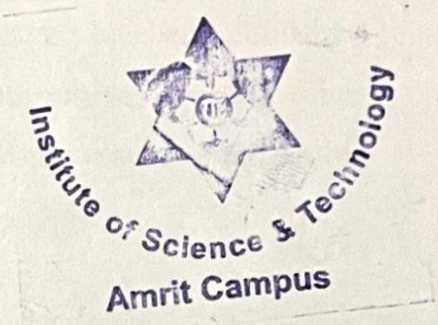
MACRO LICHENS OF SHIVAPURI NAGARJUN NATIONAL PARK, NEPAL



A Dissertation

Submitted for the Partial Fulfillment of the Requirements for the Master's Degree of Science in Botany

Submitted by:

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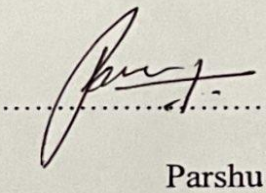
May, 2024

DECLARATION

I hereby declare that the work enclosed here is totally original to me, unless otherwise indicated by reference or acknowledgement. I further affirm that no part of the work has been published or submitted elsewhere or used in whole or in part to fulfill requirements for any other professional qualification or degree. All external literature, data, or works that are cited in this thesis have been properly acknowledged and listed in the reference section.



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RECOMMENDATIONS

This is a recommendation that Parshu Ram Regmi work on the Master's thesis titled **"Macro Lichens of Shivapuri Nagarjun National Park, Nepal"** under my guidance. The complete work has never been submitted for consideration for any other degree at any institution and is based entirely on original scientific findings. I so recommend that this thesis be approved in order to partially fulfill the requirements of M.Sc. in Botany.

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Associate Prof. Chitra Bdr. Baniya, PhD Central Department of Botany

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LETTER OF APPROVAL

The thesis work entitled **"Macro Lichens of Shivapuri Nagarjun National Park, Nepal"** submitted by Parshu Ram Regmi at the Department of Botany, Amrit Campus, Tribhuvan University has been accepted for the partial fulfillment of Master's Degree of Science in Botany with special paper Ecology and Resource Management.

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Parshu Ram Regmi

May 2024

ABBREVIATIONS

°C	Degree Celsius
$C6H_4(NH_2)_2$	p-phenylenediamine (Pd)
$CaOCl_2$	Calcium Hypochlorite
CCA	Canonical Correspondence Analysis
DCA	Detrended Correspondence Analysis
DHM	Department of Hydrology and Meteorology
DNPWC	Department of National Parks and Wildlife Conservation
GLM	Generalized Linear Model
GPS	Global Positioning System
HPLC	High Performance Liquid Chromatography
KM	Kilometer
KOH	Potassium Hydroxide
masl	Meter above sea level
Mm	Millimeter
SD	Standard Deviation
SNNP	Shivapuri Nagarjun National Park
TLC	Thin Layer Chromatography

ABSTRACT

Lichens of Shivapuri Nagarjun National Park, Nepal studied focusing the diversity along an elevation gradient ranging from 1400 to 2700 m asl. Random sampling was employed to collect lichen diversity in the national park. A total of 36 sampling plots of 5×5 m^2 each were taken with two at every elevation band of 100 m difference. All lichen species growing inside the plot were recorded. Voucher specimen of each lichen species was prepared. Latitude, longitude, aspect, elevation of each plot and substrate where each specimen growing were recorded. Lichen specimens were identified by using morphological, anatomical, and chemical such as color spot tests and thin-layer chromatography (TLC) techniques. Standard and recent keys were followed to identify each lichen specimen and verified after comparing to lichen herbaria and online resources. This study found a total of 39 lichen species belonging to 12 families and 19 genera. Parmeliaceae was the largest family comprising of 6 genera and 19 species. Foliose lichens were the most dominant life form. Corticolous was the dominant habitat followed by saxicolous species. Green algae emerged as the dominant photobiotic partner. Taxonomic keys were prepared for all lichen species. Generalized linear Model (*GLM*) with Poisson distribution of error was used to determine the lichen species richness pattern along elevation gradient. Canonical Correspondence Analysis (CCA) was used to know the lichen species distribution pattern. Species richness showed statistically significant unimodal relation (<0.001) with elevation having maximum richness of 13 species at 2300 m asl. In the CCA diagram high abundance of *Usnea florida*, *U. roseola*, *U. angulata* towards the high elevation in the CCA1 while high abundance of *Candelaria concolor* was towards the lower elevation of this study. This study has a great contribution in the understanding of lichen diversity patterns in mountainous regions and highlights the importance of considering elevation gradients in ecological studies.

Keywords: Elevation, Gradient, Photobiont, Species richness, Canonical correspondence analysis

संक्षिप्त

नेपालको शिवपुरी नागार्जुन राष्ट्रिय निकुञ्जमा भ्याउहरुको अध्ययन गरिएको छ, जसमा १४०० देखि २७०० मी. उचाईमा फरक पर्वतीय ऊँचाइको समापवतीमा विविधतालाई केन्द्रित गरिएको छ । रसायनिक परीक्षण, अन्तःकक्षीय र रंगक बिन्दु परीक्षणहरू जस्ता रुपात्मक, शास्त्रीय र थिन लेयर क्रोमेटोग्राफी (TLC) तरीकाहरुको प्रयोग गरेर राष्ट्रिय निकुञ्जमा भ्याउको विविधतालाई संग्रह गर्नका लागि यातायातीकृत नमूनावाची प्रयोग गरिएको थियो। प्रत्येक उचाईको १०० मी.को अन्तरको २ ब्याण्डमा ५×५ वर्ग मीटरको ३६ नमूना प्लट गरिएको थियो । प्लट भित्र परेका सबै भ्याउहरुके विवरण संकलन गरिएको थियो। प्रत्येक भ्याउ प्रजातिको प्रमाणित नमूना तयार गरिएको थियो। प्रत्येक प्लटको अक्षांश, देशान्तर, दिशा, ऊचाइ र प्रत्येक प्रवतिय दिशाको तत्वको उपाधि राखिएको थियो। प्रत्येक भ्याउको प्रतिनिधि पहिचान गर्नका लागि मानक र हालको किचलाहरूलाई अनुसरण गरिएको थियो र भ्याउ हर्बेरिया र अनलाइन स्रोतहरूसँग तुलना गरेपछि प्रमाणित गरिएको थियो। यो अध्ययनले १२ परिवारहरू र १९ जेनेरामा समावेश भएका कुल ३९ भ्याउ प्रजातिहरू पाईएको थियो। Parmeliaceae एक विशाल परिवार थियो जसमा ६ जेनेरा र १९ प्रजाति रहेको थियो। पत्तेदार भ्याउहरू सबैभन्दा प्रभावशाली जीवन रूप थिए । वासस्थानका हिसाबले corticolous प्रजातिका भ्याउहरु प्रमुख थिए भने त्यस पश्चात saxicolous प्रजातिहरूको बाहुल्यता थियो । हरियो लेउहरू प्रमुख photobiotic साथीको रूपमा रहेको थियो। सबै भ्याउ प्रजातिहरूको लागि शास्त्रिक किचलाहरू तयार गरिएको थियो। उच्चतामा फरक पर्वतीय समापवतीबाट भ्याउ प्रजाति धनी गर्ने प्रारूपमा पर्वतीय अभिक्षमता (जीएलआर) र सहस्त्रवितरणको खातिले पोइसन वितरणसहितको सामान्यीकृत रेखांकित (पिओस)वितरण प्रयोग गरिएको थियो। कैनोनिकल संवर्द्धन विश्लेषण (सीसीए) भ्याउ प्रजातिहरूको वितरण प्रणाली जान्नको लागि प्रयोग गरिएको थियो। प्रजातिहरूको संख्यात्मक समृद्धिको प्रारूप उच्चतामा एक द्विआवधिक संबंध देखाए (<0.001) जसमा उच्चतामा २३०० मी.को १३ प्रजातिको अधिकता देखियो। सीसीए डायाग्राममा उच्चतामा *Usnea florida, U. roseola, U. angulata* तथा सीसीए १ मा खण्डित कमी उच्चतामा *Candelaria concolor*को अधिकता देखियो। यो अध्ययन पर्वतीय क्षेत्रहरूमा भ्याउ विविधता प्रारूपहरूको बुझाईमा ठूलो योगदान प्रदान गर्दछ र पारिर्सथितिक अध्ययनहरूमा उच्चता समापवतीहरूलाई ध्यान दिनको महत्वलाई दर्साउदछ ।

मुख्यशब्दहरू: उच्चता, ग्राडियेन्ट, फोटोबायोटिक, प्रजाति समृद्धि, कैनोनिकल संवर्द्धन विश्लेषण।

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CHAPTER-1
INTRODUCTION

1.1 Background

Lichen is a Greek word that gives the meaning to the surface growth on the olive tree's bark. Theophrastus, the father of botany, around 300 BC, coined the term 'lichen' to describe a plant group outgrow on tree. Due to the descriptions only based on the outward appearances, lichens were called as mosses in some situation and also as seaweeds in others (Nash III, 2008). Thereafter, after the introduction of microscope in early 1800s, scientists began to document the lichen based on their comprehensive anatomy and were able to establish their real nature (Mulligan, 2009). Lichen is an organism created by the symbiotic relationship between an algae and fungus (Mulligan, 2009). Fungal partner also known as mycobiont produces the main lichen body and produces fruiting body whereas algal partner known as photobiont is found between the upper and lower cortex of fungi (Larsen et al., 2007). Photobiont partner, alga feeds the fungus and allows it to propagate photosynthesis whereas the mycobiont provide the structural support and protection to the algal partner (Roper, 2018). Basidiomycetous Yeasts (Cystobasidiomycetes, Pucciniomycotina) are another component except algae and fungi were elegantly visualized by Spribille et al. (2016) for the first time in the thallus cortex of pendent lichens.

Lichens are also known as pioneer species and are found in all type of terrestrial ecosystems from hot, desert, rock, tropical rain forest, to cold polar locations like arctic tundra and also even in high-altitudes (Hafellner & Calatayud, 1999). Lichens show a greater morphological variety and grow in different ways- crustose, foliose, and fruticose. About 20,000 species of lichens are recorded throughout the world spreading in different environment which roughly makes up 8% of the terrestrial ecosystem (Hawksworth et al., 1984). International workshop on lichen taxonomy was conducted in 1994, where lichenologist predicted that Nepal might constitute roughly about 2000 lichens species. The current Nepal lichen checklist listed 1129 taxa belonging to 66 families and 237 genera, where *cladonia* was the largest genus consisting 81 species of lichens, including categories specific to the infra specific range (Baniya et al., 2022).

The diversity of lichens and species composition varies depending upon the environmental conditions (example: temperature, moistures, rainfall, humidity, and many more) and type of ecosystem (Nimis & Martellos, 2001). Lichens are reported from almost all physiographic region of Nepal. The lower elevations are chiefly dominated by crustose forms, the middle

regions by foliose and the higher elevations are rich in fruticose life-forms of lichens (Baniya et al., 1999). Other research has shown that lichen diversity, composition, and distribution are also influenced by forest structure and altitude (Abas et al., 2019; Sulaiman et al., 2018). In the context of Nepal, the maximum lichen richness is recorded at an elevation between 3100-3400m and endemic lichens between 3900-4400m (Baniya et al., 2010).

Although the lichen flora is an essential part of nature, it has received less attention locally, particularly in poorer nations like Nepal. They are frequently seen as having less meaning and utility, or Jhyau. However, Limbu Yakkha and Rai people, indigenous communities of eastern Nepal, are familiar with lichens (locally known as Yangben) and consume some lichens as traditional food long before this group in Nepal gained scientific attention (Bhattarai et al., 1999; Maden et al., 2008).

In many nations, the use of living things in environmental quality research is now widely recognized. on the idea that changes in environmental parameters have an impact on the biota, biomonitoring systems measure these effects to gather information on the health of the environment (Loppi & Frati, 2006). Since it is quick, inexpensive, and produces results that can be used to make predictions about human health, the mapping of lichen diversity is becoming common practice in many countries. Epiphytic lichen diversity is frequently used as a sensitive indicator of the biological effects of air pollutants (Cislaghi & Nimis, 1997). Lichens have been extensively employed for monitoring heavy metal deposition patterns in addition to floristic changes. In fact, the element content of lichen thalli has been shown to be directly connected with environmental levels, and lichens are known for their capacity to absorb airborne stuff to concentrations substantially greater than those in the atmosphere (Bari et al., 2001; Sloof, 1995)

Even though this association weakens when conditions improve, air pollutants, particularly SO_2, are remain the key limiting factor in metropolitan environments. Harvesting and forest fires had a noticeable impact in wooded areas, indicating the need to create a more specific sample procedure to gauge air pollution in such ecosystems (Giordani, 2007).

1.2 Significance of the study

Lichens, serving as bio-indicators of habitat conditions and air quality are one of the vital elements of forest ecosystem.

In the international workshop on lichen taxonomy held in Kathmandu in 1994, the lichenologist opined that there are about 2000 lichen species but half of the predicted numbers have been

listed so far. Shivapuri Nagarjun National Park lying in close proximity to Kathmandu valley remains unexplored for more than decades. Thus, this study in SNNP can contribute in acknowledging the present status of diversity of lichens along with the elevational gradient and can add some information about the overall air quality of this area.

1.3 Objectives

The main objective of this study was to determine lichens of Shivapuri-Nagarjun National Park (SNNP), Nepal.

The Specific objectives of this study were:

- To make artificial taxonomic identification keys to lichens of SNNP.
- To determine the diversity patterns of lichens in the study area.
- To determine the lichen species composition pattern of lichens.

1.4 Limitations

SNNP occupies an area of 159 sq. km. that includes 4 districts: Kathmandu, Nuwakot, Sindhupalchowk, and Dhading. This research work aims to cover all districts but Dhading remains unexplored.

Other limitations;

- Difficult geography of the site in the SNNP limit the research work.
- Only macro lichens were studied.
- Color spot (chemical test) and TLC (Thin Layer Chromatography) test were carried but HPLC (High Performance Liquid Chromatography) test was not carried out.

CHAPTER-2

LITERATURE REVIEW

2.1 Floristic study of lichens

Paulson (1925) published an account of 31 species of lichens collected by Sommewella in 1824, from the Mt. Everest region of Nepal. Asahina (1955) reported 62 lichens from Mewa Khola of eastern Nepal based on the collection of Nakao (1952-1953). Awasthi (1957) made an extensive collection of lichen species from eastern Nepal and 3 new lichen species were recorded which were *Cetraria nepalensis, Cetraria pallida, Physica metanotricha.* Awasthi (1960) reported 38 species of lichens from Cho-Oyu Himal which were collected by R.S Rao 1958. Asahina & Kurokawa (1966), reporte133 taxa of lichens from eastern Himalayas out of which 62 taxa of lichens were from Nepal.

Kurokawa (1967) enumerated 53 species of lichen from Rolwaling Himal among which 36 species were found to be new to Nepal. Poelt (1974) reported 19 species of *Physica,* out of which 4 were new to science and 15 species were new records of Nepal. Furthermore, 2 species each of *Physoconia,* and *Physciopsis* from Nepal were recorded. Poelt (1977) enumerated the lichen genera *Ioplaca, Dermatocarpon,* and *Solorina,* from the Langtang region of central Nepal. Poelt (1977) reported 12 species of *Umbilicaria,* from Nepal. Awasthi & Joshi (1982) enumerated the genus *Peltigera,* from Nepal. (Awasthi & Awasthi (1985) enumerated a single species of *Alectoria,* 14 species *Bryoria, and* 2 species of *Sulcaria* from various region of Nepal and India. Upreti (1987) prepared the keys of 62 species of lichen genus *Cladonia,* that were recoreded from Nepal and India. Awasthi (1988) published the key of macro-lichens of Nepal and India. Kurokawa (1988) collected total of 38 species from the two genus: *Parmelia* (24 species) and *Anaptychia* (14 species) from Kathmandu valley. Sharma & Kurokawa (1990) enumerated lichens genera *Anaptychia, Parmelia,* and *Xanthoparmelia* from Nepal. Pant & Upreti (1993) recorded 5 species of *Diploschistes* from Nepal.

Sharma (1995) made a checklist of lichens in Nepal which enumerated 465 lichen species and 79 genera and 30 families. Baniya (1996) reported 99 lichen species out of which 33 species were recorded new to Nepal, from Shivapuri and Sikles area. Pathak (1998) described 52 texa of lichen from Hetauda and Dang among which 15 species were new to Nepal. Devkota (1999) enumerated 55 species of lichen from Namobuddha, Kavreplanchowk, Bagmati Province, Central Nepal and studied the antibiotic properties of *Heterodermia diademata, Parmelia nepalensis* and *Parmelia reticulate*. Devkota (2008) reported 32 species of lichen belonging to 9 families and 10 genera from Phulchowki area of Kathmandu district.

By using published literatures (Baniya et al., 2010) compiled a elevational record of 525 species of lichen flora of Nepal, belonging to 40 families and 121 genera among which 55 species were endemic to Nepal. Olley & Sharma (2013) published a checklist of the lichen of Nepal, on the basis of secondary data and the specimen collected by Sharma in 2007), which represented 792 species of lichen belonging to 187 genera. Baral (2015) recorded 81 species of lichen belonging to 15 families from Sagarmatha National Park and Manaslu Conservation Area, where Parmeliaceae was found to be dominant.

Rai et al. (2017) recorded 28 new lichen species belonging to 13 families and 21 genera from the country forest of Dadeldhura and Mahakali zone. Karmacharya et al. (2018) studied the micro-lichen from Nepal, where 18 new species were recorded from the family Graphidaceae from Nepal. Baniya (2020) prepared the lichen flora of Nepal, which consist of 550 species of lichen belonging 130 genera. This study found that the Parmeliaceae family is the most dominant consisting 110 species and 32 genera followed by physiciaceae with 64 species and 11 genera and Lecanoraceae with 49 species and 8 genera.

Baniya et al. (2022) prepared the check list of lichens of Nepal, which enumerated 1129 taxa including 1078 species and 51 infra-specific categories.

2.2 Ecology of lichens

Ahti (1977) provided an ecological description of the lichens found in the world's boreal coniferous zones, as well as an analysis of the impact of florogenetic isolations on the rate of evolution of the component flora. Rogers (1990) studied ecological strategies of lichen and found foliose species were often competitive with high relative growth rate. The decreasing importance of crustose lichen with increasing elevation could be influenced by decreasing ecological disturbance. According to Hauck & Spribille (2005) the effective immobilization of Mn in the bark of the spruce-fir forests of the Salish Mountains, northwestern Montana, may be the reason for the greater epiphytic lichen diversity on Abies compared to other confiners, including Picea and Pinus. Additionally, they proposed that the diversity of epiphytic lichens is likely to be less significant than the precipitation chemistry.

According to Pinokiyo et al. (2008), the total species richness of lichens had a unimodal distribution between 400m and 2700m elevation. Similarly, Baniya et al. (2010) studied the diversity and distribution of the lichen along the elevation gradient and found that the maximum lichen diversity was at mid-elevation ranging from 3100-3400m while the range of 4100–4200m, 3200m, and 2400–2500m was the highest elevation for crustose, fruticose, and

foliose lichens, respectively. He found a unimodal hump shaped relationship along elevation 200 to 7400m asl.

In a community forest in western Nepal, Nag et al. (2011) investigated the epiphytic lichens as a sign of the land-use pattern and forest harvesting. They discovered that communal harvesting of the forest and phorophyte determinants limited lichen diversity. However, Sankhi (2014) studied the lichens richness and composition pattern along the altitudinal gradient in the Manaslu Conservation Area and was found that there was no significant difference in species richness of lichens along altitudinal gradients and aspects.

