LICHENS OF KHAPTAD NATIONAL PARK, WEST NEPAL

A Dissertation work submitted for the partial fulfillment of the requirements of Master's Degree in Botany

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RECOMMENDATION LETTER

This is to recommend that the thesis entitled "**Lichens of Khaptad National Park, West Nepal**" has been carried out by Ms. Alina Shrestha for the partial fulfillment of Master of Science in Botany with 'Ecology and Resource Management' as special. This is her original work and has been carried out under my supervision. This thesis has not been submitted to other institutions for the award of degrees. I recommend this thesis for submission to evaluate for the Degree of Master of Science in Botany (Ecology and Resource Management), Tribhuvan University, Kirtipur, Nepal.

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LETTER OF APPROVAL

The M.Sc. Dissertation entitled "**Lichens of Khaptad National Park, West Nepal**" submitted at the Central Department of Botany, Tribhuvan University by Miss Alina Shrestha has been accepted for partial fulfillment of the requirements for Master of Science in Botany (Ecology and Resource Management).

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Alina Shrestha

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ABBREVIATIONS

ACA	Annapurna Conservation Area
CCA	Canonical Correspondence Analysis
$CaOCl_2$	Calcium Hypochlorite
DCA	Detrended Correspondence Analysis
DHM	Department of Hydrology and Meteoreology
HNO_3	Nitric Acid
KNP	Khaptad National Park
KOH	Potassium Hydroxide
Pd	*p*- phenylenediamine
RRI	Relative Radiation Index
SD	Standard deviation
sp	Species (singular = sp, plural = spp)
TLC	Thin Layer Chromatography
TUCH	Tribhuwan University Central Herbarium

ABSTRACT

Lichens are playing important role in ecosystems functioning and are widely recognized as excellent environmental indicators worldwide. However, very little is known about lichen communities and their importance in Nepal. Nepal is believed to have a rich lichen flora. This present study studied the lichen species diversity along the altitudinal gradient and effects of host species on its distribution. To fulfill these objectives present work was carried out in the Khaptad National Park, Western Nepal. Khaptad National Park is one of holy shrines in Nepal. Lichens were sampled along different forests found in Khaptad National Park from an altitude of 2200 m to 3200 m asl. A total of 98 plots, of 5 x 5 m^2 area each, were laid down. The plots were laid 10 m away from the ridges of walking trail between every 200 m distance. A total of 49 plots sampled on each sides of the study area. Detrended Correspondence Analysis (DCA) and Canonical Correspondence Analysis (CCA) were performed to analyze the species composition and environmental relations through the R- software. A total of 47 lichen species belonging to 29 genera and 14 families were recorded. Among them Parmeliaceae was largest family with 17 species. Within the recorded lichens, 27 species were foliose, 10 crustose, 7 fruticose and 3 leprose. There were 40 species found growing on the tree bark which were called as corticolous groups. DCA first axis Eigen value was 0.72 with an axis length of 8.01 *SD* units indicating a complete species turnover along the major altitudinal gradient. This gave inferences that each of the plot got a high beta diversity along the altitude. The CCA ordination showed that there was about 13 % of the total variance explained by the measured environmental variables and remaining 87% was unknown. Total lichen species richness showed significant increasing pattern with the altitude. Furthermore the number of lichen species occured more on the *Quercus* tree towards the lower altitude may be its rough bark. At the higher altitude, high air moisture would have aided the higher number of lichen species in the *Abies*, *Picea* trees. Slope and aspects did not show significant relationship to the lichen richness. Thus it can be concluded that the altitude and host have a significant effect on the distribution of the lichens.

