066	2.072
Equitability_J	0.9186	0.9511	0.9486	0.931	0.9367	0.9552	0.9686	0.9581	0.9662	0.9397	0.952	0.9575
Fisher_alpha	3.759	3.483	3.324	3.427	3.374	3.427	3.348	3.213	3.135	3.032	3.048	3.065
Berger-Parker	0.24	0.2069	0.1875	0.25	0.2419	0.2	0.1905	0.2319	0.2055	0.2278	0.1923	0.1688
Chao-1	10	10	10	10	10	10	10	10	10	10	10	10

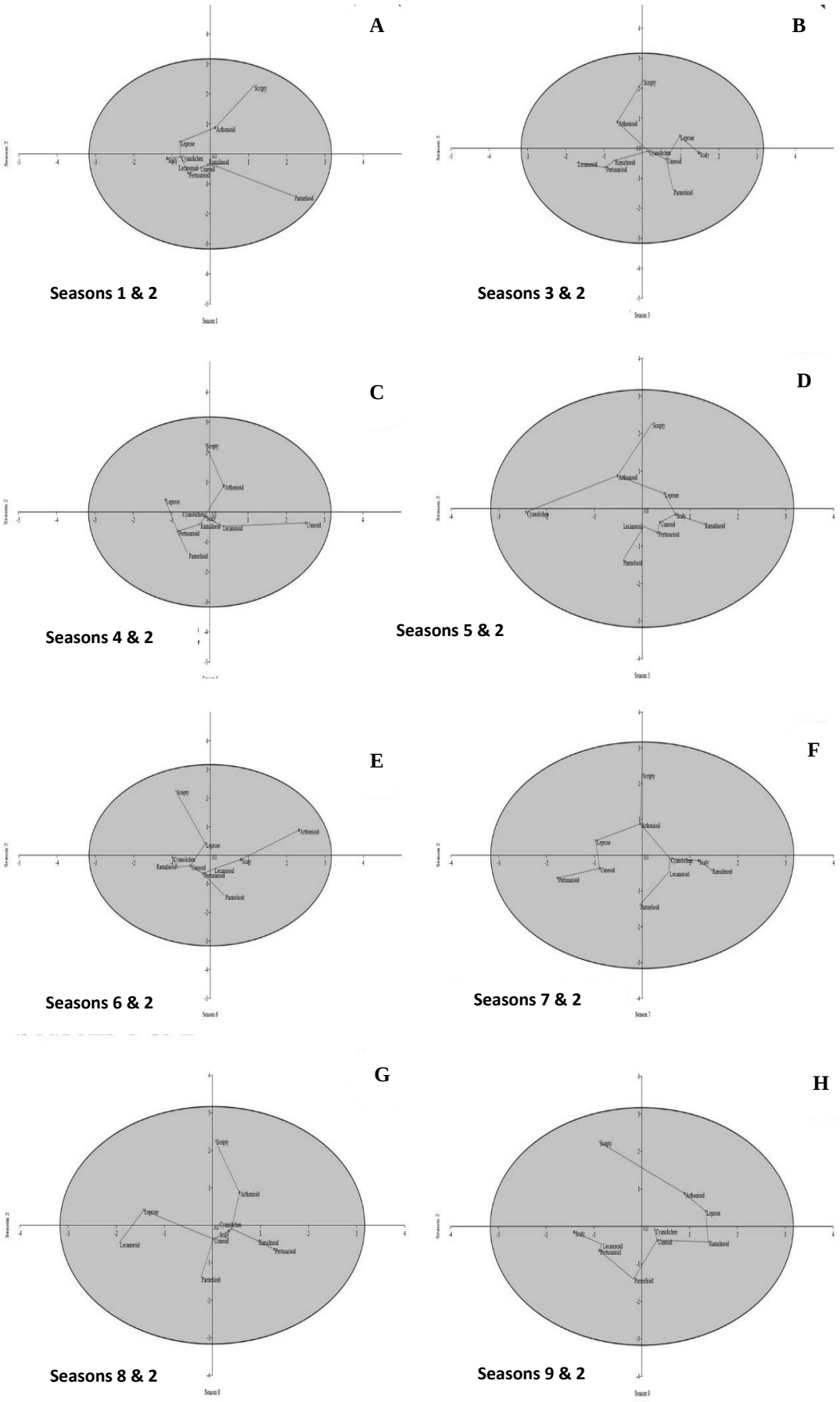

Figure 5. Principle component analysis of lichens distribution in various seasons

Among the twelve seasons, the second season was more impactful than the other seasons. The primary stage of the COVID-19 season is ecologically impactful for the lichen's diversity and thallus fragmentation and spores' delivery from the matured thalli of all access types. Immobility and artificial human-used material hazards did not harm the lichen's distribution and the thallus developments. Most of the macro lichen's thalli were detached from the substrata anonymously due to the wind speed and heavy rainfall (Rajaprabu and Ponmurugan 2022a,b). Whether they matured well or other anthropogenic effects, such as the inability to survive in extreme conditions, heavy rainfall, larger heat temperate, high wind speed, and other activities. Meanwhile, the local folklore and tribal peoples were collecting the fresh thalli of Evernia, dried samples of Parmelioid, and Usneoid lichens. Based on the lichen group, the maximum distribution was observed in Usneoid and Ramalinoid categories. Due to the humid condition and large amount of rain with sunny climatic conditions, the lichens were distributed with classy fluctuations in thallus growth (Rajaprabu and Ponmurugan 2022a,b). The least distribution was found with Leprose and Scaly lichens.

The richness was reduced dependently and independently with nature. The multiple-purposed cryptogams are losing their diversity for unspecified reasons. There are many anthropogenic activities that the Governances do not regularize. Natural Well-wishers are started to initiate awareness and conservation strategies such as parks, restricted areas, and more. Possibly the lichens can be used for agriculture fertilizers for Nitrogen deficiency and NO_3 fixations through a large amount of transplantation of terrestrial tree bark. The fire also imprecated the lichens, but no consideration of the species diversity loss and taxonomical threats were not initiated here and globally. The Parmelioid lichens are found to be edible by the folklores and local tribes of this area. That might be used to cure what kind of diseases and the applications to be studied in brief. Species protection regulation should be added to the cryptogams, including lichen. The health of lichens was encountered with only morphological appurtenance. The forest wealth was described with the denser lichen patches and the shrinkages of Parmelioid lichens, especially the *Dirinaria*, and *Parmoterma*, acting as a wealth analysis tool of the forest ecosystems.

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