Chongbang et al. (2018) studied the effects of elevation, land use and canopy openness on species richness and composition of lichen in Kanchanjunga Conservation Area and was found that lichen diversity gradually increased from cultivated land to forest and canopy openness influenced the distribution of lichen communities in the Himalayas.

Shrestha (2021) studied the diversity of lichen in Khaptad National Park, and found that total species richness showed significant increasing pattern with the elevation and lichen occurred more in *Quercus* tree. Thakur (2019) studied the lichen diversity of Daman along elevation gradient and highest species richness was found at an elevation of 1326m and 2126m and showed by model hump shaped graph. (Bhatta, 2023) studied the lichen of Api Nampa Conservation Area and found that total lichen species, fruticose lichens and green algal lichens richness were found to have a linear relationship with elevation.

CHAPTER-3

MATERIALS AND METHODS

3.1 Study Area

3.1.1 Location and Physiography

Shivapuri Nagarjun National Park (SNNP) lying on the northern periphery of Kathmandu valley, 12 KM away from Ratnapark, the main center of the capital city (Figure 1). It covers an area of 150 sq. km and has an elevation gradient ranging from 1350m asl to 2732m asl. Geographically SNNP located within $27^0$43' to $27^0$52' N latitude and $85^0$13' to $85^0$45' E longitude. This bar claims part of Kathmandu, Nuwakot, Dhading, and Sindupalchowk districts of Nepal. The SNNP was established as the country's ninth national park in 2002. It was managed under the Shivapuri Watershed Development Board and was later declared Shivapuri Watershed and Wildlife Reserve, prior its declaration as national park.

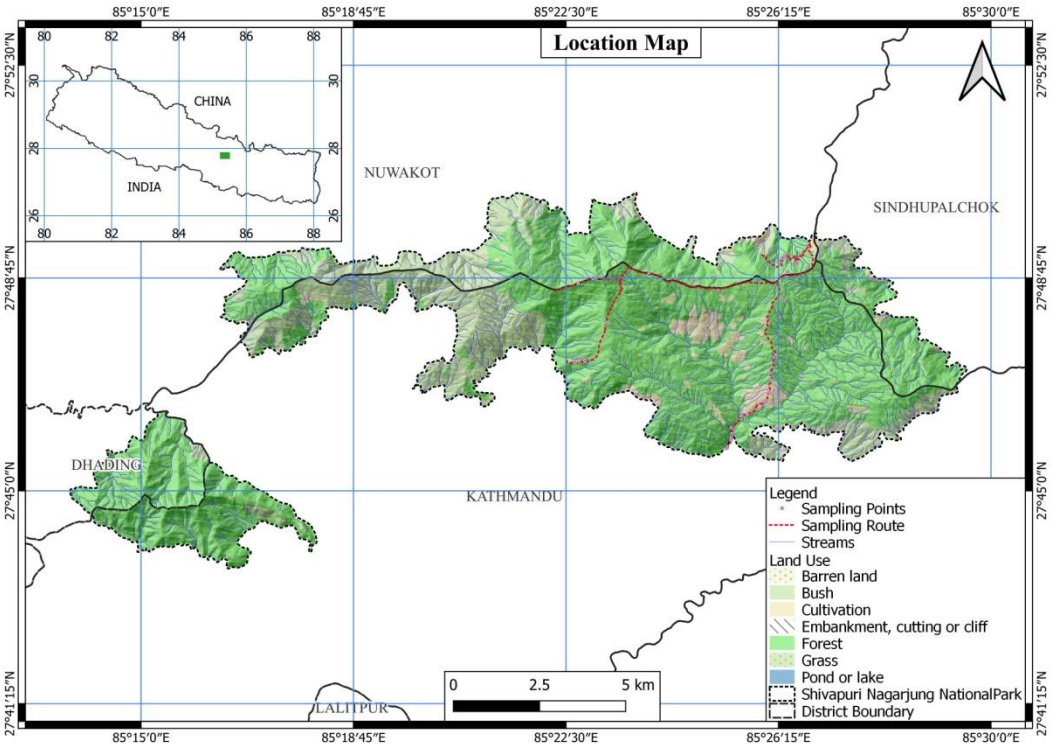

Figure 1: Map of study area.

3.1.2 Climate

The SNNP experiences climatic variations due to topographical changes and variations in elevation. The closest location to the current research area is Budhanilkantha station in Kathmandu, where the climatic data for this area was obtained (Figure 2). The mean maximum and minimum temperature were recorded. 25.59°C and 13.09°C respectively.

The region experiences the average monthly temperatures of 29.13°C for the maximum in June and 3.87°C for the lowest in January. In the same way, the average annual precipitation was 161.45 mm, with July having the most rainfall (502.08 mm) and November having the least amount (0.76 mm) (Figure 2).

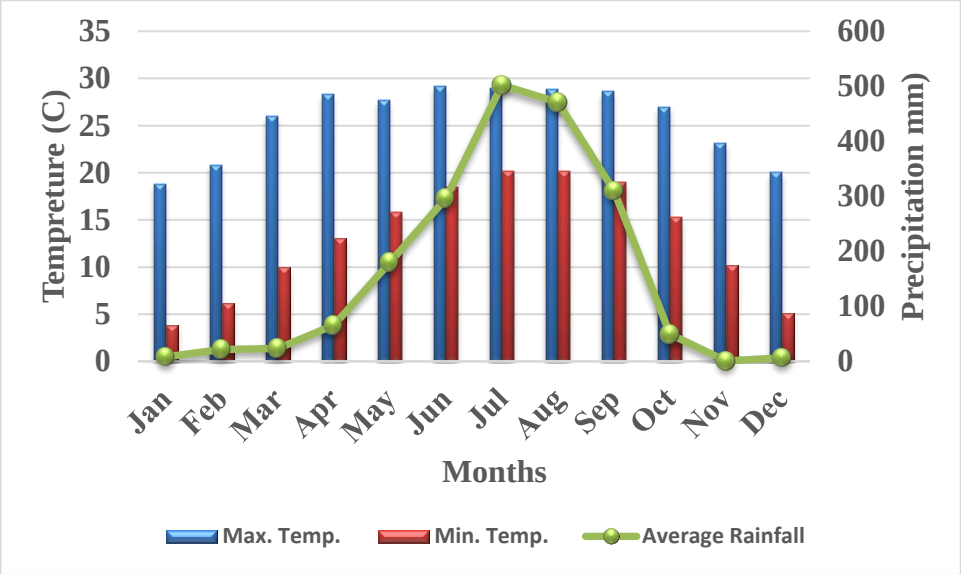

Figure 2: Climatic data of SNNP (Station Index= 1071; Average of 2010 to 2023 A.D.; Source: DHM 2023)

3.1.3 Vegetation and fauna

SNNP lies in the transition zone between sub-tropical and temperate climate. Depending upon the elevation and topographical aspects, the vegetation of SNNP characterizes as a variety of natural forest including pine, oak, rhododendron, etc (Majupuria & Kumar, 1998; Sigdel, 2008). In higher elevation, a variety of medicinal herbs, 129 species of mushroom and 2122 floral species out of which 449 are vascular and 16 are endemic plants (DNPWC, 2019).

The park has 24 mammalian species such as Himalayan Black Bear, leopard, Jungle cat, and Rhesus monkey. This park is also home to 106 species of moths and butterflies, 318 species of birds, 14 of them are threatened. 18 species of Herpetofauna found in SNNP. Frogs and toads are common amphibians. King cobra, green pit viper, rat snake, skink, lizards, geckos are common reptiles found in SNNP (DNPWC, 2019).

3.1.4 Places of attention

From Kathmandu, the park is easily accessible. Trekking is the main attraction for visitors to the park. The park is connected by trekking paths leading to Gosaikunda, Helambu, Nagarkot, and Langtang National Park. Within the park there are a number of Buddhist and Hindu sacred

sites. Mid-April is Nepalese New Year's Day, when pilgrims from the Kathmandu valley and surrounding regions come to Baghdwar and Bishnudwar in the park, the source of the sacred rivers Bagmati and Bishnumatii. From the northern parts of the park, visitors can enjoy breath-taking landscapes of the high Himalayas. Similarly, the southern park hills offered expansive views of the Kathmandu valley.

3.2 Method of data collection

3.2.1 Sampling

Random systematic sampling was done from an elevation of 1400 masl to 2700 masl along the elevation gradient. A total of four sampling plot was taken on the both side of transect (walking trail) but due to difficulty in taking plots on some sites according to its sloppy nature, I had done less than four plots. At first, random place was selected at Sundarijal area. Two 5m x 5m plot was taken 5m away from the trail in between 100m. Then, the consecutive plots were taken every 100 m along the assumed transect on the study sites. A total of 36 plots were taken in the study area. Information such as latitude, longitude, aspect and elevation were collected of each specific plots by using GPS Probe and Compass. Along with Locality, lichen habitat, life form, type of substratum, Host species etc. all were noted.

3.2.2 Lichen collection

GPS, knife, measuring tape, hammer, hand lens, note books, pen, pencil, and newspaper used during lichen collection. The habitat of the lichen thallus such as tree bark, soil, and rock, and the type of host tree were recorded. Elevation, direction, latitude and longitude and others ecological notes were recorded. The lichen inside the plot were collected and packed in paper envelops, and curated according to the standard protocol of (Awasthi, 2000). Digital photograph of the lichen species was taken in the field (Photoplate 8 A).

3.2.3 Herbarium preparation

The specimens collected from the study area were dried. After the identification of lichen specimens, herbaria were prepared by following the standard protocol of Nayaka (2014) with all the collected level ecological notes.

3.2.4 Lichen identification

The collected lichens specimens were taken to the laboratory of Central Department of Botany, Tribhuwan University, Kritipur. Where, further work on lichen identification was carried out.

The lichen specimens were identified by studying the morphology, anatomy, color spot test, and thin layer chromatography (TLC). The character was then matched with key of (Awasti, 2007). The cross checking of lichen species was also done with lichen herbaria present in TUCH checklist and internet. To identify lichens and to develop artificial keys to the family, genus, and species, the macrolichens keys of Awasti (2007) and the checklist of lichens of Nepal Baniya et al.(2022) were used.

3.2.4.1 Morphology

Under a stereomicroscope with a 10×1.5 mm magnification, the morphological characteristics of various lichen species, including thallus color, texture, the presence or absence of maculae, pycnidia, pseudocyphellae, cilia, soredia, isidia, apothecium, and rhizinea, were examined.

3.2.4.2 Anatomy

A compound microscope has been used to examine the lichen thallus and fruiting bodies' anatomy. Lichen sections were mounted on temporary slides using a 5% potassium hydroxide (KOH) solution and stained with cotton blue in order to examine anatomical structures (Brodo, 2003).

3.2.4.3 Color spot test

Following the application of specific chemicals, the lichen thallus exhibits its distinctive color, often known as a color reaction. This is a crucial component for lichen identification. Aqueous potassium hydroxide (KOH); [K], Bleaching powder or an aqueous solution of calcium hypochlorite $(CaOCl)_2$); [C], and an aqueous solution of p-phenylenediamine ($C_6H_4(NH_2)_2$); [Pd] are the three chemical reagents employed in the identification of the lichens. KC test was also performed in which K test was immediately followed by C test (Nayaka, 2005).

3.2.4.4 Thin Layer Chromatography (TLC)

Thin layer chromatography must be used to identify lichen chemicals that show up as spots on TLC plates because many lichen substances are undetected in color spot tests. Those locations can be located with the aid of the TLC instructions (Photoplate 8 D-E).

First, little fragments of the lichen thallus were placed in microtubes together with a few drops of acetone to extract the lichen components. For the TLC, two thin aluminum plates with silica gel precoated on them were used: one at the plate's base (the loading line) and another at 15 cm (the ending line). Using tiny capillaries, an equal distance of acetone extract from each lichen

was put into a 2 cm line. The TLC plate's first and last spots served as the control. As a control, *Parmelinella wallichiana* was employed. Following the completion of loading, the TLC plate was allowed to pass through the solvent for 40–50 minutes by being kept in a jar containing solvent-A (toulene–diaxane–acetic acid). The plate was removed from the jar and allowed to dry in the air when the solvent level reached the solvent front, which was at 13 cm. The materials that were separated on the TLC plate were often paler in color; therefore, the TLC plate was sprayed with a 10% sulfuric acid solution and placed in a hot air oven that was preheated to 110°C for a few minutes to allow the spots to properly form. Following the development of the spots, the product was identified by comparing its color and location to the charts provided by Culberson (1972) and Culberson & Kristinsson (1970).

3.3.5 Statistical analysis

After completing the fieldwork and identifying the lichen specimens that were thus gathered, data input and data verification were carried out. The families, life forms, habitat groupings, and photobiontic partners of each detected lichen species were also categorized. The composition pattern of lichen species along elevation gradients and aspects was analyzed using Ordination.To identify the type of species response curve among the various ordination methodologies, Detrended Correspondence Analysis (DCA) was used. The determinant of further analysis was the gradient length of the DCA first axis. Using the first axis gradient length of 5.01 > 3 SD units found by DCA analysis, the Canonical Correspondence Analysis (CCA) was carried out. The dominant species and environmental variables, including elevation and aspect, that were presented in the CCA plot. For regression, Generalized Linear Model (GLM) was employed to examine the correlation between the overall richness of lichen species and elevation gradient between 1400 and 2700 meters.

R is a popular and free software package. The package vegan 2.6.2 Oksanen et al. (2022) and R version 4.3.1 (R Core Team 2024) were used for the data analysis (ordination and their graphical depiction). For additional graphical presentations, Microsoft Excel (Microsoft Office 2010) was utilized.

CHAPTER-4

RESULTS

4.1 Lichens diversity

All together 39 species of lichens under 19 genera and 12 families were identified and recorded within the study area, Shivapuri-Nagarjun National Park (Table 1). The Parmeliaceae was the largest family with 19 species belonging to 6 genera followed by Physciaceae with 6 species; Caliciaceae, Cladoniaceae, Collemataceae and Ramaliaceae with 2 species each and the Candelariaceae, Coccocarpiaceae, Lobariaceae, Peltigeraceae, Stereocaulaceae and Vericellariaceae with a single species each (Figure 3).

Table 1 : List of Lichens species and their family, growth forms, photobiontic partners and habitat.

S.N.	Name of Species	Families	Growth form	Photobiontic partner	Habitat
1	*Candelaria concolor* (Dicks.) Arnold	Candelariaceae	Foliose	Green algal lichens	corticolous
2	*Cladonia ramulosa* (With.) J.R. Laundon	Cladoniaceae	Fruticose	Green algal lichens	Terricolous
3	*Cladonia squamosa* Hoffm.	Cladoniaceae	Fruticose	Green algal lichens	Terricolous
4	*Coccocarpia pellita* (Ach.) Müll. Arg. em.R. Sant.	Coccocarpiaceae	Foliose	Blue green algal lichens	corticolous and saxicolous

5	*Dirinaria aegialita* (Afzel. ex Ach.) B.J. Moore	Caliciaceae	Foliose	Green algal lichens	corticolous and saxicolous
6	*Dirinaria applanata* (Fée) D.D. Awasthi	Caliciaceae	Foliose	Green algal lichens	corticolous and saxicolous
7	*Heterodermia diademata* (Taylor) D.D. Awasthi	Physciaceae	Foliose	Green algal lichens	corticolous and saxicolous
8	*Heterodermia hypochraea* (Vain.) Swinscow & Krog	Physciaceae	Foliose	Green algal lichens	corticolous
9	*Heterodermia incana* (Stirt.) D.D. Awasthi	Physciaceae	Foliose	Green algal lichens	corticolous
10	*Heterodermia speciosa* (Wulfen) Trevis.	Physciaceae	Foliose	Green algal lichens	corticolous

11	*Hypotrachyna cirrhata* (Fr.) Divakar, A. Crespo, Sipman, Elix & Lumbsch	Parmeliaceae	Foliose	Green algal lichens	corticolous
12	*Hypotrachyna laevigata* (Sm.) Hale	Parmeliaceae	Foliose	Green algal lichens	corticolous
13	*Hypotrachyna minarum* (Vain.) Krog & Swinscow	Parmeliaceae	Foliose	Green algal lichens	corticolous
14	*Hypotrachyna nepalensis* (Taylor) Divakar, A. Crespo, Sipman, Elix & Lumbsch	Parmeliaceae	Foliose	Green algal lichens	corticolous
15	*Lepraria yunnaniana* (Hue) Zahlbr.	Stereocaulaceae	Crustose	Green algal lichens	corticolous

16	*Leptogium asiaticum* P.M. Jørg.	Collemataceae	Foliose	Blue green algal lichens	corticolous
17	*Leptogium resupinans* Nyl.	Collemataceae	Foliose	Blue green algal lichens	corticolous
18	*Leucodermia boryi* (Fée) Kr.P. Singh & S.R. Singh	Physciaceae	Foliose	Green algal lichens	corticolous
19	*Lobaria retigera (Bory) Trevis.*	Lobariaceae	Foliose	Blue green algal lichens	corticolous and terricolous
20	*Myelochroa entotheiochroa* (Hue) Elix & Hale	Parmeliaceae	Foliose	Green algal lichens	corticolous
21	*Nephromopsis laii (A. Thell & Randlane) Saag & A. Thell*	Parmeliaceae	Foliose	Green algal lichens	corticolous
22	*Parmelinella simplicior* (Hale) Elix & Hale	Parmeliaceae	Foliose	Green algal lichens	corticolous

23	*Parmelinella wallichiana* (Taylor) Elix & Hale	Parmeliaceae	Foliose	Green algal lichens	corticolous
24	*Parmotrema latissimum* (Fée) Hale	Parmeliaceae	Foliose	Green algal lichens	corticolous
25	*Parmotrema melanothrix* (Mont.) Hale	Parmeliaceae	Foliose	Green algal lichens	corticolous
26	*Parmotrema reticulatum* (Taylor) M. Choisy	Parmeliaceae	Foliose	Green algal lichens	corticolous
27	*Parmotrema tinctorum* (Despr. ex Nyl.) Hale	Parmeliaceae	Foliose	Green algal lichens	corticolous
28	*Peltigera polydactylon* (Neck.) Hoffm.	Peltigeraceae	Foliose	Blue green algal lichens	corticolous and terricolous

29	*Polyblastidium hypoleucum* (Ach.) Kalb	Physciaceae	Foliose	Green algal lichens	corticolous
30	*Ramalina conduplicans* Vain.	Ramalinaceae	Fruticose	Green algal lichens	corticolous
31	*Ramalina usnea* (L.) R. Howe	Ramalinaceae	Fruticose	Green algal lichens	corticolous
32	*Usnea angulata* Ach.	Parmeliaceae	Fruticose	Green algal lichens	corticolous
33	*Usnea filipendula* Stirt.	Parmeliaceae	Fruticose	Green algal lichens	corticolous
34	*Usnea florida* (L.) F.H. Wigg.	Parmeliaceae	Fruticose	Green algal lichens	corticolous
35	*Usnea himalayana* C. Bab.	Parmeliaceae	Fruticose	Green algal lichens	corticolous
36	*Usnea orientalis* Motyka	Parmeliaceae	Fruticose	Green algal lichens	corticolous
37	*Usnea pseudomontifuji* Asahina	Parmeliaceae	Fruticose	Green algal lichens	corticolous
38	*Usnea roseola* Vain.	Parmeliaceae	Fruticose	Green algal lichens	corticolous

39	*Varicellaria velata* (Turner) I. Schmitt & Lumbsch	Vericellariaceae	Crustose	Green algal lichens	corticolous

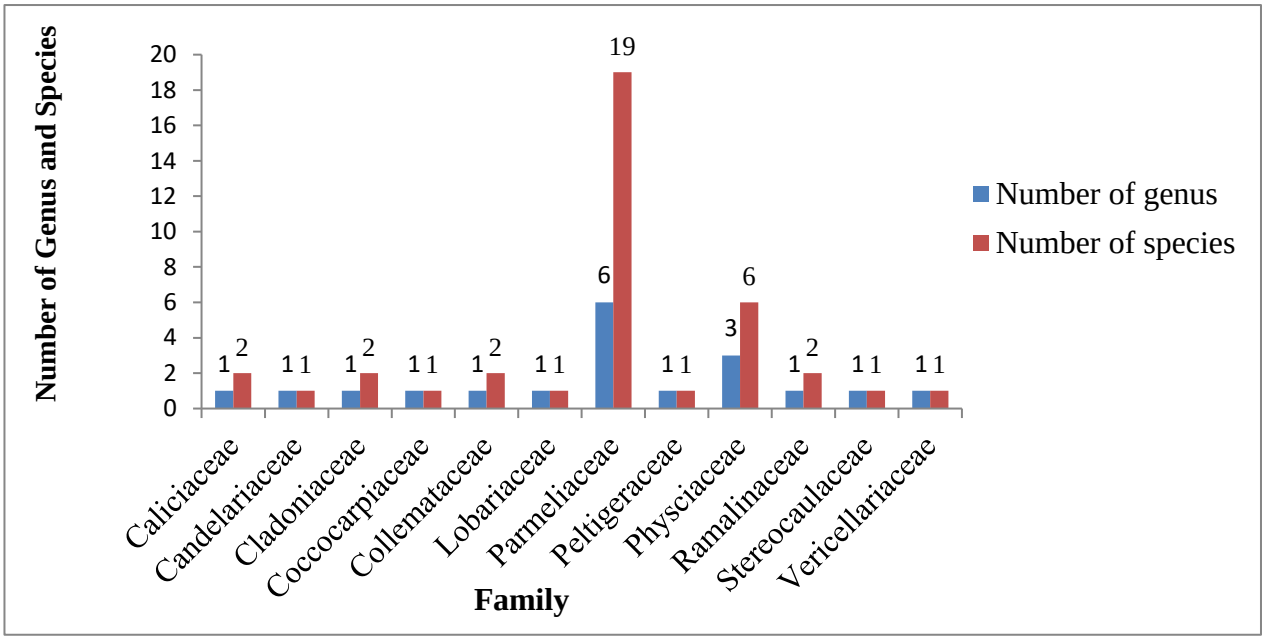

Figure 3: Number of genus and species in each family.