Keywords: *Khaptad National Park, lichen species diversity, Detrended correspondence analysis, Canonical correspondence analysis, altitudinal gradient, host species.*

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CHAPTER-1
INTRODUCTION

1.1 Background

The word 'Lichen' was first introduced in the Greek literature by the father of Botany, Theophrastus (c.371-c.287 BC). Primarily he intended to describe the outgrowth from the Olive bark (Hawksworth and Hill 1984; Hale 1974). Lichens are a highly diversed group. Universally, lichens are distributed and exhibited a distinctive symbiotic organism (Seaward, 1977). According to Hawksworth and Hill (1984), lichen is an association between fungus and algae as symbionts. Algae resulting a stable thallus of specific structure. Whereas fungus resulting a major skeleton and absorption. Lichens are the result of mutually benefited symbionts, alga and fungi (Sharma, 1995). The lichen symbiosis is thought to be a mutualism, since both fungi and the photosynthetic partners, photobionts, or alga benefit from it. It is present in a wide range of habitats throughout the world and dominates terrestrial ecosystems i.e. about 8% (Larson, 1987).

The systematic study of lichens was begun after the Swedish Doctor, Erik Acharius, his first publication was 'Lichenographiae Suecia prodromus' published in 1798. He introduced the terms: soredia, isidia and cephalodia (Hale, 1974; Hawksworth and Hill, 1984). Alexander Zahlbruckner designated them into families, genera and species (Hawksworth and Hill, 1984). In Nepal, lichenologists have estimated about 2000 lichen species (Sharma, 1995). A total of 550 species of lichens were reported from Nepal, among these recorded lichens, 39% are crustose, 45% are foliose and 17% are fruticose (Baniya, 2020). While Olley and Sharma (2013) have revised and recorded a total of 792 taxa from 187 genera to occur in Nepal. Currently, there are 838 species of lichens recorded in Nepal (Rai *et al*., 2017; Karmacharya *et al*., 2019).

Altitude gradient plays an effective role on the species richness pattern of the many organism (Rahbek, 2005). The effect of altitude on the lichens species is also described by many investigators. Different elevation patterns were discovered like unimodal, decreasing, increasing with the increasing in the elevation. (Baniya *et al*., 2012; Tu *et al*., 2010; Pinokiyo *et al*., 2008).

Tree species are considerd as one of the very important driver of the species composition for many organism groups. The diversity and the composition patterns are regulated by tree, stand and landscape scale factors (Odor *et al*., 2013). Ecology of lichens could be described with reference to the substratum, habitat and phorophyte preferences (Rai *et al*., 2017). Also, light can be considered as one of the main driving factors of lichen composition and diversity where epiphytic lichens are related to the light condition in open forests (Odor *et al*., 2013). Substrate has an important role in determining the distribution of epiphytic species (Mezaka *et al*., 2008). Different physical factors like temperature, rainfall, aspects, soil moisture, humidity, vegetation cover, their type and many other environmental factors influence the diversity of the plants as well as lichens groups. The distribution of lichens can be explained by the substrate types and rainfall (Giordani 2007), temperature and moisture (Sillett and Antoine 2004), humidity (Pinokiyo *et al*., 2008), forest types (Li *et al*., 2013), elevation (Baniya *et al*., 2010, 2012) and radiation (Svaboda *et al*., 2011).

1.2 Significance of the Study

Lichens are one of the first life forms developed in rock that are pronounced as pioneer flora of succession. Nepal has a rich lichen flora but very few studies have been done so far in the country (Baniya *et al.,* 1999) and lichens are an overlooked and less studied group in Nepal. Although there are several potentialities for detailed exploration of lichens, yet in practice very little importance and efforts have been made on Lichenology. In the International workshop on lichen taxonomy held in Kathmandu in 1994, Lichenologists opined that there are about 2000 lichens species in Nepal but very few were studied until now. Among the study so far done, all the study focused only in the Eastern and Central part of the Nepal, the Western part is still less explored. Thus, the study in the western part of the Nepal is important. This study in the pristine land of Khaptad can contribute in the study on the flora of lichen from the Western Nepal, which will add information of lichens of this area.

1.3 Objectives

The main objective of this study was to find out the diversity of lichens in Khaptad National Park.

Specific objectives were:

- To describe the taxonomic treatment of the lichen.
- To study the lichen ecology found in the area.
- To study lichens based upon dominant forest species.

1.4 Limitations of work

Khaptad National Park (KNP) includes four districts of the Far western province of Nepal i.e. Achham, Bajhang, Bajura and Doti. The present research work has been carried out in Doti and Bajhang, only two districts of the study area. This study aimed to cover all the four districts but we only sampled in two districts due to the difficult geographical area. And also some sites in the Doti and Bajhang is avoided due to the absence of the suitable habitat for the sampling. Lack of the suitable site and the difficult geography of the site limit the research work.

CHAPTER- 2
LITERATURE REVIEW

Floristic Study of lichens in Nepal

Wallich (1826) for the first time published illustrative records of lichen flora in Nepal. Awasthi (1957) made an extensive collection of lichen species from eastern Nepal among which *Cetraria nepalensis, Cetraria pallida* and *Physica melanotricha* were new ones. Awasthi (1960) described 38 species of lichens collected by R.S. Rao from Cho-Oyu Himal (1958). Aashina and Kurokawa (1966) presented a total of 133 taxa of lichens from Eastern Himalayas among which 62 were from Nepal. Poelt (1966) described 6 species of *Ochrolechia* and 12 species of *Lecanora* from Nepal, out ofwhich 3 species of *Ochhrolechia* were new to science. Kurokawa (1967) enumerated 53 species of lichens from Rolwaling Himal, out of which 26 species were new to Nepal.Bystrek (1969) described 12 species of *Alectoria* from eastern Nepal and 3 taxa (*A. perspinosa, A. poeltii* and *A. variabilis)* were new report to science.

Yoshimura (1971) reported four species of *Lobaria* from Nepal in his monographic study of Eastern Asian *Lobaria.* Abbayes (1974) worked out *Cladonia* and out of the 20 species enumerated, 10 taxa were new reports. Kurokawa (1974) enumerated 13 species of *Anaptychia*, out of which 3 were new reports. Poelt (1974) revised the genera *Physcia, Physconia* of the Himalayan region. Out of the 19 species of *Physcia*, 4 were new to science, and 15 species were new report from Nepal, and 2species of *Physciopsis* and *Physoconia* were also reported from Nepal. Schmidt (1974) reported *Chaenotheca* and *Coniocybe*, out of the 8 taxa mentioned, 6 were newreport to science from Nepal. Vezda and Poelt (1974) reported *Dimerella lutea* and described *Pachyphiale himalayensis* as new record to science from Nepal. Poelt (1974) described 12 species of *Umbilicaria* from Nepal. Lamb (1977) has stated the occurrence of 10 species of *Stereocaulon* in Nepal. Hertel (1977) reported 24 saxicolous species from Nepal, out of which 7 species were new to science.

Awasthi and Awasthi (1985) described 14 species of *Bryoria*, 2 species of *Sulcaria* and a singlespecies of *Alectoria* from India and Nepal. Upreti (1987) prepared an artificial identification key for 62 species of lichen genus *Cladonia* reported from

Nepal and India. Awasthi (1988) published artificial keys for 71 genera and 697 species of macro lichens from India and Nepal. Kurokawa (1988) collected total of 38 species from the two genus: *Parmelia* (24 species) and *Anaptychia* (14 species) from Kathmandu valley.

Sharma and Kurokawa (1990) collected 10 species of *Anaptychia* and 21 species of *Parmelia* from Nepal, out of which *Parmelia erumpens* and *P. sinuosa* were new to Nepal. Awasthi (1991) published a *Bibliotheca Lichenologica* comprising artificial keys to 163 genera and 1150 species of microlichens from India, Nepal and Srilanka. Sharma (1995) enumerated 465 species of lichens covering 79 genera and 30 families from Nepal. Baniya (1996) enumerated 99 taxa, out of which 33 species were new report to Nepal. Pathak (1998) enumerated 52 taxa from Dang and Hetauda, out of which 15 species were new to Nepal. Baniya *et al* (1999) studied diversity of lichens in Nepal and documented the major lichen species present in the five physiographic regions of Nepal. Devkota (1999) studied the floristic composition of Namoboudha, Kavrepalanchowk and described 55 species and studied the antibiotic properties of *Heterodermia diademata, Parmelia nepalensis* and *Parmelia reticulata.* Thapa (1999) studied the apothecial anatomy of some foliose and fructicose lichens of Namoboudha.