4.1.1 Lichen diversity based on Growth form

Three growth forms Crustose, Foliose and Fruticose were distinguished among the species encountered. The Foliose growth form was found to be the most dominant life form with 26 species followed by Fruticose growth form with 11 species and crustose with 2 species (Figure 4).

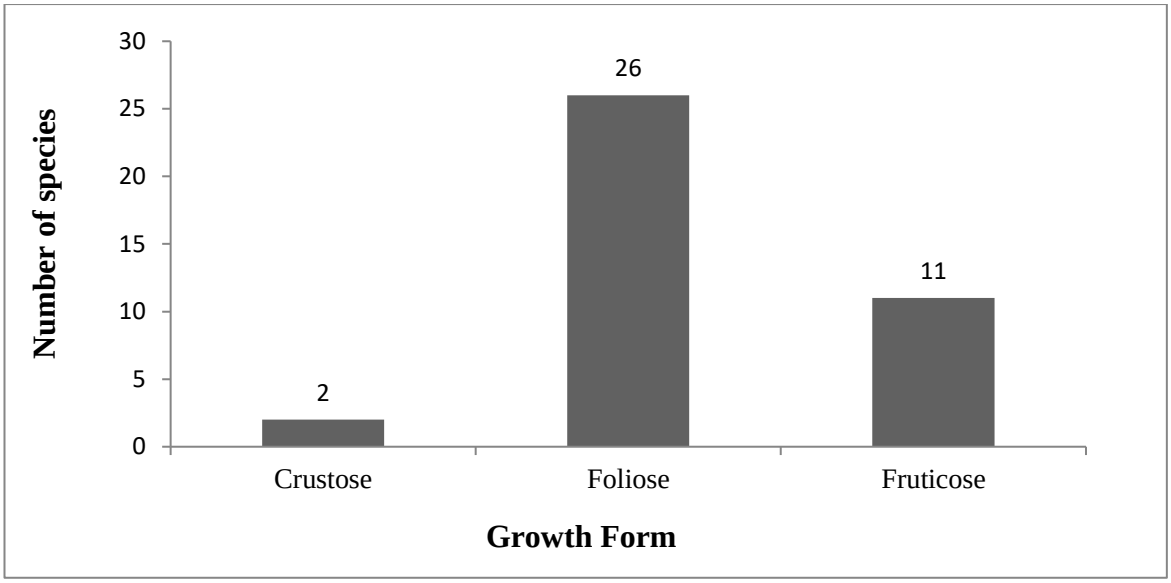

Figure 4: Number of species based on growth form.

4.1.2 Lichen diversity and habitat

Of the 39 species of lichen, 31 species were Corticolous that is growing on tree bark only, 2 species were Terricolous, other 2 were both Corticolous and Terricolous and remaining 4 were both Corticolous and Saxicolous (Figure 5)

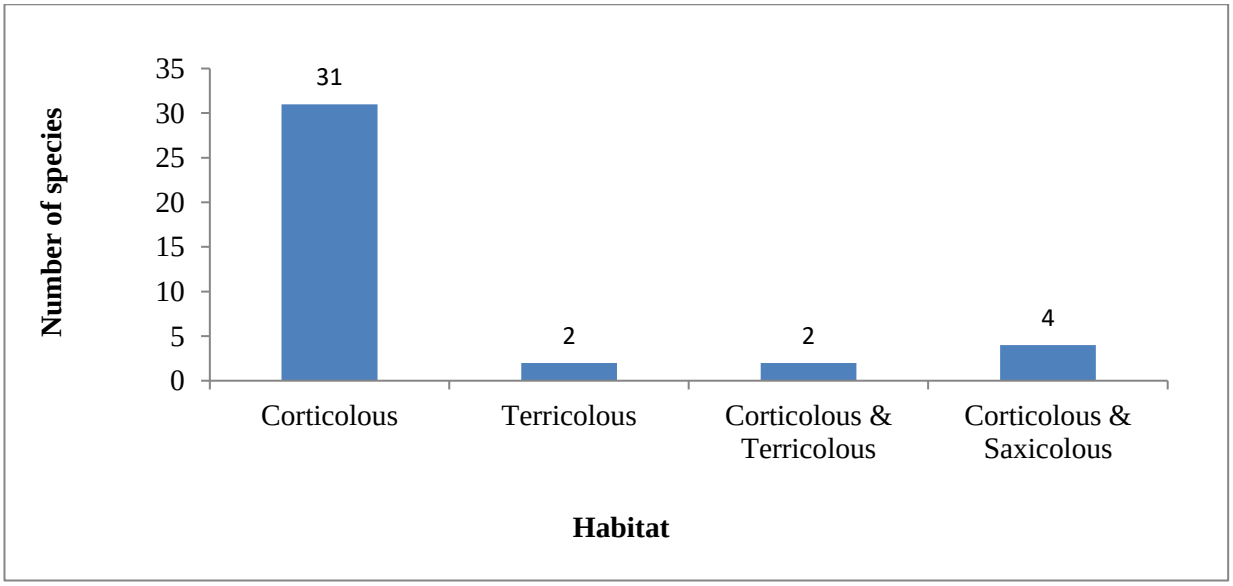

Figure 5: Number of species based on habitat.

On studying the microhabitat of the collected macrolichens Tree trunk showed the most suitable habitat accompanying 34 species followed by Canopy branch 27 species, Rock 7 species and Soil 3 species. Regarding the microhabitat specificity, there was no single species recorded exclusively on Soil (Figure 6). Only one species of lichen, *Hterodermia diademata* was found among all microhabitats.

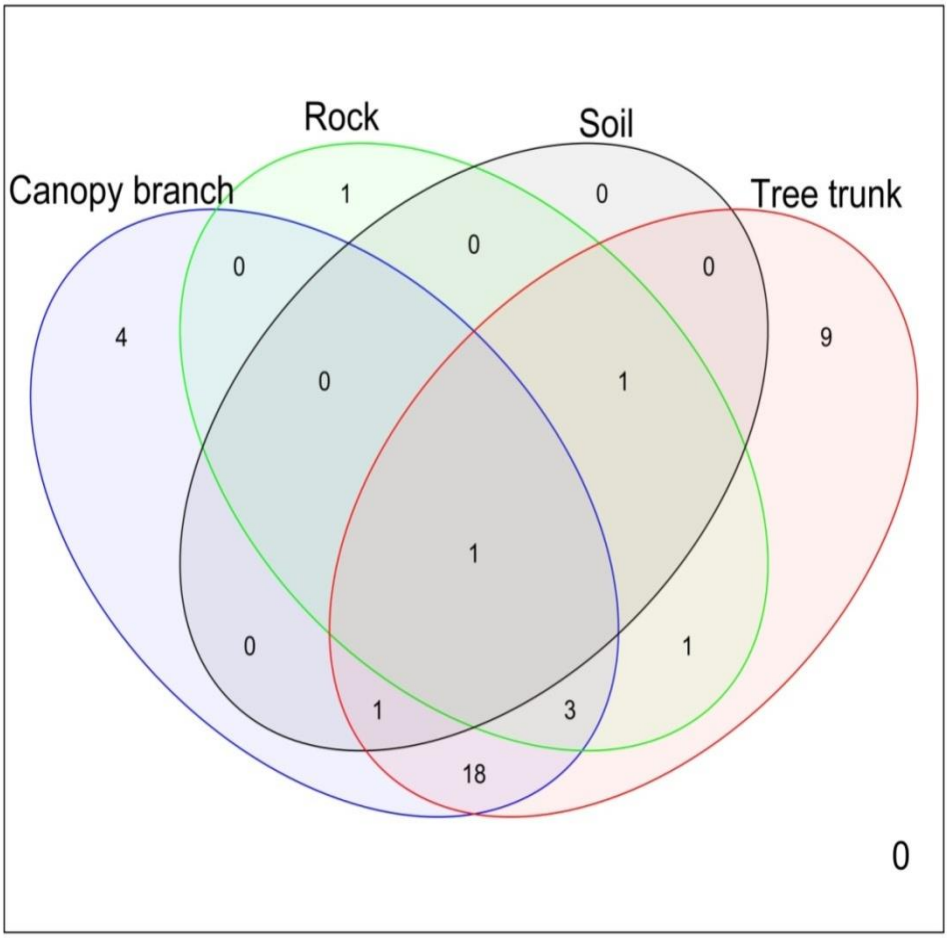

Figure 6: Distribution of lichens based on microhabitat.

4.1.3 Lichen diversity based on photobiontic partner

Two photobiont partners of lichens were distinguished from the study area. Green algal lichens were more prevalent than Blue green algal lichens, where 34 lichen species have green algae as photobiontic partner and only 5 lichen species have blue green algae as photobiontic partner (Figure 7).

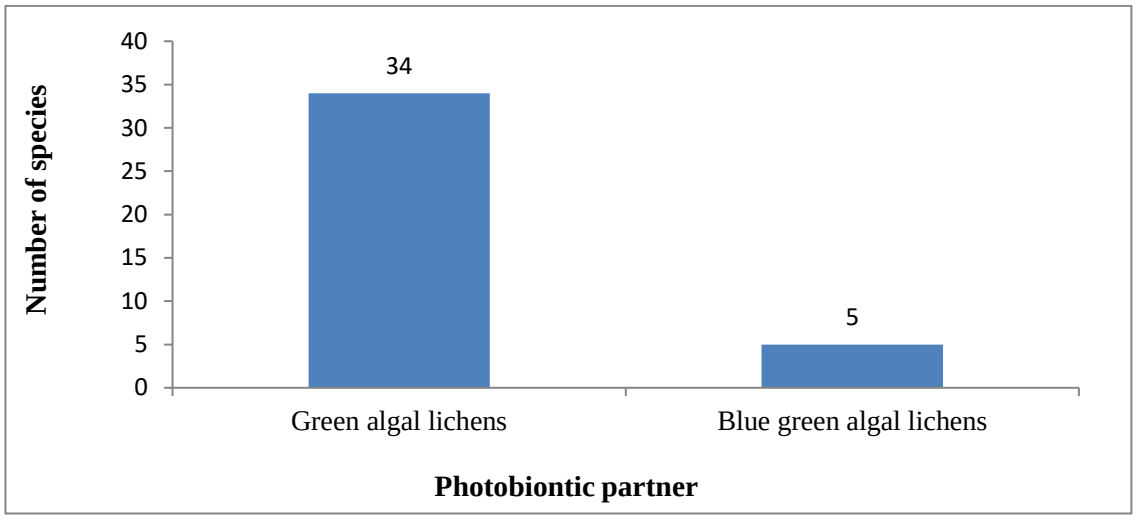

Figure 7: Number of species with photobiontic partner

4.1.4 Lichen diversity based on aspect

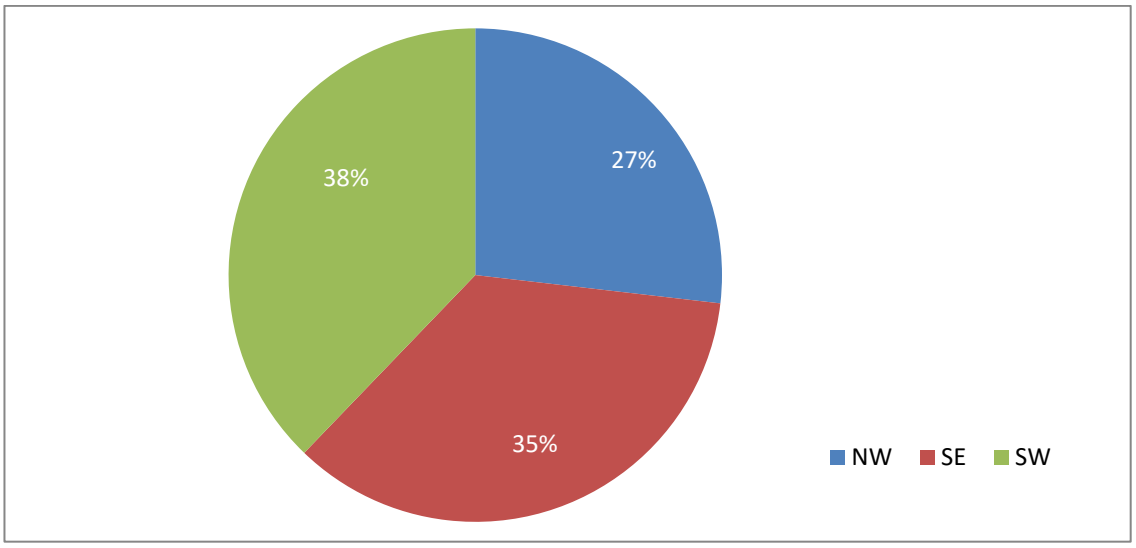

Figure 8: Percentage of species based on aspects.

Maximum percentage of lichen species are found to be in Southwest (SW) followed by Southeast (SE) and Northwest (NW) (Figure 8).

4.2 Taxonomic Description

Keys to the genera and species are produced for identification convenience using pertinent material that is currently available. Each species is listed with its most recent name, author reference, taxonomy description, chemistry, substrate type, range, and studied specimens.

Artificial key to the Families of the Studied Lichens

1a. Thallus crustose ……..2

1b. Thallus otherwise ……....3

2a. Thallus leprose ……..……. **Stereocaulacea**

2b. Thallus with rimmed wart like structure……**Vericellariaceae**

3a. Thallus foliose……..……...4

3b. Thallus fruticose……..……..11

4a. Photobiont blue-green algae……..5

4b. Photobiont green algae……..8

5a. Thallus blackish, homoiomerous, and gelatinous when wet……..**Collemataceae**

5b. Thallus heteromerous……6

6a. Pseudocyphellae present on lower surface……**Lobariaceae**

6b. Pseudocyphellae absent on lower surface ……7

7a. Thallus lead grey, lobes rounded short rhizines through margin……....**Coccocarpiaceae**

7b. Thallus lobes large, lower side distinctly reticulate……...…...**Peltigeraceae**

8a. Thallus yellow on upper side…….**Candelariaceae**

8b. Thallus otherwise……..9

9a. Thallus closely adnate, rhihines absent, flabellate-plicate……..**Caliciaceae**

9b. Rhizines present……10

10a. Thallus usually small and narrow lobed…… **Physciacea**

10b. Thallus large lobed, loosely adnate to substratum…… **Parmeliaceae**

11a.Thallus dimorphic with horizontal primary thallus and erect podetia as secondary thallus……...……..…..…**Cladoniaceae**

11b.Thallus uniform not dimorphic, centrally hollow, chondroid tissue absent…….....**Ramalinaceae**

CALICIACEAE Chevall. 1826

Dirinaria (Tuck.) Clem., Gen. fung. (Minneapolis): 84 (1909)

Thallus foliose, closely attached lobes, dichotomously to pinnately branched, grey to darker grey; soredia and isidia absent or present; heteromerous, both side corticated, absent rhizines, photobiont green algae medulla white; Apothesia laminal.

Key to species

1a. Thallus with thick isidia ……*D. aegialita*

1b. Thallus sorediate on lamina……*D. applanate*

Dirinaria aegialita (Afzel. ex Ach.) B.J. Moore, Bryologist 71: 248 (1968)

Thallus usually corticulous, rarely saxicolous to 6cm across; lobes 0.5-1.5 mm wide, plicate flabellate centrally can fluent. Upper side grey with isidioid, medulla white. Apothecia to 1.5mm in diameter **[Photoplate 1(E)].**

Chemistry: Cortex K^+ yellow, C^-, P^+ yellow, KC^- and Medulla K^-, C^-, P^-, KC^-

Chemical component: Divaricatic acid present

Substratum: Corticolous and Saxicolous

Distribution: India, Nepal, Sri Lanka, South-East Asia, Africa, South America, and Pacific Oceanic Island.

Specimen examined: PRR-05

Dirinaria applanata (Fée) D.D. Awasthi, J. Indian bot. Soc. 49: 135 (1970)

Thallus corticolous or saxicolous, lobes to 1.5 (-2) mm wide, confluent plicate flabellate; upper side grayish white, sorediate, soredia granules. Apothecia 1.5mm in diameter **[Photoplate 1(F)].**

Chemistry: Cortex K^+ yellow, C^-, P^+yellow and Medulla K^-, C^-, P^-, KC^-

Chemical component: Divaricatic acid and triterpenoids present

Substratum: Corticolous and Saxicolous.

Distribution: India, Nepal, Sri Lanka, cosmopolitantly distributed in tropical to sub-tropical region of the world.

Specimen examined: PRR-06

CANDELARIACEAE Hakul. 1954

Candelaria A. Massal., Flora, Regensburg 35: 567 (1852

Thallus corticolous, foliose in rosettes: to 15mm across, minutely lobate; heteromerous, corticated on both sides; upper side yellow. Photobiont a green alga. Medulla white. Lecanorine small apothecia.

Candelaria concolor (Dicks.) Stein

Thallus corticolous, foliose, rosettiform, lobes to 2 mm long, 0.5mm wide, granular soredia at end **[Photoplate 1(A)].**

Chemistry: Cortex K^-, C^-, KC^-, P^-

Chemical component: Calycin and pulvinic acid present

Substratum: Corticolous

Distribution: India, Nepal, China, Japan, Temperate Europe, Africa, Madagascar, North America and New Zealand.

Specimen examined: PRR-01

CLADONIACEAE Zenker 1827

Cladonia P. Browne, Prim. fl. holsat. (Kiliae): 90 (1756)

Thallus dimorphic, usually terricolous, lignicolous, or corticolous. Primary horizontal either crustose or squamulose to sub foliose, persistent or soon disappearing. Secondary thallus, a podetium, arising from primary thallus, branched or unbranched, scyphose or escyphpose. Apothecia develops on margin of scyphi or terminal of podetia tips.

Key to species

1a. Podetia up to 20mm tall, with narrow scyphi, medulla P^+ red ……*C. ramulosa*

1b. Podetia more than 20mm tall, with wide open scyphi, medulla P^-……*C. squamosa*

Cladonia ramulosa (With.) J.R. Laundon, Lichenologist 16(3): 225 (1984)

Thallus terricolous, dimorphic squamules. Primary thallus small, persistent or disappearing. Podetia 5-20mm tall, simple, escyphose, brown hymenial disc at maturity. Podetial side loosely sorediate or corticated: Apothecia terminal and brown **[Photoplate 1(B)].**

Chemistry: Podetia K^-, C^-, P^+ orange red

Substratum: Terricolous

Distribution: India, Nepal, Sri Lanka, tropical Asia, Europe, Africa, North, Central, and South America, Philippines, Australia, pacific island and New Zealand.
Specimen examined: PRR-02

Cladonia squamosa Hoffm., Deutschl. Fl., Zweiter Theil (Erlangen): 125 (1796) [1795]
Thallus dimorphic, squamulose: Primary thallus minute, grayish brown, persistent or disappearing: Podetia grey to brownish to 30mm tall, escyphose and simple. Podetia surface areolate, verrucose and corticated at base, granulose and microsquamulose in upper parts. Brown black hymenial disc at tip of podetia [**Photoplate 1(C)].**
Chemistry: Podetia K^+ yellow, C^-, KC^-, P^+ yellow
Substratum: Terricolous
Distribution: India, Nepal, Sri Lanka, Circumpolar in the northern hemisphere, Asia, Africa, Europe, Philippines, N and S America, New Zealand.
Specimen examined: PRR-03

COCCOCARPIACEAE Henssen 1986
Coccocarpia Pers., in Gaudichaud-Beaupré in Freycinet, Voy. Uranie., Bot. (Paris) 4: 206 (1827) [1826-1830]
Thallus foliose, dorsiventral, dichotomously branched; upper side lead grey, bluish grey to brownish black, with or without isidia, lacking soredia, and pseudocyphellae, with or without isidia; lower side black, heavily rhzinat. Thallus corticated on both side, heteromerous. Rod shaped pycnoconidia present, up to 5µm long. Photobiont or cyanobacteria.

Coccocarpia pellita (Ach.) Müll. Arg., Flora, Regensburg 65: 320 (1882)
Thallus foliose, corticolous or mscicolous over rock, closely attached, lobes 2-3 (-6)mm wide; upper side brownish grey to leaden grey, isidia present; lobes rounded, short black rhizines present. Apothecia rare to 2mm in diameter **[Photoplate 1(D)].**
Substratum: Corticolous to Saxicolous
Distribution: India, Nepal, Sri Lanka, China, Japan, South-East Asia, Central and South America, Australia and New Zealand.
Specimen examined: PRR-04

COLLEMATACEAE Zenker 1827

Leptogium (Ach.) Gray, Nat. Arr. Brit. Pl. (London) 1: 400 (1821)

Thallus commonly foliose, rarely squamulose or fruticose, Gelatinous in water, homoisomerous, upper side greenish brown, lead grey olive-black, wrinkled to smooth, soredia absent, with or without isidia. Lower side with or without hyphal hairs or tomentose. Thallus both sides corticated. Apothecial disc orange-red ,red-brown to black. Lichen substances usually absent.

Key to species

1a. Thallus with isidia……..*L. asiaticum*

1b. Thallus without isidia, apothecia on same side of tomentose……*L. resupinans*

Leptogium asiaticum P.M. Jørg., Herzogia 2: 466 (1973

Thallus foliose, corticolous, adnate, lobes orbicular to 6mm wide, upper side dark broen to brown-black; isidia present, globular to squamiform. Bluish black tomentum is present. Apothecia absent. Telephonic acid present in tomentum [**Photoplate 3(D)]**.

Substratum: corticolous

Distribution: India, Nepal, Sri Lanka, China, Japan, Africa and Australia.

Specimen examined: PRR-16

Leptogium resupinans Nyl., Annls Sci. Nat., Bot., sér. 4 15: 368 (1861)

Thallus foliose, loosely adnate, corticolous, lobes 3-6mm wide; upper side grey to brown with tomentum, lower side daek grey etomentose. Isidia not known. Sessile apothecia present to 1.5mm in diam; muriform ascospore present with 5-9 transverse and 1-2(-3) longitudinal septa [**Photoplate 3(E)].**

Substratum: corticolous

Distribution: India, Nepal, Bolivia and E. Africa.

Specimen examined: PRR-17

LOBARIACEAE Chevall. 1826

Lobaria (Schreb.) Hoffm., Deutschl. Fl., Zweiter Theil (Erlangen): 138 (1796) [1795]

Thallus foliose, dorsiventral, dichotomously large lobed; upper side yellow-grey, grey-brown to dark brown to blackish; lower side lacking cyphellae, and pseudocyphellae. Thallus corticated on both side, heteromerous, medulla usually white, isidia and soredia present or absent.

Lobaria retigera (Bory) Trevis., Lichenoth. Veneta 1-2: no. 75 (1869)

Thallus corticolous,loosely attached; lobes 10-20mm wide, pale brown on upper surface, reticulately ridged, with coralloid isidia usually on ridges; lower surface brown, rhizinate; photobiont a blue green algae **[Photoplate 4(A)]**

Chemistry: Upper cortex K^- and Medulla K^+ yellow, C^-, KC^-, P^-

Chemical component: Thelephoric acid present

Substratum: Corticolous

Distribution: Nepal, Eastern Asia, and Philippines.

Specimen examined: PRR-19

PARMELIACEAE F. Berchtold & J. Presl 1820

Key to genus

1a. Thallus regularly fruticose…….....*Usnea*

1b. Thallus foliose ……..... 2

2a. Thallus with pseudocyphellae on lower side, apothecia usually nephromoid…… …… ……..…..... *Nephromopsis*

2b. Thallus otherwise……..……...3

3a. Medulla orange……...…… *Myelochroa*

3b. Medulla white……..……4

4a. Rhizine dichotomously branched….……..…….*Hypotrachyna*

4b. Rhizine otherwise, simple……..…….5

5a. Lobes large, lobe margins with or with out cilia…….…….. *Parmotrema*

5b. Lobes narrower, rhizines up to the margin on lower side…… *Parmelinella*

Hypotrachyna (Vain.) Hale, Phytologia 28(4): 340 (1974)

Thallus foliose, attached, heteromerous, both side corticated, lobes small to medium; cilia absent or present, isidia and soredia absent or present, photobiont green algae, medulla white, lower surface rhizinate; rhizines dichotomously branched. Apothecia laminal.

Key to species

1a. Thallus divaricately branched, lobes canaliculated, medulla K^+ red, long rhizines on lower surface……..……..2

1b. Thallus sub dichotomously branched, medulla K^+, rarely ciliate……...…..3

2a. Uniformly rhizinate on lower side, rhizines short, medulla K^+ red.....*H. nepalensis*

2b. Lower side with or without rhizines, when present scattered near margins, medulla K^+ red ……*H. cirrhata*

3a. Lower side dense rhizines up to margin……..……..*H. laevigata*

3b. Lobes narrow, not rotund……*H. minarum*

Hypotrachyna cirrhata (Fr.) Divakar, A. Crespo, Sipman, Elix & Lumbsch, in Divakar, Crespo, Núñez-Zapata, Flakus, Sipman, Elix & Lumbsch, Phytotaxa 132(1): 31 (2013)

Thallus corticolous, erect to pendulous, lobes 2-4mm wide, upper side grey to darker grey, isidia and soredia are absent, lower side black rarely with elongated rhizines. Apothecia to 6mm in diam, hollow stalk [**Photoplate 2(E)].**

Chemistry: Cortex K^+ yellow, C^-, P^+ yellow, KC^- and Medulla K^+ yellow turning into red, C^-, P^+ orange red, KC^-

Chemical component: Salazinic acid present

Substratum: Corticolous

Distribution: India, Nepal, Sri Lanka, Japan, Taiwan, S. China, Central and South America.

Specimen examined: PRR-09

Hypotrachyna laevigata (Sm.) Hale, Smithson. Contr. bot. 25: 44 (1975)

Thallus foliose, adnate, heteromerous, both side corticatrd, lobes; narrow, curved axils, upper side light grey to grey-green, lower side; black, with dichotomously branched rhizines reaching edges, medulla white. Apothecia rare, disc dark brown **[Photoplate 2(F)].**

Chemistry: Medulla K^-, C^+ orange, KC^+ orange

Substratum: Corticolous

Distribution: India, Nepal, China, Japan, Java, Europe, America.

Specimen examined: PRR-11

Hypotrachyna nepalensis (Taylor) Divakar, A. Crespo, Sipman, Elix & Lumbsch, in Divakar, Crespo, Núñez-Zapata, Flakus, Sipman, Elix & Lumbsch, Phytotaxa 132(1): 32 (2013)

Thallus corticolous, sub erect, to pendulous, grayish-brown, absent isidia and soredia, lower side; black-brown, with simple or branched rhizines. Apothecia to 10mm diam **[Photoplate 3(B)].**

Chemistry: Cortex K^+ yellow, C^-, P^+ yellow and Medulla K^+ yellow turning red, C^-, KC^-, P^+ orange-red

Chemical component: Salazinic acid and protoloshesterinic acid present

Substratum: corticolous

Distribution: Bhutan, India, Nepal, China, java, Mexico, Russia, Thailand and Vietnam.

Specimen examined: PRR-13

Hypotrachyna minarum (Vain.) Krog & Swinscow, Lichenologist 19(4): 420 (1987)

Thallus foliose, corticolous or saxicolous, lobes 2 (-4) mm wide, upper side pale grey, densely isidiate; lower side black, dense rhizines, medulla white. Apothecia rare to 2mm in diameter **[Photoplate 3(A)].**

Chemistry: Medulla K^-,C^+ rose, KC^+ red, P^-.

Substratum: Corticolous

Distribution: India, Nepal, England, Japan, Brazil, Central America.

Specimen examined: PRR-12

Myelochroa (Asahina) Elix & Hale, Mycotaxon 29: 240 (1987)

Thallus foliose, lobes linear to irregular shaped, upper side is grey or blue-grey to yellow, lower surface black with un-branched rhizines. Medulla yellow-orange red. Apothecia are leconorine.

Myelochroa entotheiochroa (Hue) Elix & Hale, Mycotaxon 29: 240 (1987)

Thallus corticolous attached to 6cm across, lobes 3-5mm wide, upper side pale grey and postulate, soredia absent; lower side simple rhizonates. Thallus both sides corticated. Medulla orange red **[Photoplate 4(B)].**

Chemistry: Medulla K^+, C^+ yellow

Chemical component: Leucotylic acid present

Substratum: Corticolous

Distribution: India and Nepal

Specimen examined: PRR-20

Nephromopsis Müll. Arg., Flora, Regensburg 74(3): 374 (1891)

Thallus foliose, irregularly low bed; upper surface greenish yellow, smooth, lacking pseudocyphellae, soredia and isidia; lower side white, dark brown to black brown, pseudocyphellate. Thallus both side corticated and heteromerous.

Nephromopsis laii (A. Thell & Randlane) Saag & A. Thell, in Randlane, Saag & Thell, Bryologist 100(1): 111 (1997)

Thallus corticolous, irregularly foliose, loosly adnate lobes complicated to 10mm wide. Upper side greenish yellow; lower side white to brownish pseudocyphellate, rhizines short, medulla white. Apothecia marginal round to kidney shaped to 5mm in diameter **[Photoplate 4(C)].**

Chemistry: Cortex K^-, C^-, P^- and Medulla K^-, C^-, P^-, KC^-

Chemical component: lichesterinic acid and usnic acid present

Substratum: Corticolous

Distribution: India, Nepal, China, Japan, Taiwan, Russia, and Vietnam.

Specimen examined: PRR-21

Parmelinella Elix & Hale, Mycotaxon 29: 241 (1987)

Thallus foliose, leathery, heteromerous, both sides corticated; lobes white rotund, cilia simple; upper side greenish grey to yellow, isidiate or non-isidiate, with or without soredia; lower surface black, simple rhizine present in central part; marginal zone brown, nude shiny. Apothecia imperforated, laminal, with brown to dark brown disc.

Key to species

1a. Thallus isidiate……...…….*P. wallichiana*

1b. Thallus lacking isidia…….……*P. simplicior*

Parmelinella simplicior (Hale) Elix & Hale, Mycotaxon 29: 242 (1987)

Thallus corticolous, foliose, loosely attached; lobes sub-linear 3-6mm white; upper surface grey to olivaceous grey, soredia and isidia are absent; lower surface black, sparsely rhizinate. Apothecia up to 6mm diam. Medulla white **[Photoplate 4(D)].**

Chemistry: Cortex K^+ yellow and Medulla K^+ yellow turning red, C^-, P^+ orange, KC^-

Chemical component: Salazinic acid present

Substratum: Corticolous

Distribution: India, Nepal, Sri-Lanka

Specimen examined: PRR-22

Parmelinella wallichiana (Taylor) Elix & Hale, Mycotaxon 29: 242 (1987)

Thallus corticolous, foliose, loosely attached; lobes subotund, cilia axils; upper surface grey, rough in center, and shiny at periphery, isidiate, soredia not known; lower surface centerly

black, brown and shiny towards margin. Medulla white. Apothecia lacanorine laminal **[Photoplate 4(E)].**

Chemistry: Cortex K^+ yellow, C^-, P^- and Medulla K^+ yellow turning red, C^-, P^+ orange-red

Chemical component: Consalazinic, atranorin and salazinic acids present

Substratum: Corticolous

Distribution: India, Nepal, Sri-Lanka, China, Japan, South-East Asia, Africa, and Australia.

Specimen examined: PRR-23

Parmotrema A. Massal., Atti Inst. Veneto Sci. lett., ed Arti, Sér. 3 5: 248 (1860) [1859-1860]

Thallus foliose, loosely attached, heteromerous, both side corticated, large; lobes rotund margin with or without cilia; upper surface pale grey to grey-green, with or without maculae, isidiate and sorediate, non-pseudocyphellae; lower surface rhizinate, rhizines simple to branched, medulla white. Apothecia laminal, lecnorine, with brown disc, pycnidia laminal immersed.

Key to species

1a. Lobes margin lacking cilia……...…2

1b. Lobes margin with cilia…….3

2a. Medulla C^+ rose red……*P. tinctorum*

2b. Medulla K^+ red…….*P. latissimum*

3a. Maculae dense, reticulately fissured……*P. reticulatum*

3b. Maculae not fissured……*P. melanothrix*

Parmotrema latissimum (Fée) Hale, Phytologia 28(4): 337 (1974)

Thallus corticolous, foliose, heteromerose, both sides corticated; lobes 8-20mm white, cilia absent; upper surface grey, emaculate, isidia and soredia absent; lower surface centrally black, marginal zone tane, nude; medulla white. Apothecia to 16mm in diam. Imperforated **[Photoplate 4(F)].**

Chemistry: Cortex K^-, C^-, P^- and Medulla K^+ yellow becoming orange red, C^-, P^+ orange red

Substratum: Corticolous

Distribution: India, Nepal, China, Central and South America.

Specimen examined: PRR-24

Parmotrema melanothrix (Mont.) Hale, Phytologia 28(4): 337 (1974)

Thallus corticolous, foliose, heteromerous, both sides corticated; lobes 6-12mm white, ciliate; upper surface grey, white maculate, non-isidiate and non-sorediate; lower surface centrally black, white marginal tane to white area, nude; medulla white. Apothecia to 10mm in diameter, imperforated **[Photoplate 5(A)].**

Chemistry: Cortex K^+ yellow, C^-, P^- and Medulla K^-, C^-, KC^-, P^-

Substratum: Corticolous

Distribution: India, Nepal, Brazil, and Re-union Island

Specimen examined: PRR-25

Parmotrema reticulatum (Taylor) M. Choisy, Bull. mens. Soc. linn. Soc. Bot. Lyon 21: 148 (1952)

Thallus corticolous, foliose, heteromerous, both sides corticated; lobes 5-10mm white, ciliate; upper surface pale greenish to grey, white maculate, maculae articulately fissured, sorediate, non-isidiate; soralia, usually marginal, linear or capitate, soredia granular; lower surface centrally black, rhizinates; rhizines black simple to branched black. Apothecia rare **[Photo Plate 5(B)].**

Chemistry: Cortex K^+ yellow, C^-, P^-, KC^- and Medulla K^+ yellow turning red, C^-, P^+ orange red

Chemical component: salazinic and atranorin acids present

Substratum: Corticolous

Distribution: India, Nepal, Sri-Lanka

Specimen examined: PRR-26

Parmotrema tinctorum (Despr. ex Nyl.) Hale, Phytologia 28(4): 339 (1974)

Thallus corticolous, foliose, heteromerous, both sides corticated, large lobes 10-20(-30) mm wide, ecilate; upper surface grey to darker, emaculate, granular isidia; lower surface centrally black, marginal area tan to brown, nude. Medulla white. Apothecia rare **[Photoplate 5(C)].**

Chemistry: Cortex K^+, C^-, KC^-, P^- and Medulla K^-, C^+ rose red, KC^+ red, P^-

Chemical component: Lecanoric and atranorin acids present

Substratum: Corticolous

Distribution: China, Indonesia, Africa, America, Australia, India, Nepal, and Sri-Lanka.

Specimen examined: PRR-27

Usnea Dill. ex Adans., Fam. Pl. 2: 7 (1763)

Thallus fruticose, shruby, erect to pendulous, atttached by a blakish holdfast, greenish grey to yellowish gery in colour, corticated, heteromerous medulla white to red pigmented, central axis elastic or solid. Photobiont green algae. Apothecia lecanorine, lateral, terminal, and usually ciliate.

Key to species

1a. Thallus dichotomously branched and articulated…….……*U. himalayana*

1b. Thallus otherwise……..…2

2a. Main branches filamentous with lateral branchlets arising at right angle to the axis ……..*U. angulata*

2b. Branching sympodial to sub sympodial, thallus erect bushy to procumbent……3

3a. Thallus with apothecia …….……..4

3b. Thallus without apothecia……..…….……..5

4a. Thallus with articulated branches ……...……*U. orientalis*

4b. Thallus without articulated branches……..……*U. florida*

5a. Central axis red…….….*U. roseola*

5b. Central axis colorless……6

6a. Thallus sorediate……...*U. filipendula*

6b. Thallus without soredia and isidia…….……*U. pseudomontifuji*

Usnea angulata Ach., Syn. meth. lich. (Lund): 307 (1814)

Thallus corticolous, pendulous, yellow brown to greyish brown, main branches filamentous with lateral branches arising at right angle to the axis; surface tuberculate, pseudocyphellate and isidiate, esorediate; central axis solid, colorless. Apothecia absent **[Photoplate 6(B)].**

Chemistry: Central axis I^-

Substratum: Corticolous

Distribution: India, Nepal, Southern and Eastern Africa, America.