Shrestha (2001) studied the nutrients content in lichens in the *Quercus semicarpifolia* forest in the Phulchowki hills. Baniya and Gupta (2002) enumerated a total of 77 species of Lichens belonging to 25 families and 28 genera from an elevation of 2,900 to 3,400 m a.s.l. in Thodimai region of Annapurna conservation area (ACA), and 78 species of lichens under 15 families and 17 genera from an elevation of 1,100 to 2,300 m a.s.l. in between line transect of Arun river bridge to Tashigaun in the buffer zone of Makalu-Barun National Park. Baniya *et al* (2003) studied the floristic composition, use and database of lichens of Kakani, Central Nepal and enumerated 64 species of lichens under 18 families and 21 genera.

Baniya *et al* (2010) carried out an important study on lichen richness throughout Nepal using the published data of elevation records and reported 525 species of lichens belonging to 40 families and 121 genera, out of which 55 species were endemic to Nepal. Olley and Sharma (2013) published a provisional checklist of the lichens of Nepal, on the basis of the published literatures and the specimens collected

during 2007 (Sharma *et al.*, 2007) that included 792 taxa of lichen present in Nepal. Rai *et al* (2017) reported 28 new species of lichens from Dadeldhura, Nepal. Karmacharya *et al* (2019) reported 18 graphidoid lichen species of *Diorygma*, *Graphis*, *Pallidogramme* and *Phaeographis* as new records from Nepal.

Altogether there are 838 species of lichens are reported from Nepal (Olley & Sharma 2013, Rai *et al.*, 2017 & Karmacharya *et al.*, 2019).

Ecology of Lichens

The composition of lichen communities was determined by substratum qualities such as age of the part of tree where the lichen is growing, bark texture, chemistry and also the habitat conditions, aspect and climate (Barkman, 1958; Rose, 1976; Gustafsson *et al.*, 1992; Selva, 1994). Coppins (1976) studied the distribution patterns of epiphytic lichens in the British Isles that concluded that the climatic factors determined the distributional tendencies of the smaller number of species. Ahti (1977) described lichens of the boreal coniferous zones of the world and presented ecological condition, the influence of florogenetic isolations of the evolutionary rate of the component flora.

Mc Cune and Antos (1982) studied the epiphytic communities in low elevation conifer forests of the Swan Valley of Western Montana observing that young stands of epiphytes tend to equate with dry stands and that of old stands with wet stands. Rogers (1990) studied ecological strategies of lichens and found foliose species were often competitive with high relative growth rate. The decreasing importance of crustose growth forms with increasing altitude, especially in forest plots, could be influenced by decreasing ecological disturbances.

Hauck and Spribille (2005) described that the higher epiphytic lichen diversity on *Abies* than on other confiners, such as *Picea* and *Pinus* may be caused by the effective Mn immobilization in the bark in the spruce-fir forests of the Salish Mountains, northwestern Montana. They also suggested that the precipitation chemistry is probably of subordinate significance for the epiphytic lichen diversity. Nag *et al* (2011) studied the epiphytic lichens as indicator of land-use pattern and forest harvesting in a community forest in west Nepal. They found lichen diversity was constrained by phorophyte determinants and community harvesting of the forest.

Tarasova *et al* (2016) carried their study of lichens of forest rocky communities of the hill Muroigora in Arkhangelsk region of northwest Russia. In this study they found the highest lichen species richness i.e. 33% on the trunks and branches of the *Picea abies*, 13 % on the bark of *Betula pubescens*, 9% on the bark of *Salix caprea*, 7% on the bark of *Populus tremula* of the total lichen flora. Chongbang *et al* (2018) studied the lichen diversity along land-use gradients in Kanchenjunga in Eastern Nepal. They concluded that the substrate types that depend on land-use types as well as canopy openness significantly affect the distribution of lichen communities.

Since many studies done so far lacked the western part of Nepal and unable to represent the whole Nepal. So this present study can add a brick for the foundation of the study of the lichens from western Nepal also.