Specimen examined: PRR-32

Usnea filipendula Stirt., Scott. Natural. 6(3): 104 (1881) [1881-1882]

Thallus fruticose, corticolous up to 20mm tall, heteromerous, corticated, pale grey to green, pendant, thick cortex, solid central axis, filamentous branches circular in cross section **[Photoplate 6(C)].**

Chemistry: Medulla K^+ red, KC^-, C^-, P^+ yellow

Substratum: Corticolous

Distribution: India, Nepal.

Specimen examined: PRR-33

Usnea florida (L.) F.H. Wigg., Prim. fl. holsat. (Kiliae): 91 (1780)

Thallus fruticose, blackish base, heteromerous, grey to greenish, pendulous, central axis solid, non isidiate, papillate mostly on main branches, soralia absent. Apothecia frequent, arising at tip of primary and secondary branches. Cortex thick, medulla thin **[Photoplate 6(D)].**

Substratum: Corticolous

Distribution: Belgium, Germany, Italy, Norway, Poland, Russia, and Spain

Specimen examined: PRR-34

Usnea himalayana f. major Asahina, J. Jap. Bot. 42: 258 (1967)

Thallus fruticose, pendulous, grey to grayish green, dichotomously branching, branches articulate, pseudocyphellate, nonsorediate, nonisidiate, nonpapillate, central axis solid white. Apothecia not known **[Photoplate 6(E)].**

Chemistry: Central axis I^- and Medulla K^+ red, P^+ orange red

Chemical component: Stictic acid and norstictic acids present

Substratum: Corticolous

Distribution: India, Nepal, Japan, Malaysia, Philippines, Taiwan.

Specimen examined: PRR-35

Usnea orientalis Motyka, Lich. Gen. Usnea, Stud. Monogr. (Leopoli) 2: 536, 547 (1937)

Thallus corticolous, fruticose, erect, greenish grey to yellowish grey, sympodial to anisotomic dichotomous, densely branched. Soredia, isidia, and pseudocyphellae are absent. Central axis solid and colorless. Apothecia terminal, with densely ciliate at margin **[Photoplate 6(F)].**

Chemistry: Central axis I^- and Medulla K^+ yellow becoming red, P^+ yellow

Chemical component: Salazinic and usnic acids present

Substratum: Corticolous

Distribution: India, Nepal, China, Bhutan, Japan.

Specimen examined: PRR-36

Usnea pseudomontifuji

Thallus corticolous, fruticose, pendent; branching sympodial to subsympodial, grayish green to whitish grey; lateral branchlets dense, simple to branched; isidia and soredia not seen; central axis solid, reddish brown. Apothecia not seen **[Photoplate 7(A)].**

Chemistry: Central axis I^- and Medulla K^-, P^+ red

Substratum: Corticolous

Distribution: India, Nepal, China, Japan, Taiwan.

Specimen examined: PRR-37

Usnea roseola Vain., Bot. Mag., Tokyo 35: 46 (1921)

Thallus corticolous, sub erect-pendent, to 13c.m long, rigid, pale green, branching sub dichotomous to sympodial; main branches verruculose to tuberculate, pseudocyphellate becoming sorediate and isidiate; central axis solid, irregular. Apothecia absent **[Photoplate 7(B)].**

Chemistry: medulla K^+ yellow, P^-

Chemical component: Diffractic acid present

Substratum: Corticolous

Distribution: Nepal, India, China, East Africa.

Specimen examined: PRR-38

PELTIGERACEAE Dumort. 1822

Peltigera Willd., Fl. berol. prodr.: 347 (1787)

Thallus foliose, loosely attached, large; lobes dorsiventral, upper side bluish brown or reddish brown, smooth, tomentum present or absent, with or without isidia or soredia; lower side rhizinate and veined. Thallus corticated only on upper side, photobiont green algae or cynobacteria. Medulla white or brownish. Apothecia marginal or sub marginal.

Peltigera polydactylon (Neck.) Hoffm., Descr. Adumb. Plant. Lich. 1(1): 19 (1789) [1790]

Thallus usually terricolous, sometimes saxicolous or corticolous; lobes to 4-5mm long, 10-15mm wide; upper side grayish brown, lacking isidia and soredia and etomentose; lower side veined and reticulate. Apothecia saddle-shaped. photobiont a Nostoc **[Photoplate 5(D)].**

Substratum: Corticolous

Distribution: India, Nepal, China, Japan, Europe, and N. America.

Specimen examined: PRR-28

PHYSCIACEAE Zahlbr. 1898

Key to genus

1a. Lobes narrow ribbon like, circinately revolute at apices……..….*Leucodermia*

1b. Thallus otherwise…….…….2

2a. Thallus corticated only on upper side or both side……..…*Heterodermia*

2b. Thallus corticated only on upper side……..*Polyblastidium*

Heterodermia Trevis., Atti Soc. ital. Sci. nat. 11: 613 (1868)

Thallus foliose closely adnate, sub erect to pendulous, dichotomously divided, both side corticated or only upper side corticated, heteromerous, photobiont a green alga. Apothecia sessile, laminal to pedicellate, lecanorine, asci 8- spored, 2- celled ascospore.

Key to species

1a. Thallus sorediate, soralia on main lateral lobes……..……..…….*H. speciosa*

1b. Thallus lacking soredia …….....2

2a. Thallus with apothecia ……..……3

2b. Thallus without apothecia……...…….*H. hypochraea*

3a. Thallus with numerous apothecia, apothecia without margin lobule……..*H. diademata*

3b. Thallus with marginal apothecia, with margin lobule…….….*H. incana*

Heterodermia diademata (Taylor) D.D. Awasthi, Geophytology 3: 113 (1973)

Thallus corticolous and saxicolous, to 15mm across, both sides corticated; upper side grey to grey white, nonisidiate, and nonsorediate; lower side pale brown with rhizines. Apothecia in large number to 7mm diam **[Photoplate 2(A)].**

Chemistry: Cortex K^+ yellow, C^-, P^+ yellow and Medulla K^+ yellow, C^-, P^+ yellow, or P^-

Chemical component: zeorin and atranorin acids present

Substratum: Corticolous and saxicolous

Distribution: India, Nepal, Sri-Lanka, China, Japan, Taiwan, Africa, Central and South America.

Specimen examined: PRR-07

Heterodermia hypochraea (Vain.) Swinscow & Krog, Lichenologist 8(2): 119 (1976)

Thallus corticolous in rosette form, to 6cm across, divided, lobes sub-erect to 2mm wide; upper side corticated; lower side white with marginal rhizines, lacking soredia **[Photoplate 2(B)].**

Chemistry: Medulla K^- or K^+ violet, P^+ pale yellow or P^-.

Substratum: Corticolous

Distribution: India, Nepal, China, Japan, Taiwan, and South America.

Specimen examined: PRR-10

Heterodermia incana (Stirt.) D.D. Awasthi, Geophytology 3(1): 114 (1973)

Thallus corticolous, corticated only on upper side, rosulate, irregularly branched, lobes; spathulate, upperside; white to whitish grey, isidia and soredia absent, lower side; white with marginal rhizines. Apothecia pedicellate to 8mm in diam **[Photoplate 2(C)].**

Chemistry: Cortex K^+ yellow, C^-, KC^-, P^- and Medulla: K^+ yellow, C^-, P^+ yellow or P^-

Chemical component: Atranorin and zeorin acids present

Substratum: Corticolous

Distribution: India, Nepal, Sri-Lanka, China, Taiwan, and Thailand.

Specimen examined: PRR-08

Heterodermia speciosa (Wulfen) Trevis., Atti Soc. ital. Sci. nat. 11: 614 (1868)

Thallus corticolous or saxicolous, lobes plane to 1.5mm diam, both side corticated, upper side; grayish white, sorediate, lower side; brownish, rhizinate. Apothecia marginally sorediate, sessile, to 8mm in diam. Medulla white **[Photoplate 2(D)].**

Chemistry: Cortex and medulla K^+ yellow, C^-, KC^-, P^+ yellow

Chemical component: Zeorin acid present

Substratum: Corticolous.

Distribution: India, Nepal and tropical region of the world.

Specimen examined: PRR-14

Leucodermia Kalb, in Mongkolsuk, Meesim, Poengsungnoen, Buaruang, Schumm & Kalb, Phytotaxa 235(1): 22 (2015)

Thallus either foliose to somewhat bushy sub-fruticose, lobes; linear elongate, ribbon like dichotomously branched, with long rhizines at their margin, loosely attached thallus, corticated only on upper side. Apothecia pruinose disc and polyblastidium-type ascospore.

Leucodermia boryi (Fée) Kalb, in Mongkolsuk, Meesim, Poengsungnoen, Buaruang, Schumm & Kalb, Phytotaxa 235(1): 34 (2015)

Thallus foliose to sub-fruticose, loosely attached lobes; 0.4-3mm white, ribbon like, tangled, dichotomously branched, circinately revolute at tips, corticated only on upper side, lower side;

ecorticated, canaliculated, powdery, with long black rhizines along margins. Apothecia apical to sub apical, 1-5mm wide with lobulate to crenulate margin and with sparce short black cilia. Ascospore polyblastidium type, picnidia rare, immersed **[Photoplate 3(F)].**

Chemistry: Cortex K^+ yellow, C^-, KC^-, P^+ yellow and Medulla K^+ yellow, C^-, KC^-, P^+ pale yellow

Chemical component: Zeorin and atranorin acids present

Substratum: Corticolous

Distribution: India, Nepal, Sri-Lanka, China, Japan, Korea, Taiwan, Philippines, Fuji, Central Africa and Central and South America.

Specimen examined: PRR-18

Polyblastidium Kalb, in Mongkolsuk, Meesim, Poengsungnoen, Buaruang, Schumm & Kalb, Phytotaxa 235(1): 38 (2015)

Thallus foliose, upperside corticated, heteromerous, lobes; partial dichotomous, lower surface; not corticated cobweb-like structure, erhizinate or only marginal rhizine present. Apothecia laminal brown.

Polyblastidium hypoleucum (Ach.) Kalb, in Mongkolsuk, Meesim, Poengsungnoen, Buaruang, Schumm & Kalb, Phytotaxa 235(1): 42 (2015)

Thallus corticolous to 15mm across, lobes; to 2mm wide, corticated only in upper side, lacing isidia and soredia, lower side; white to brown with marginal rhizines. Apothecia to 5(-10)mm diam **[Photoplate 5(E)].**

Chemistry: Medulla K^+ yellow to deep yellow, C^-, P^+ pale yellow

Substratum: Corticolous

Distribution: India, Nepal, Japan, China, Korea, and North America.

Specimen examined: PRR-29

RAMALINACEAE C. Agardh 1821

Ramalina Ach., in Luyken, Tentam. Histor. Lichen. Gen. Prim. Lin. Distrib. nov., Göttingae: 95 (1809)

Thallus fruticose, heteromerous, erect or pendulous, branched, narrow strap shaped or white lobed, greenish grey to yellowish brown, attached by holdfast, pseudocyphellate or non-pseudocyphellate, corticated on all sides, medulla loose or solid or hollow, usuall sorediate, non-isidiate. Apothecia lacanorine, lamenal, peltate to sessile.

Key to species

1a. Branches less than 1mm wide, thallus bushy…….*R. usnea*

1b. Branches more than 1mm wide, thallus flattened ……..…*R. conduplicans*

Ramalina conduplicans Vain., Ann. bot. Soc. Zool.-Bot. fenn. Vanamo 1(no. 3): 35 (1921)

Thallus corticolous, shrubby, greenish grey, branched, upper surface smooth scarcely pseudocyphellate, lower surface rugose, medulla solid. Apothecia common, lamenal **[Photoplate 5(F)].**

Chemistry: Medulla K^-, C^-

Chemical component: Usnic acid and salazinic acid present

Substratum: Corticolous

Distribution: India, Nepal and Eastern Asia

Specimen examined: PRR-31

Ramalina usnea (L.) R. Howe, Bryologist 17: 81, fig. 1, pl. 12, figs 1-2 (1914)

Thallus corticolous, fruticose, pendulose branched, branches ribbon like to 1mm wide, bushy, pseudocyphellate, esorediate, medulla solid. Apothecia to 0.5mm in diam **[Photoplate 6(A)].**

Chemistry: Medulla K^-, C^-, P^-

Substratum: Corticolous

Distribution: India and Nepal.

Specimen examined: PRR-30

STEREOCAULACEAE Chevall. 1826

Lepraria Ach., Methodus, Sectio prior (Stockholmiæ): 3 (1803)

Thallus crustose to subfoliose or squamulose with powdery, granular, cottony, membranous or subsquamulose to subfoliose appearance, variously coloured, loosely attached to ubstratum, revealing lower surface, lobes absent or present, medulla absent or present.

Lepraria yunnaniana (Hue) Zahlbr., in Handel-Mazzetti, Symb. Sinic. 3: 224 (1930)

Thallus leprose, of cottony hypothallus, powdery soredia, margin diffuse, lobes usually absent, rarely indistinct, medulla sometimes present, white **[Photoplate 3(C)].**

Chemistry: K-, C-, KC+ pink

Chemical component: Divaricatic acid present

Substratum: Corticolous

Distribution: South America, China, Africa, New Guinea, Montane, India (Saag et al., 2009).

Specimen examined: PRR-15

VARICELLARIACEAE B.P. Hodk., R.C. Harris & Lendemer ex Lumbsch & Leavitt 2018

Varicellaria Nyl., Mém. Soc. Imp. Sci. Nat. Cherbourg 5: 119 (1858)

Varicellaria velata (Turner) I. Schmitt & Lumbsch, in Schmitt, Otte, Parnmen, Sadowska-Deś, Lücking & Lumbsch, MycoKeys 4: 31 (2012)

Thallus fissured to areolate, with thin to moderately thick verrucae; margins: entire, unzoned upper surface: whitish gray to yellowish gray, rugose-plicate, dull, pruinose; lacking soredia or isidia **[Photoplate 7(C)].**

Chemistry: K-, C+ red, KC-, P-

Substratum: Corticolous

Distribution: Cosmopolitan distribution

Specimen examined: PRR-39

4.3 Sampling intensity

Sampling intensity in the present study seemed satisfactory (Figure 9). The species accumulation curve showed an increasing number of species with increasing number of plots studied and then plateau after addition further more plots (Figure 9). An asymptotic plot after addition of plots indicated sufficient sampling. This study started from the lower elevation. At lower elevation, the curve raised sharply at the beginning indicating a high rate of lichen species richness that accumulated with initial sampling effort while at high elevation the curve raised very slowly, showing that the rate of adding new lichen species was lower and fewer.

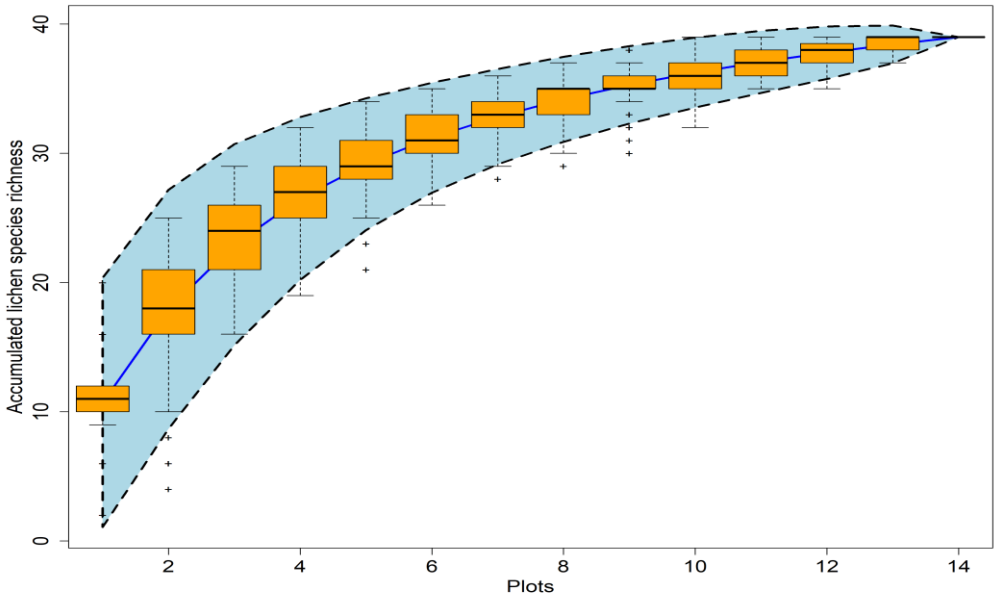

Figure 9: Species intensity curve of lichens.

4.4 Species richness of lichen along the elevation gradient

The total lichen species richness showed statistically significant a non-monotonic and hump-shaped relationship (Figure 10) with the elevation. The GLM regression analysis suggested that the species richness of the lichens in the study area gradually increased with the increase in elevation, and peaked at an elevation of 2300m (13 species) showing highest species richness and then started to decrease with elevation increases.

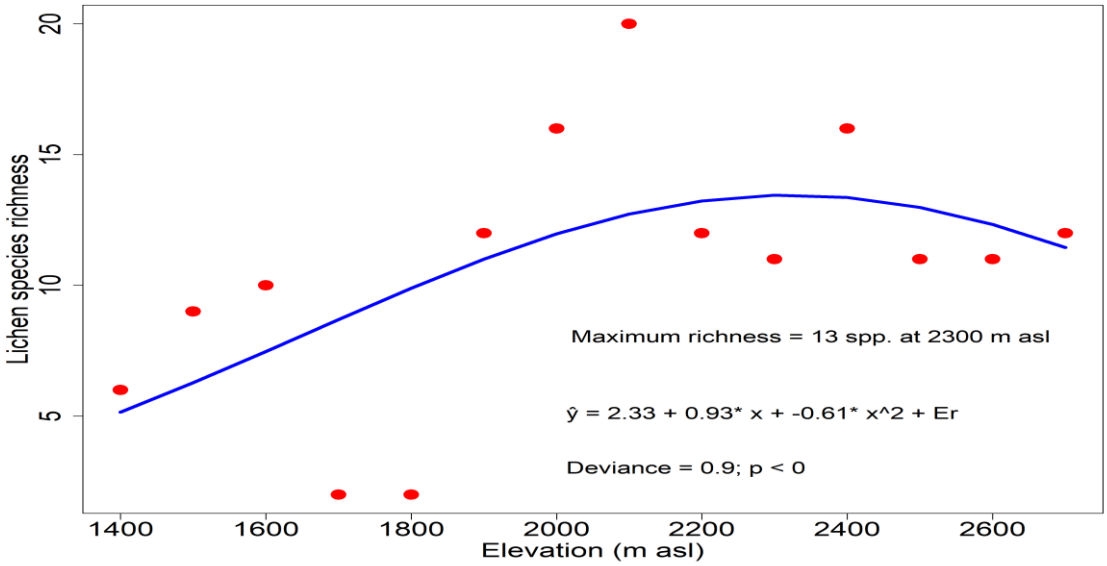

Figure 10: Relationship between lichen species richness and elevation.

4.5 Species composition

The Deterended Correspondance Analysis (DCA) summary showed that there is a moderate to strong eigen value by the first axis, i.e. 0.56 which is greater than 0.5 signifies that species responses to environmental variable are more gradual and potentially non-linear (Table 2). The axis length i.e. length of gradient in terms of standard deviation (SD) units for the first axis was 5.01 SD units and then shifted to slightly lower of 2.74 SD units, 1.80 SD units, and 1.65 SD units for second, third and fourth axis respectively. The length of the first axis was greater than 3 SD units which means that there is a considerable amount of variation in species composition along this gradient suggesting for the CCA.