CHAPTER-3
MATERIALS AND METHODS

3.1 Study Area- Khaptad National Park

3.1.1 Location and Physiography

Khaptad National Park (KNP) is the protected area situated in the Far-western Province of Nepal (Figure 1). It covers an area of 225 sq. km. as core zone and buffer zone of 216 sq. km. The national park occupies over the four districts: Achham, Bajhang, Bajura and Doti. The park is the only mid-mountain national park in the western part of Nepal. The altitude of Khaptad National Park ranges from 1,400 m asl to 3,300 m asl.

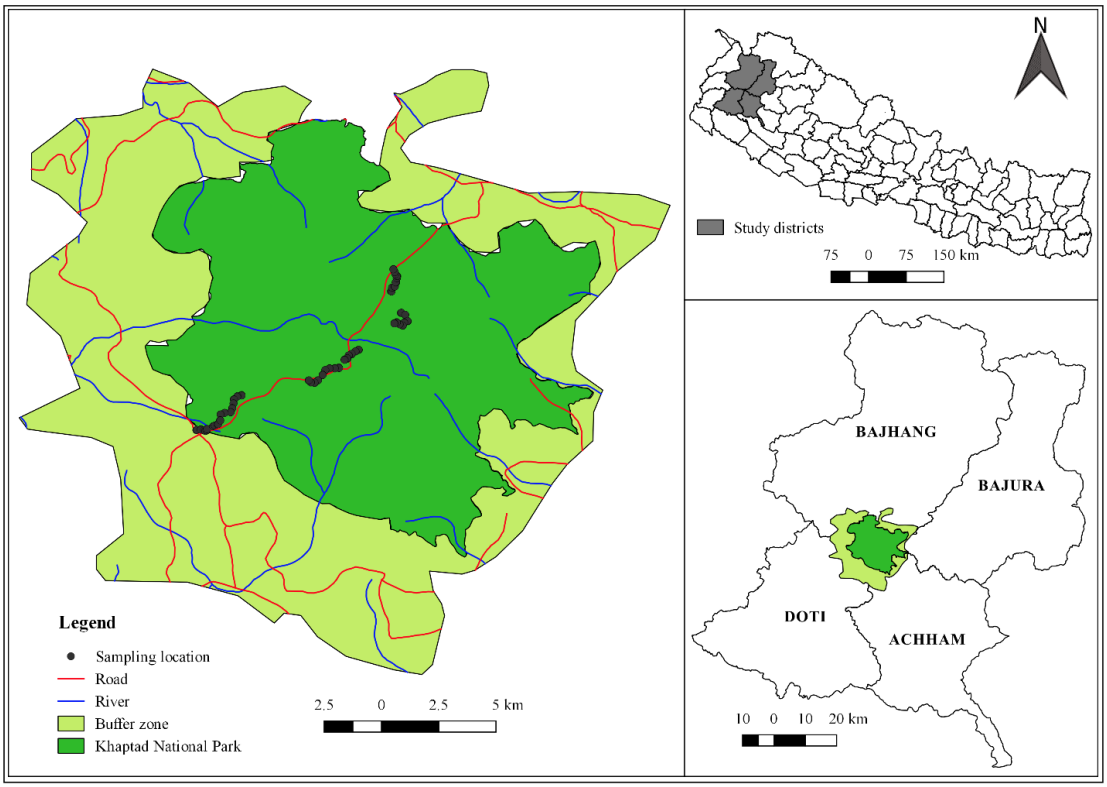

Figure 1. Map of study area: Khaptad National Park showing the location of study sites.

3.1.2 Climate

The study area is characterized by cold condition. The climatic data of this study area is taken from Silgadhi station, Doti which is the nearest site of the present study area (Figure 2). The mean yearly maximum and minimum temperature of the area is 26.36°C and 13.99° C respectively. The area experiences the maximum average monthly temperature during May (32.5 °C) and minimum during January (5.16°C). Similarly, the maximum precipitation of the area is 298.58 mm and area receive the highest precipitation in July. The average annual relative humidity of the area is 69.69 %.

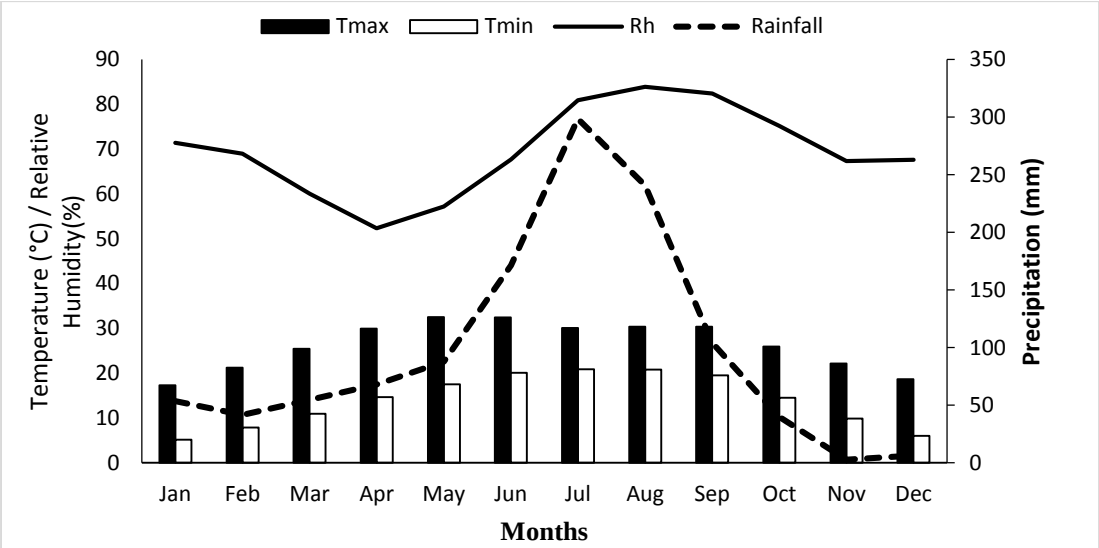

Figure 2: Five years (2015-2019) climatic graph showing Average monthly temperature, Humidity and Rainfall of Silgadhi station. (Source: DHM, 2020).

3.1.3 Vegetation and Fauna

Khaptad National Park reveals a remarkable fecundity and plentitude of dense ambient forests of *Shorea, Pinus* and *Alnus* in subtropical zone; *Quercus* sp., *Aesculus* sp., *Daphniphyllum* sp., *Abies* sp., *Picea* sp., in temperate zone and *Quercus* sp., *Taxus* sp., *Betula* sp., etc. in subalpine zone (DNPWC, 2018). The landscape consists of 22 subalpine meadows, locally called *Patan* or *Kharka*, which is the major attraction of this area. Khaptad is well known for its flora spread over Patans

(Moorlands), forested slopes, rivulets and the Khapar Lake. The park consists of 567 species of flora, 295 vascular plants, 6 pteridophytes, 8 gymnosperms, 238 dicots and 43 monocots (Bhuju *et al*., 2007). In the spring Khaptad has a magical touch when flowers such as primulas, buttercups, wild berries and bistortas are blooming. The lush green and pristine forest are filled with fir, oak, hemlock, laurel, Nepalese alder and rhododendrons.

All these plants and flowers attract a wide variety of butterflies, moths and insects. Bird watchers can enjoy the 287 bird species to which Khaptad is a home. Some examples: Impeyan pheasant, peregrin falcon, white rumped vulture, partridge, bul bul, flycatcher and the cuckoo. The 23 mammals living in Khaptad include leopards, musk deer, barking deer, wild boar, goral, himalayan black bear, yellow-throated marten, wild dogs and rhesus and langur monkeys.

3.1.4 Study Sites

The present study was carried out on the both sides along the walking trial from Jhigrana to Khaptad National park and further to the Bajhang. The study work started from the Jhigrana (about 2200 m asl) and reached up to Bajhang via Bichpani, Khaptad Headquarter and Baba Ashram. The study area falls on the temperate and sub-alpine zone with elevation ranging from 2200 m to about 3200 m. The area mostly comprised of *Rhododendron, Quercus, Abies, Acer* forest. The study area receives heavy snowfall during winter and can be visited during April to October. In the month of June, pilgrims from the nearest districts visits the national park and perform their rituals. The area receives frequent rainfall throughtout the year which makes the land moist.