Table 2 : DCA summary

DCA AXIS	DCA1	DCA2	DCA3	DCA4
Eigenvalues	0.56	0.25	0.18	0.13
Additive Eigenvalues	0.56	0.25	0.18	0.13
Decorana values	0.64	0.23	0.10	0.04
Axis lengths	5.01	2.74	1.80	1.65

The CCA analysis showed that the constrained analysis only explained 28 % of the total variance (Table 3). This clearly shows that the variability of collected lichen species is highly affected by other unknown or unconstrained factors so far (Appendix-I).

Table 3 : Summary of CCA

	Inertia	Proportion
Total	2.78	1
Constrained	0.77	0.28
Unconstrained	2.02	0.72

The environment-species composition (figure 11) showed that the elevation had strong effect on the lichen species composition than Aspect. On the basis of lichen species distribution, elevation gradient is represented by CCA axis 1. As we move from left to along CCA axis 1, the right end of the axis represents species like *Usnea florida, Usnea angulata, Usnea roseola, Leucodermia boryi*. Highest abundance of these species was towards the highest elevation in this study. Likewise, the left end of axis represents species like *Candelaria concolor, Coccocarpia pellita, Parmelinella wallichiana, Peltigera polydactylon*. Highest abundance of these species were towards the lower elevation in this study.

Similarly, CCA axis 2 represented distribution of lichen species based on the aspect. Lichen species like *Parmotrema reticulatum, Heterodermia incana, Cladonia squamosa* showed high abundance towards North west aspect while the species like *Parmotrema latissimum, Heterodermia diademata* were found towards South east aspect.

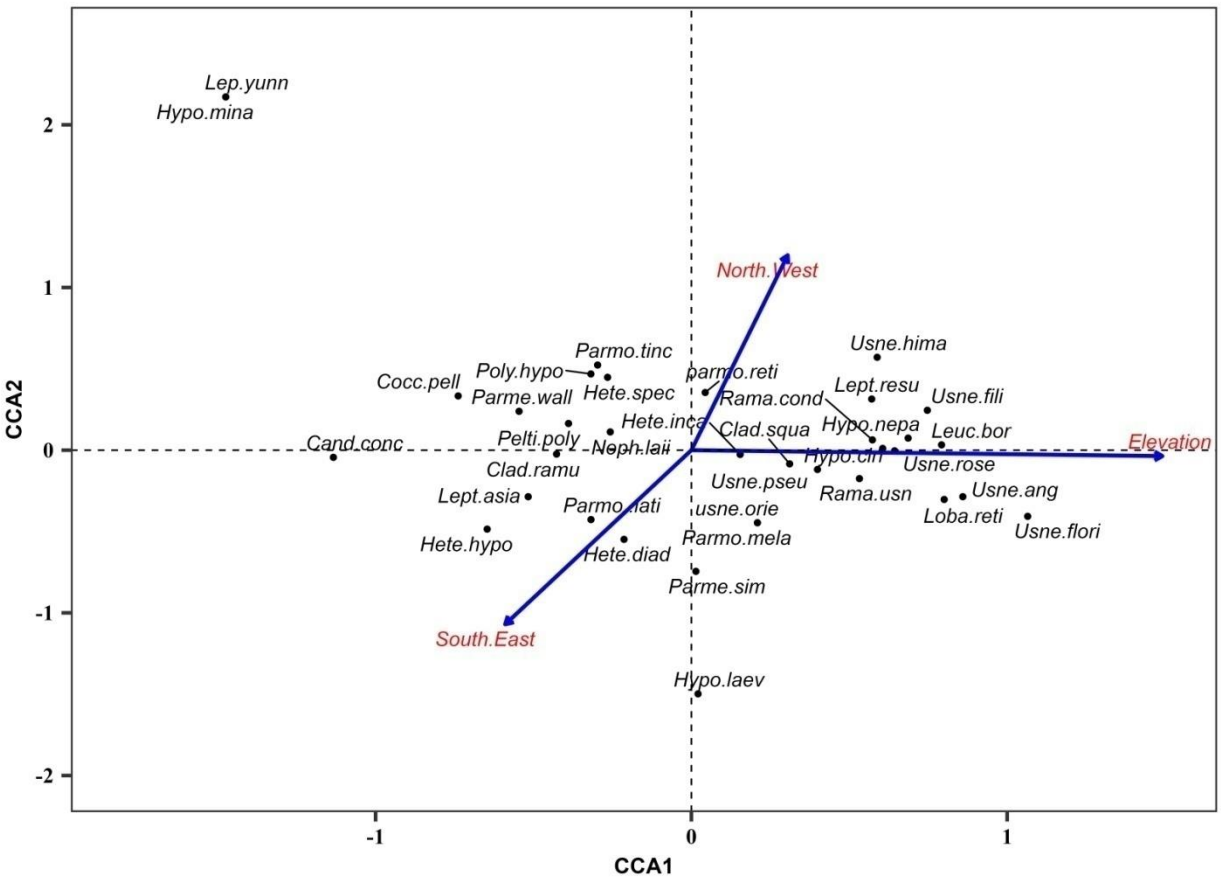

Figure 11: CCA plot for lichen species composition of the study area.

CHAPTER- 5

DISCUSSION

The present study was carried out in the Shivapuri-Nagarjun National Park within an elevation rang of 1400-2700m asl. In total, 39 species of lichens were identified throughout the elevational gradient, where family Parmeliaceae was found to be dominant followed by Physciaceae. Previous studies within the same and adjacent study area also depicted similar sort of results. Baniya (1996) collected 99 species from Shivapuri and Sikles, out of which 72 lichen species were from shivapuri National Park. His study also pointed parmeliaceae as the most dominant family. This is because Baniya (1996) carried out the study by covering the whole area and deeper forest of National Park and collected all life forms of lichen species, while the present study was carried along the walking trail and was only focused on macrolichens. Devkota (2008) studied lichens flora of Phulchowki, where she identified 32 species of macrolichens within the elevational gradient of 1500-2700m asl, where family parmeliaceae was found to be dominant. Lichen species like *Cladonia ramulosa, Parmelinella wallichiana, Usnea orientalis Ramalina usnea, Parmotrema reticulatum, Peltigera polydactylon, Leptogium resupinas, Heterodermia speciosa, Heterodrmia incana, Heterodermia diademata, Hypotrachyna nepalensis, Hypotrachyna cirrhata* were corresponded to this present study. Same climatic condition, similar forest type and similar elevation in both studies might have attributed for the similar lichen species. Species identified in this study have previously been reported from many places of Nepal by (Baniya et al., 2010; Baral, 2015; Devkota, 2008; Shrestha, 2021). All these studies are consistent with Thell et al. (2012), who illustrate Parmeliaceae as the most dominant family. The reason behind the dominancy of Parmeliaceae is because of the long distance dispersal events from the Northern to Southern hemispheres and also occurrence in temperate to sub polar regions (Divakar et al., 2019).

Among the growth forms studied, foliose lichens were dominant followed by fruticose and crustose. Similar results were also reported from Shrestha (2021) in Khaptad National Park, Chongbang et al. (2018) in Kanchanjungha Conservation Area and Kumar et al. (2011) in Kollihills of Tamilnadu. This is because foliose lichens were found commomly on all elevational zone and family Parmeliaceae being dominant consists more foliose lichen and are not affected by the landscape condition and depends upon a small amount of fragmentation to disperse to new sites (Cáceres et al., 2007). In contrast, Karmacharya et al. (2022) and Pinokiyo et al. (2008), discovered crustose lichens as dominant form, and this variation could be

attributed to habitat differences and differences in microclimatic condition. In present study, most of the fruticose lichen species were reported only from higher elevation. This finding is comparable to Wolseley & Pryor (1999) as fruticose lichens prefer area having good air quality with appropriate light appearance.

Chongbang et al. (2018) in his study highlighted that the distribution of lichen community is significantly affected by the substrate type. In present study, most of the recorded lichens (31 species) were corticolous and mainly on the tree trunk and canopy branches. Similar findings were observed by (Bhatta, 2023; Karmacharya et al., 2018; Pinokiyo et al., 2008; Stofer et al., 2006). This reflects the importance of wood component of the forest as the habitat of lichens (Negi & Upreti, 2000). Also the nature of the substratum, pH of bark, water holding capacity, buffer capacity of substratum plays an important role in the distribution of lichens (Barkman, 1958; Bates, 1992).

On studying the distribution of lichen based on photobiontic partner, this present study showed that green algal lichens (34 species) more prevalent than blue green algal lichens (5 species). Similar findings were shown by (Bhatta, 2023; Karmacharya et al., 2022; Kumar et al., 2011; Shrestha, 2021). This is because cyanolichens donot adapt to versatile environmental condition rather they are confined to habitats with specific moisture, light and nutrient levels and very sensitive to the altered microclimatic conditions (Hedenås, 2002; Sillett, 1994). Distribution of lichens based on microhabitat, canopy branches posses mostly green algal foliose and fruticose lichens were recorded in present studies. The efficiency of these species on the canopy branches could be explained by their ability to tolerate high levels of light (Kermit & Gauslaa, 2001).

The growth of lichen community and its composition vary across different altitudinal ranges because of the differences in elevation and the climatic variables like precipitation, water humidity and temperature (Bässler et al., 2016). Various patterns of relationship of lichens specie richness with altitudinal gradient were observed. The present study reported that elevation is one of the components to determine the composition and distribution of lichen species and their species richness. In this present study, it was observed that the species richness of lichen was 5 species at 1400m asl and then it gradually increased as elevation increased and reached peak (13 species) at 2300m asl and then slightly dropped at 2700m asl thus showing a hump shaped relationship. Similar observation were reported in the previous studies by (Baniya et al., 2010; Bruun et al., 2006; Pinokiyo et al., 2008; Rai et al., 2014; Rashmi & Rajkumar, 2019). This is because intermediary elevations can function as an intermediary or transitional zone which facilitates the higher species diversity (Pasaribu et al., 2023). Also, spatial

heterogeneity and diversity in habitat can influence species richness at local level. However, Rahbek (2005) concluded that shorter extent of altitudinal gradient can incomplete pattern. In contrast, monotonic trends have reported from the study by (Chongbang et al., 2018; Sankhi, 2014; Shrestha, 2021; Svoboda et al., 2010).

Beside elevation, aspect and slope are other important determinants for the growth and distribution of lichen community as these variables can alter the amount of solar radiation and evapotranspiration (Pentecost, 1979; Rodriguez et al., 2017). The present study reported that lichen species are more prevalent in south west than north west. North facing slope have unfavorable condition, warmer and humid while south facing slope have favourable condition (Körner, 2007). Due to high temperature, the thalli dries out resulting into partial loss of cellular wall and affecting growth rates (Armstrong & Smith, 1997). Similar results has been also observed in the saxicolous lichens studied by (Armstrong & Welch, 2007).

Some species like *Candelaria concolor*, *Dirinaria aplanata* and *Dirinaria aegialita* were reported mostly from lower elevation near to Kathmandu Valley and this area is highly influenced by anthropogenic activity. These species were also reported by Karmacharya et al. (2018) from highly polluted area of Kathmandu Valley. This is because *Candelaria concolor* ,*Dirinaria aplanata*, *Dirinaria aegialita* are nitrophilous species and are able to grow in polluted area (Díaz et al., 2021; Nag et al., 2020; Shukla & Upreti, 2011). Similarly *Parmotrema tinctorum* was predominantly found close region to the SNNP away from the influence of human activity. Nag et al. (2023) also support this finding in panjunaya village Baitadi district, Western Nepal.

CHAPTER-6

CONCLUSIONS

A total of 39 lichen species from 12 families and 19 genera were identified from this study in the SNNP, ranging in elevation from 1400 to 2700m asl. At an elevation of 2300m asl, the total lichen species richness reached its highest, consisting of 13 species, and displayed a non-monotonic hump-shaped relationship. With 19 species, the Parmeliaceae was the largest family. Foliose lichens were the most common type of life-form. At higher elevations (2000 m asl–2700 m asl), the majority of fruticose lichens were found. The number of crustose lichens was only two. The most commonly occurring lichen species were *Parmotrema reticulatum*, *Hypotrachyna cirrhata*, *Parmotrema latissimum*, *Parmelinella wallichiana*, and *Ramalina usnea*.

CHAPTER-7

RECCOMENDATION

Nepal's capital city is located in the Kathmandu Valley and its northern part is attached with SNNP. There is an extremely high population density in this city. Therefore, it is crucial to check the city's air quality utilizing lichens rather of more costly tools. The current status of foliose lichen at the lower elevation of SNNP will serve as a baseline for future research on the effects of environmental changes and biomonitoring studies in the Kathmandu Valley.

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Appendix-I: List of Lichens species including their short forms, Frequency, and their CCA1 scores, CCA2 scores, CCA3 scores.

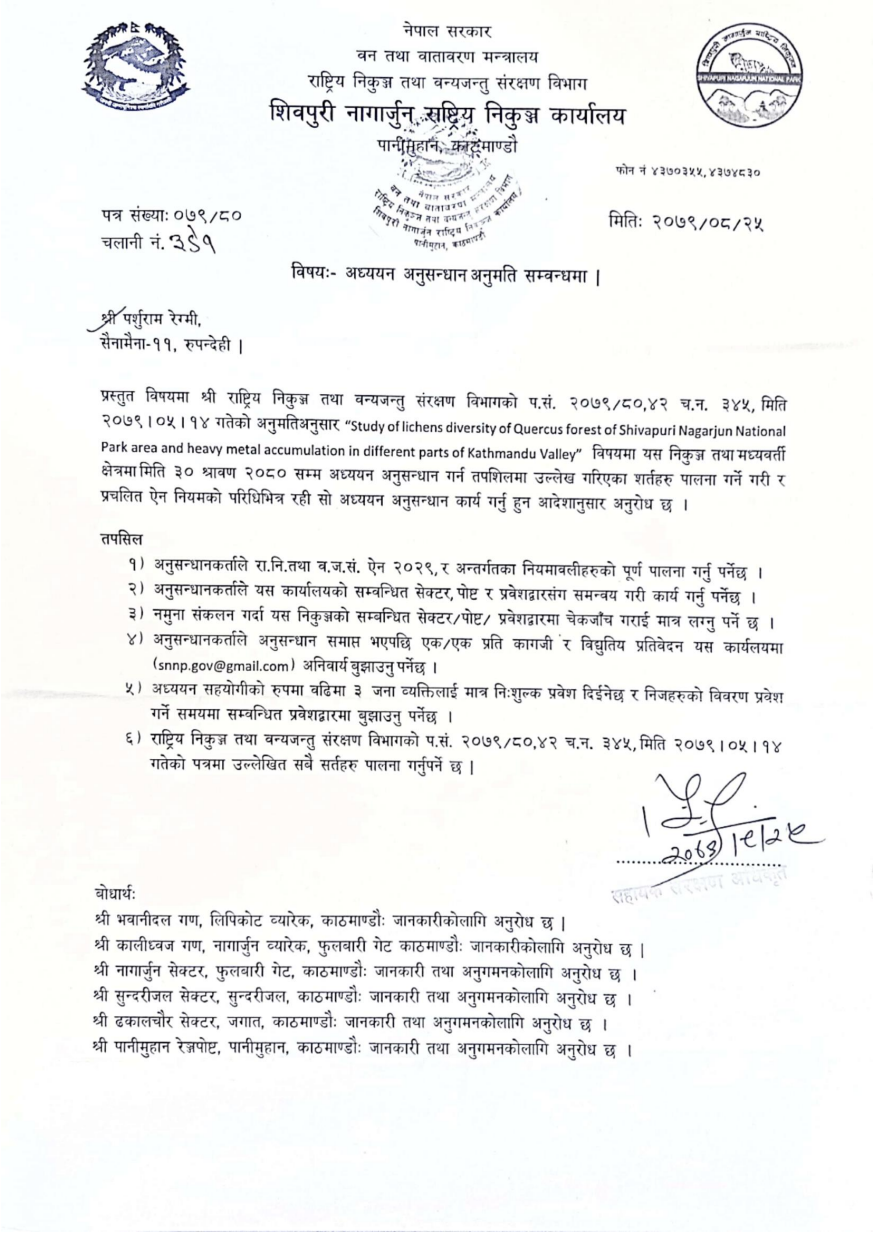
Name of lichens	Short forms	Frequency	CCA1	CCA2	CCA3
Candelaria concolor	Cand.conc	3	-1.13	-0.04	0.51
Cladonia ramulosa	Clad.ramu	9	-0.43	-0.02	0.19
Cladonia squamosa	Clad.squa	3	0.31	-0.08	-0.42
Coccocarpia pellita	Cocc.pell	6	-0.74	0.33	-0.49
Dirinaria aegialita	Diri.aegi	1	-1.83	-0.77	-0.77
Dirinaria applanata	Diri.appl	2	-1.96	-0.72	-0.75
Heterodermia diademata	Hete.diad	9	-0.21	-0.55	0.12
Heterodermia hypochraea	Hete.hypo	2	-0.65	-0.49	0.06
Heterodermia incana	Hete.inca	8	0.15	-0.03	-0.20
Heterodermia speciosa	Hete.spec	5	-0.27	0.45	-0.16
Hypotrachyna cirrhata	Hypo.cirr	11	0.61	0.01	0.01
Hypotrachyna laevigata	Hypo.laev	1	0.02	-1.50	-1.13
Hypotrachyna minarum	Hypo.mina	1	-1.47	2.17	-0.67
Hypotrachyna nepalensis	Hypo.nepa	9	0.69	0.07	-0.34
Lepraria yunnaniana	Lep.yunn	1	-1.47	2.17	-0.67
Leptogium asiaticum	Lept.asia	3	-0.52	-0.29	0.38
Leptogium resupinans	Lept.resu	5	0.57	0.31	0.23
Leucodermia boryi	Leuc.bor	6	0.79	0.03	-0.37
Lobaria retigera	Loba.reti	1	0.80	-0.30	0.83
Myelochroa entotheiochroa	Myel.ento	1	-2.09	-0.67	-0.72
Nephromopsis laii	Neph.laii	2	-0.26	0.11	1.04
Parmelinella simplicior	Parme.sim	3	0.01	-0.74	-0.07
Parmelinella wallichiana	Parme.wall	10	-0.55	0.24	0.42
Parmotrema latissimum	Parmo..lati	10	-0.32	-0.43	0.26
Parmotrema melanothrix	Parmo.mela	7	0.21	-0.45	0.42
Parmotrema reticulatum	parmo.reti	20	0.04	0.35	0.10
Parmotrema tinctorum	Parmo.tinc	5	-0.30	0.52	0.56
Peltigera polydactylon	Pelti.poly	2	-0.39	0.16	1.07
Polyblastidium hypoleucum	Poly.hypo	9	-0.32	0.47	-0.15
Ramalina conduplicans	Rama.cond	9	0.57	0.06	-0.12
Ramalina usnea	Rama.usn	13	0.53	-0.17	-0.27
Usnea angulata	Usne.ang	2	0.86	-0.29	-1.21
Usnea filipendula	Usne.fili	6	0.75	0.25	0.20
Usnea florida	Usne.flori	1	1.07	-0.41	0.78
Usnea himalayana	Usne.hima	4	0.59	0.57	-0.10
Usnea orientalis	usne.orie	7	0.21	-0.45	0.42
Usnea pseudomontifuji	Usne.pseu	3	0.40	-0.12	-0.44
Usnea roseola	Usne.rose	13	0.64	0.00	0.01
Varicellaria velata	Vari.vela	1	-2.09	-0.67	-0.72

Appendix II: Table showing the Elevation, Latitude, Longitude and Host of each lichen species.

Name of lichens	Elevation	Latitude	Longitude	Host
Candelaria concolor	1400-1900	27.7626	85.4223	*Albizia procera, Alnus nepalensis, Schima wallichii*
Cladonia ramulosa	1500-2400	27.7667	85.4237	*Quercus semecarpifolia, Rock, Alnus nepalensis, Pinus roxburghii, Quercus semecarpifolia,* Soil
Cladonia squamosa	1900-2600	27.8124	85.3837	*Ficus racemosa, Quercus semecarpifolia, Soil*
Coccocarpia pellita	1500-2400	27.7724	85.4283	*Pyrus pashia, Alnus nepalensis, Schima wallichii, Berberis* sp., Soil, Rock
Dirinaria aegialita	1500	27.7659	87.4236	Rock
Dirinaria applanata	1400	27.7625	85.4226	*Fraxinus florihunda, Maesa* sp.
Heterodermia diademata	1500-2400	27.8185	85.8439	*Quercus semecarpifolia,* Rock, *Alnus nepalensis, Pinus roxburghii,* Soil
Heterodermia hypochraea	1400-2400	27.7626	85.4223	*Castanopsis indica,* Rock
Heterodermia incana	1600-2700	27.825	85.4166	*Pyrus pashia, Berberis* sp., *Quercus semecarpifolia*
Heterodermia speciosa	1500-2700	27.7667	85.4237	*Rhododendron , Schima wallichii , Berberis* sp., *Quercus semecarpifolia ,* Rock
Hypotrachyna cirrhata	2000-2700	27.7824	85.4354	*Pyrus pashia, Schima wallichii, Berberis* sp., *Quercus semecarpifolia*
Hypotrachyna laevigata	2200	27.8208	85.4352	*Alnus nepalensis*
Hypotrachyna minarum	1600	27.7685	85.4336	*Alnus nepalensis*
Hypotrachyna nepalensis	2100-2700	27.8141	85.4421	*Castanopsis indica, Quercus semecarpifolia, Alnus nepalensis, Pinus roxburghii*
Lepraria yunnaniana	1600	27.7713	85.4263	*Rhododendron* sp.
Leptogium asiaticum	1500-2400	27.7666	85.4238	*Schima wallichii, Berberis* sp., *Quercus semecarpifolia , Maesa* sp.
Leptogium resupinans	2000-2600	27.8123	85.3829	*Pyrus pashia, Schima wallichii, Berberis* sp., *Quercus semecarpifolia, Castanopsis indica*
Leucodermia boryi	2100-2700	27.8191	85.4393	*Berberis* sp., *Quercus semecarpifolia*
Lobaria retigera	2400	27.7991	85.3869	*Quercus semecarpifolia,* Soil
Myelochroa entotheiochroa	1400	27.7626	85.4223	*Maesa* sp.
Nephromopsis laii	1900-2100	27.7893	85.4361	*Ficus racemosa , Berberis* sp.
Parmelinella simplicior	2100-2200	27.8185	85.4394	*Alnus nepalensis*
Parmelinella wallichiana	1500-2400	27.8191	85.4395	Rock, *Castanopsis indica, Quercus semecarpifolia, Alnus nepalensis, Pinus roxburghii, Berberis sp.*

Parmotrema latissimum	1400-2400	27.776	85.4336	*Fraxinus florihunda, Pyrus pashia, Schima wallichii, Berberis* sp., *Quercus semecarpifolia*
Parmotrema melanothrix	2000-2400	27.8185	85.4394	*Pyrus pashia, Berberis* sp., *Quercus semecarpifolia, Alnus nepalensis*
Parmotrema reticulatum	1500-2700	27.7789	85.4346	*Pyrus pashia, Schima wallichii, Berberis* sp., *Quercus semecarpifolia, Castanopsis indica, Maesa* sp.
Parmotrema tinctorum	1600-2400	27.772	85.4263	*Pyrus pashia, Schima wallichii, Berberis* sp., *Quercus semecarpifolia, Castanopsis indica*
Peltigera polydactylon	1900-2000	27.788	85.3805	Soil, *Quercus semecarpifolia, Pinus roxburghii*
Polyblastidium hypoleucum	1600-2400	27.8168	85.443	*Castanopsis indica, Quercus semecarpifolia, Alnus nepalensis, Pinus roxburghii, Berberis* sp.
Ramalina conduplicans	2000-2700	27.7893	85.4361	*Pyrus pashia, Schima wallichii, Berberis* sp., *Quercus semecarpifolia, Castanopsis indica*
Ramalina usnea	2000-2700	27.7893	85.4361	*Pyrus pashia, Schima wallichii, Berberis* sp., *Castanopsis indica*
Usnea angulata	2300-2700	27.8123	85.3829	*Castanopsis indica, Quercus semecarpifolia, Alnus nepalensis, Pinus roxburghii, Berberis* sp.
Usnea filipendula	2100-2600	27.7846	85.4349	*Pyrus pashia, Schima wallichii, Berberis* sp., *Quercus semecarpifolia, Castanopsis indica*
Usnea florida	2500	27.7991	85.3869	*Berberis sp., Quercus semecarpifolia*
Usnea himalayana	2000-2700	27.8191	85.4393	*Schima wallichii, Berberis* sp., *Quercus semecarpifolia, Castanopsis indica*
Usnea orientalis	2000-2700	27.7893	85.4361	*Castanopsis indica, Alnus nepalensis, Pinus roxburghii, Berberis* sp.
Usnea pseudomontifuji	2000-2700	27.885	85.4394	*Castanopsis indica, Quercus semecarpifolia, Pinus roxburghii, Berberis* sp.
Usnea roseola	2000-2700	27.7846	85.4349	*Castanopsis indica, Quercus semecarpifolia, Alnus nepalensis, Pinus roxburghii, Berberis* sp.
Varicellaria velata	1400	27.7626	85.4323	*Albizia procera.*

Appendix-III: Permission letter from Department of National Park and Wildlife Conservation (DNPWC) for collection of lichen specimens



नेपाल सरकार
वन तथा वातावरण मन्त्रालय
राष्ट्रिय निकुञ्ज तथा वन्यजन्तु संरक्षण विभाग
शिवपुरी नागार्जुन राष्ट्रिय निकुञ्ज कार्यालय
पानीमुहान, काठमाण्डौ

फोन नं ४३७०३५५, ४३७४८३०

पत्र संख्या: ०७९/८०
चलानी नं. ३९९

मितिः २०७९/०८/२५

विषयः- अध्ययन अनुसन्धान अनुमति सम्बन्धमा ।

श्री पर्शुराम रेग्मी,
सैनामैना-११, रुपन्देही ।

प्रस्तुत विषयमा श्री राष्ट्रिय निकुञ्ज तथा वन्यजन्तु संरक्षण विभागको प.सं. २०७९/८०,४२ च.न. ३४५, मिति २०७९।०५।१४ गतेको अनुमतिअनुसार "Study of lichens diversity of Quercus forest of Shivapuri Nagarjun National Park area and heavy metal accumulation in different parts of Kathmandu Valley" विषयमा यस निकुञ्ज तथा मध्यवर्ती क्षेत्रमा मिति ३० श्रावण २०८० सम्म अध्ययन अनुसन्धान गर्न तपशिलमा उल्लेख गरिएका शर्तहरु पालना गर्ने गरी र प्रचलित ऐन नियमको परिधिभित्र रही सो अध्ययन अनुसन्धान कार्य गर्नु हुन आदेशानुसार अनुरोध छ ।

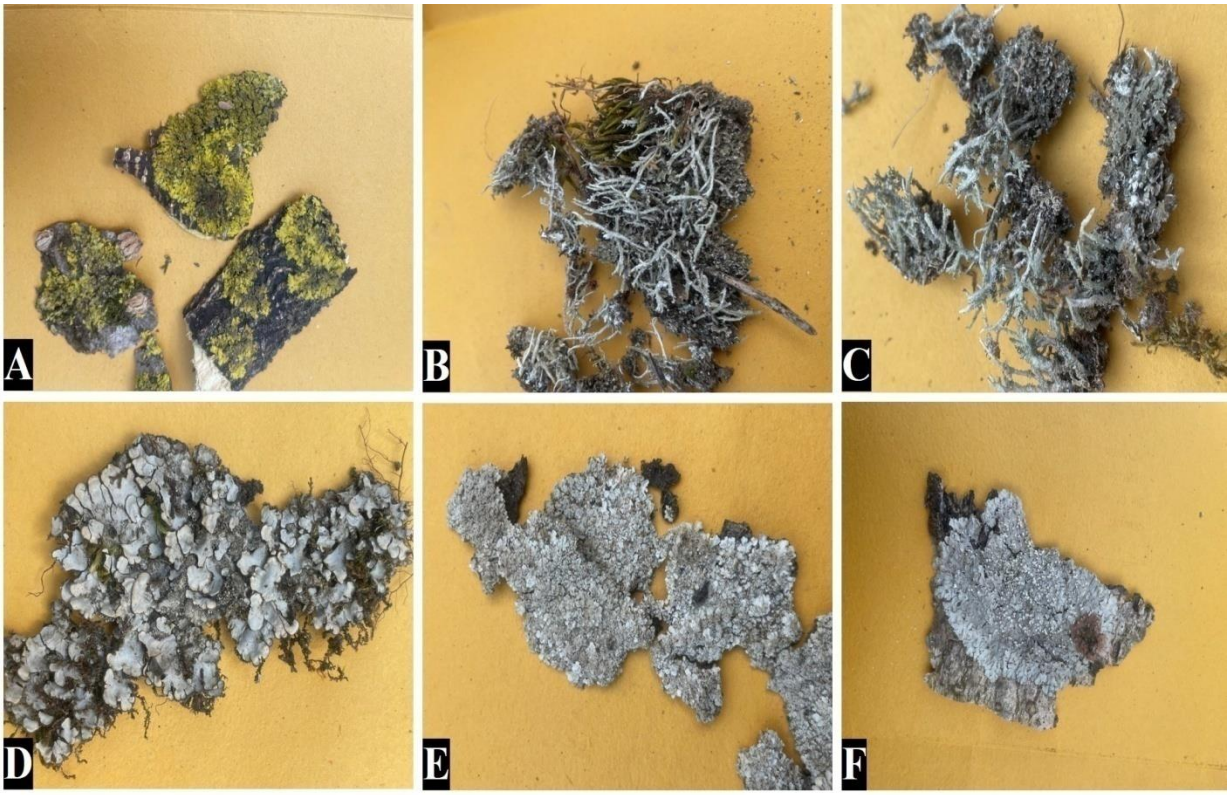
तपसिल

१) अनुसन्धानकर्ताले रा.नि.तथा व.ज.सं. ऐन २०२९, र अन्तर्गतका नियमावलीहरुको पूर्ण पालना गर्नु पर्नेछ ।
२) अनुसन्धानकर्ताले यस कार्यालयको सम्बन्धित सेक्टर, पोष्ट र प्रवेशद्वारसंग समन्वय गरी कार्य गर्नु पर्नेछ ।
३) नमुना संकलन गर्दा यस निकुञ्जको सम्बन्धित सेक्टर/पोष्ट/ प्रवेशद्वारमा चेकजाँच गराई मात्र लग्नु पर्ने छ ।
४) अनुसन्धानकर्ताले अनुसन्धान समाप्त भएपछि एक/एक प्रति कागजी र विद्युतिय प्रतिवेदन यस कार्यलयमा (snnp.gov@gmail.com) अनिवार्य बुझाउनु पर्नेछ ।
५) अध्ययन सहयोगीको रुपमा बढिमा ३ जना व्यक्तिलाई मात्र निःशुल्क प्रवेश दिईनेछ र निजहरुको विवरण प्रवेश गर्ने समयमा सम्बन्धित प्रवेशद्वारमा बुझाउनु पर्नेछ ।
६) राष्ट्रिय निकुञ्ज तथा वन्यजन्तु संरक्षण विभागको प.सं. २०७९/८०,४२ च.न. ३४५, मिति २०७९।०५।१४ गतेको पत्रमा उल्लेखित सबै सर्तहरु पालना गर्नुपर्ने छ ।

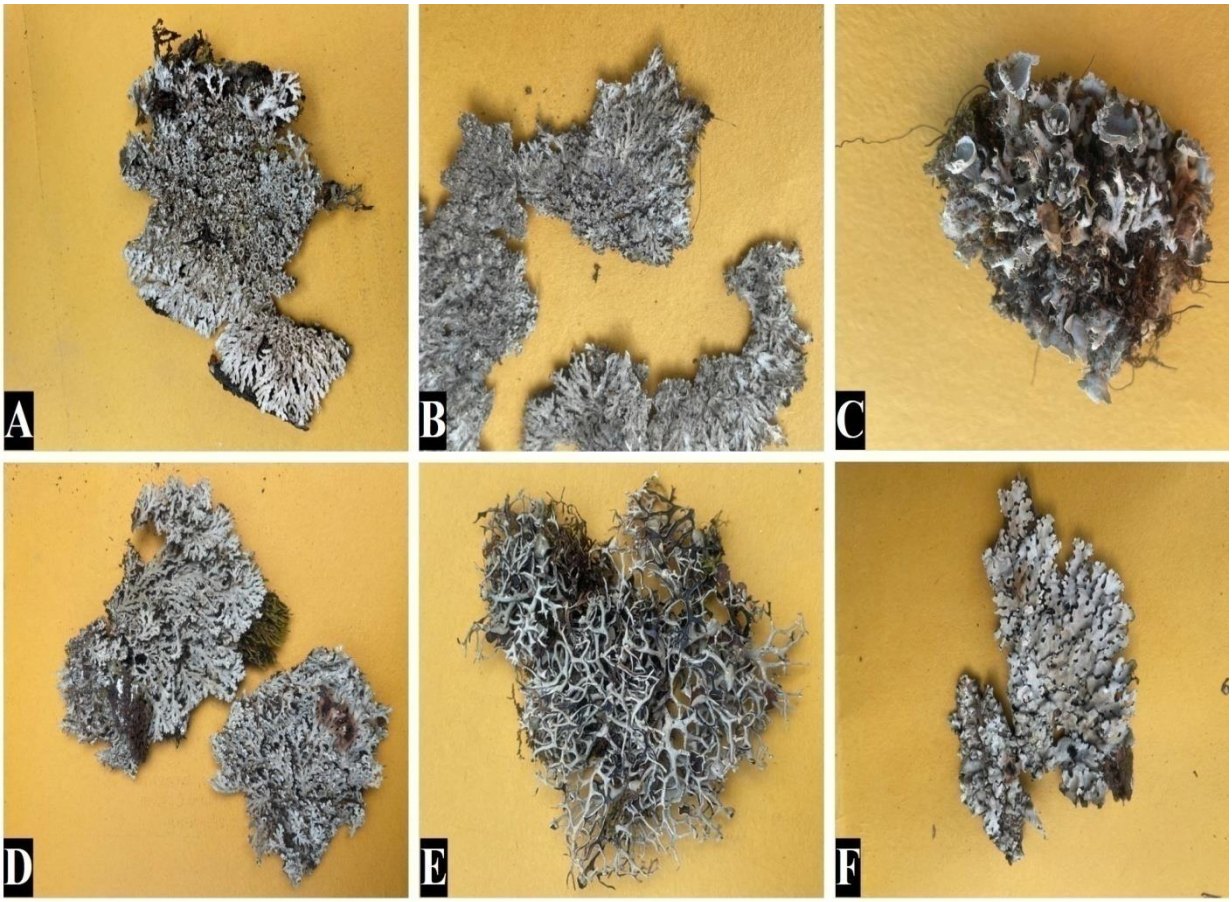
२०७९/८/२५

बोधार्थः
श्री भवानीदल गण, लिपिकोट व्यारेक, काठमाण्डौः जानकारीकोलागि अनुरोध छ ।
श्री कालीध्वज गण, नागार्जुन व्यारेक, फुलबारी गेट काठमाण्डौः जानकारीकोलागि अनुरोध छ ।
श्री नागार्जुन सेक्टर, फुलबारी गेट, काठमाण्डौः जानकारी तथा अनुगमनकोलागि अनुरोध छ ।
श्री सुन्दरीजल सेक्टर, सुन्दरीजल, काठमाण्डौः जानकारी तथा अनुगमनकोलागि अनुरोध छ ।
श्री ढकालचौर सेक्टर, जगात, काठमाण्डौः जानकारी तथा अनुगमनकोलागि अनुरोध छ ।
श्री पानीमुहान रेञ्जपोष्ट, पानीमुहान, काठमाण्डौः जानकारी तथा अनुगमनकोलागि अनुरोध छ ।

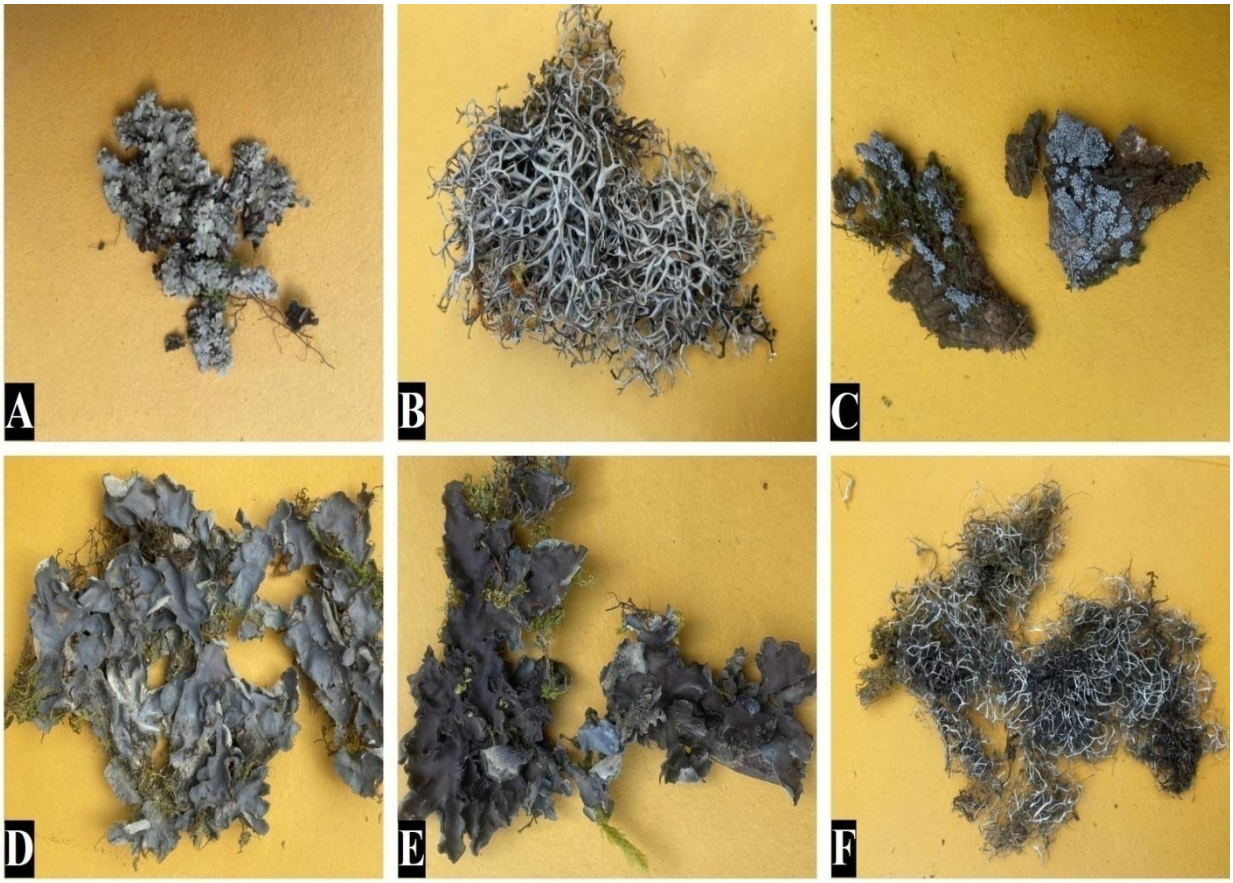
Appendix-IV: Photo plates



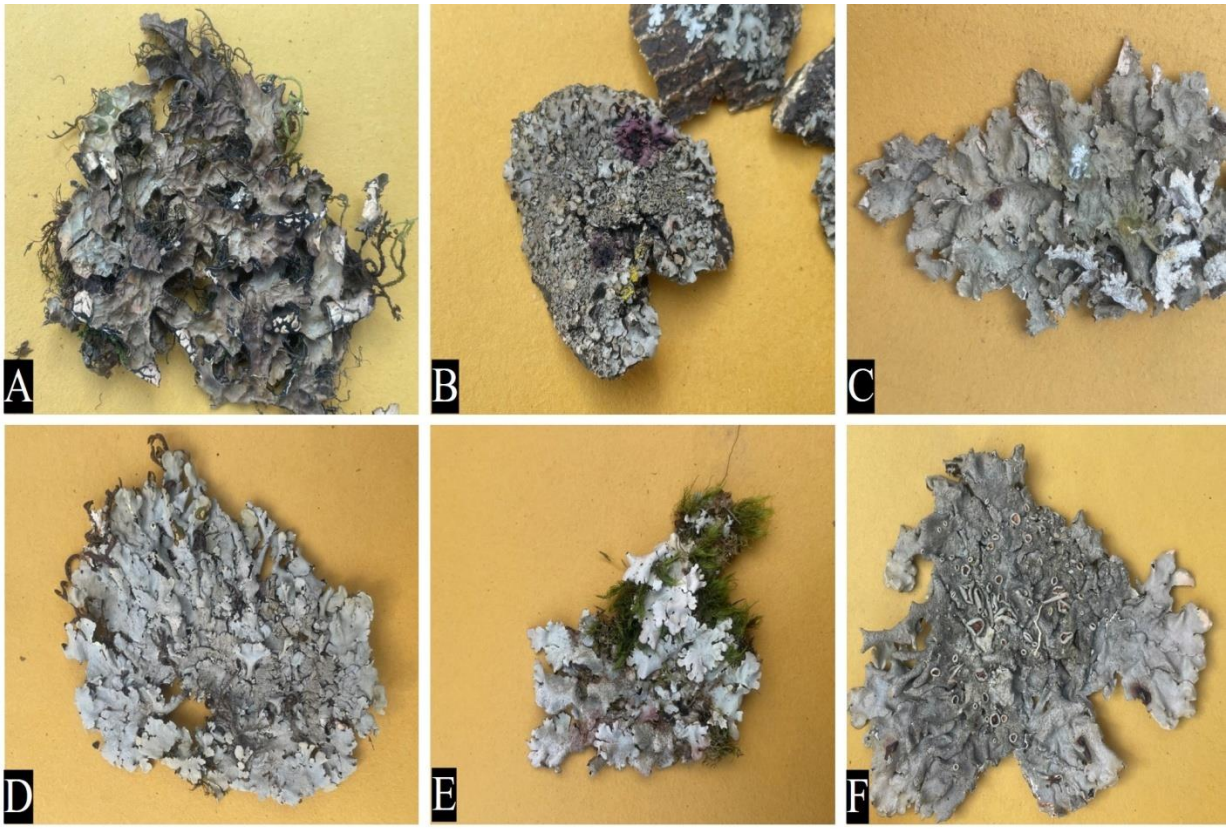
Photoplate 1: **A.** *Candelaria concolor*, **B.** *Cladonia ramulosa*, **C.** *Cladonia squamosa*, **D.** *Coccocarpia pellita*, **E.** *Dirinaria aegialita*, **F.** *Dirinaria applanata*



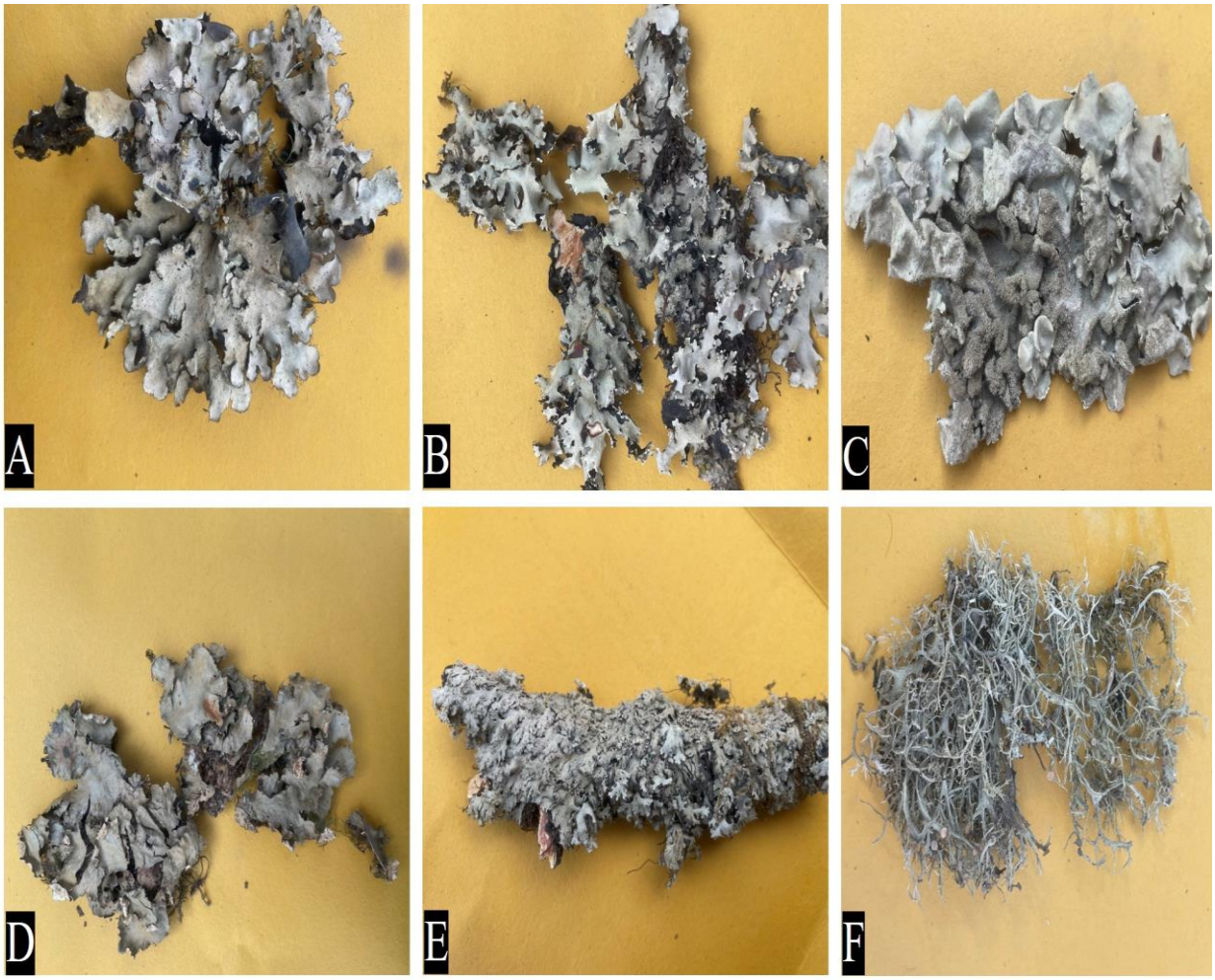
Photoplate 2: A. *Heterodermia diademata*, **B.** *Heterodermia hypochraea*, **C.** *Heterodermia incana*, **D.** *Heterodermia speciosa*, **E.** *Hypotrachyna cirrhata*, **F.** *Hypotrachyna laevigata*



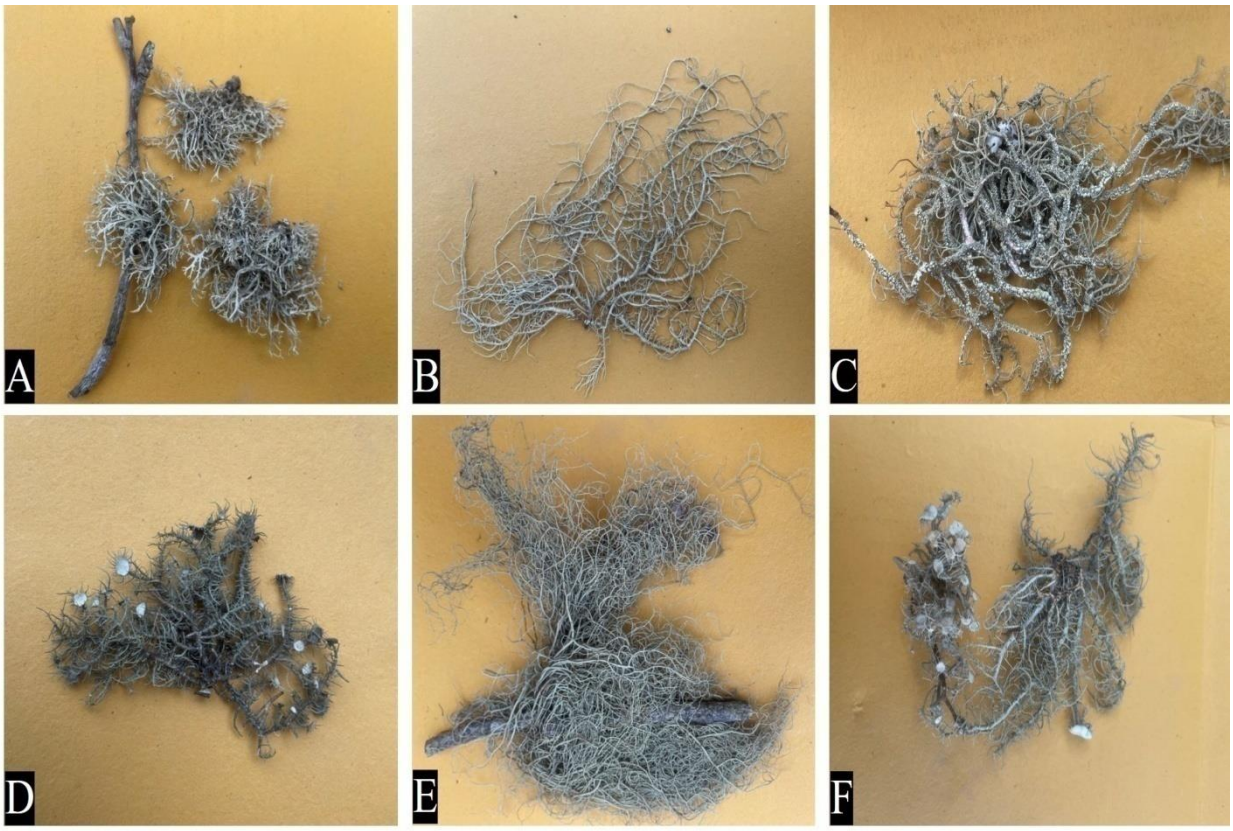
Photoplate 3: **A.** *Hypotrachyna minarum*, **B.** *Hypotrachyna nepalensis*, **C.** *Lepraria yunnaniana*, **D.** *Leptogium asiaticum*, **E.** *Leptogium resupinans*, **F.** *Leucodermia boryi*



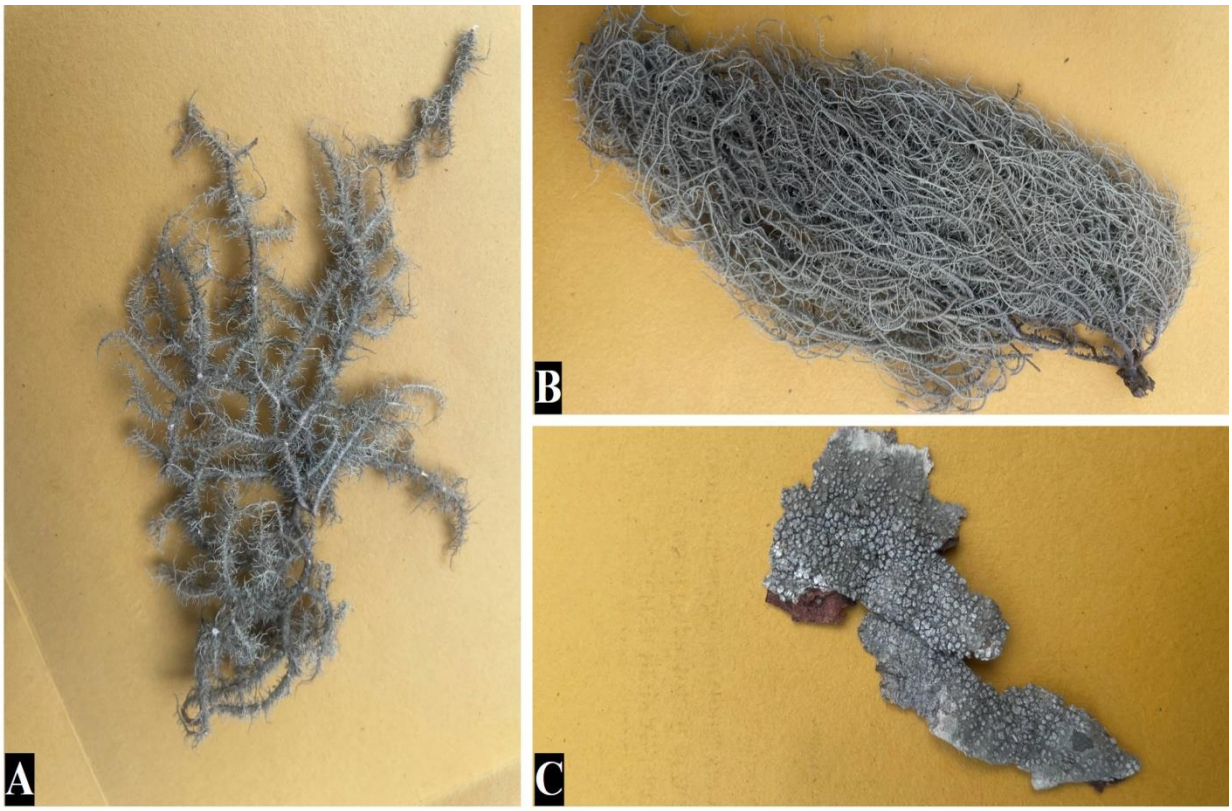
Photoplate 4: **A.** *Lobaria retigera*, **B.** *Myelochroa entotheiochroa*, **C.** *Nephromopsis laii* **D.** *Parmelinella simplicior*, **E.** *Parmelinella wallichiana*, **F.** *Parmotrema latissimum*



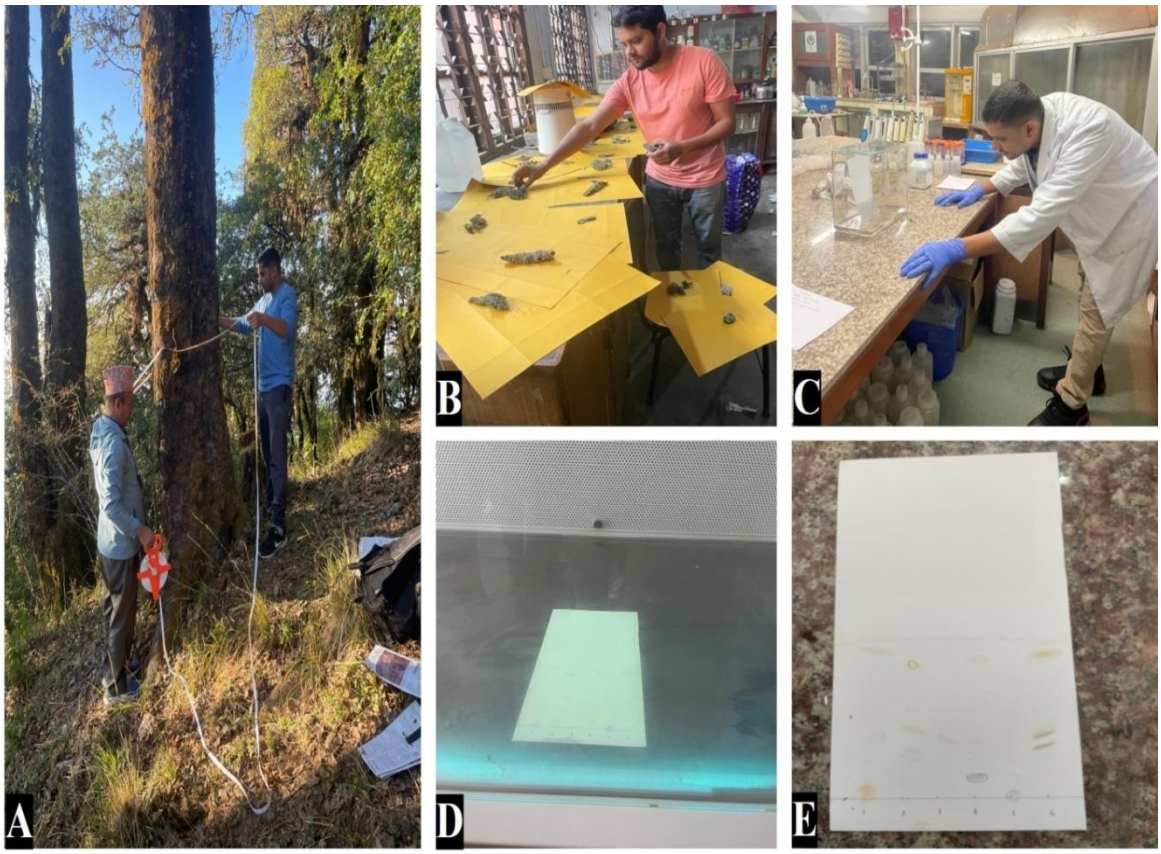
Photoplate 5: **A.** *Parmotrema melanothrix*, **B.** *Parmotrema reticulatum*, **C.** *Parmotrema tinctorum*, **D.** *Peltigera polydactylon*, **E.** *Polyblastidium hypoleucum*, ***F.*** *Ramalina conduplicans*



Photoplate 6: **A.** *Ramalina usnea*, **B.** *Usnea angulata*, **C.** *Usnea filipendula*, **D.** *Usnea florida*, **E.** *Usnea himalayana*, **F.** *Usnea orientalis*



Photoplate 7: **A.** Usnea pseudomontifuji, **B.** *Usnea roseola*, **C.** *Varicellaria velata*



Photoplate 8: **A.** collection of lichen specimens, **B-C.** Lab work, D-**E.** TLC of lichen species

APPENDIX V: Certificate Of Participation

10th Graduate Conference 2024

HIMALAYAN KNOWLEDGE CONCLAVE

"Empowering Tomorrow: Science, Society, Sustainability"

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is presented to

Parshu Ram Regmi

for valuable contribution as a Paper Presenter/Poster Presenter/Participant/Volunteer at the 10th Graduate Conference held on April 4-5, 2024, hosted by the Central Department of Environmental Science, Institute of Science and Technology, Tribhuvan University, Kirtipur, Nepal.

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