3.2 Primary Data Collection

3.2.1 Sampling

Random systematic sampling method was done for sample collection. The walking trail was assumed as the transect and the plots were taken 10 m away from the ridges of trail on the both sides. At first, a random place was selected at Jhigrana. First plot of 5 m X 5 m was done in that place.Then, the consecutive plots were taken every 200 m along the assumed transect wherever forests were available. The sampling plots

were taken between altitude 2200 m to 3200 m asl. GPS probe were used to collect the information of latitude, longitude, aspect, altitude and slope know the location of that specific plots. A total of 98 plots were taken in the study area. Locality, lichen habitat, life form, type of substratum, substratum species etc. all were noted (Appendix I).

3.2.2 Lichen Collection

The lichen species were collected with the help of a knife, chisels-hammer and notes on substrata and environmental variables were taken. The type of host tree, habitat of the lichen thallus (on trunk, branch, twigs or leaves, soil and rock substratum) together with altitudes and other ecological notes were recorded. On each sample plot, all the specimens were collected and packed in paper envelopes. Digital photographs of the lichen species were taken in the field and the photo number were noted.

3.2.3 Herbarium

After the collection and identification of the lichen specimens, herbaria were prepared according to the methods given by Nayaka (2014) with all the collected labeled ecological notes. All the prepared herbarium were deposited at the Tribhuwan University Central Herbarium (TUCH), Central Department of Botany, Kirtipur.

3.2.4 Taxonomic Treatments

All the collected lichen specimens were studied upto the genera in the laboratory of the Central Department of Botany, Tribhuwan University, Kirtipur. Then, the identification upto the species level was done in the laboratory of CSIR- National Botanical Research Institute, Lucknow, India. The lichen specimens were identified by studying the morphology, anatomy and chemistry of the specimens. The micro and macrolichens keys of Awasthi (1991, 2007) and an annotated checklist of Indian Lichens of Singh and Sinha (2010) were used for lichen identification and to prepare artificial keys to the family, genera and species.

3.2.4.1 Morphology and Anatomy

The morphological characters of the lichen specimens were studied under stereomicroscope. The anatomical studies of lichen thallus and fruiting bodies were examined under compound microscope with magnification 10-40x. Anatomical structures were studied by preparing slides. The lichen sections were mounted in 5% solution of potassium hydroxide (KOH) and was stained in cotton blue (Nayaka, 2005). The prepared slides were studied under the compound microscope.

3.2.4.2 Colour Reaction

The lichen thallus shows its characteristic colour after the treatment of certain chemicals termed as colour reaction. This is an important part for the identification of lichens. Three chemical reagents used in the identification of the lichens are: (i) Aqueous Potassium hydroxide (KOH); [K], (ii) Bleaching powder or aqueous solution of Calcium hypochlorite $(CaOCl)_2$); [C], (iii)aqueous solution of *p*-phenylenediamine ($C_6H_4(NH_2)_2$); [Pd] and Ethanol. In addition, HNO_3, Lactophenol, Cotton Blue were also used in required case (Nayaka, 2005).

All the above procedures were applied on each of the lichen thallus at the laboratory of the Central Department of Botany, Tribhuwan Unierstity, Kirtipur and CSIR-National Botanical Resaerch Institute, Lucknow, India. Some difficult lichen specimens (Appendix II) were investigated by thin-layer chromatography (TLC) run in solvent A.

3.2.4.3 Thin Layer Chromatography (TLC)

Many lichen substances are undetectable in colour spot test and Thin layer chromotaography have to be performed to detect those lichen substances which appear as spots on the TLC plates. With the help of the TLC manuals, those spots can be identified. The procedure of Culberson and Kristinson (1970) was followed for the TLC.

Firstly, the extraction of the lichen substances was done by using few drops of acetone added to small pieces of the lichen thallus in a microtubes. Silica gel pre-coated thin aluminium plates were used for the TLC. A line was drawn at 2cm from

the base of the plate (loading line) and another at 15 cm (finishing line). On the 2 cm line acetone extract of each of the lichen was loaded at equal distance with the help of fine capillaries. The first and last spot on the TLC plate were used as the control. *Parmelinella wallichiana* was used as control.

After the loading was complete, the TLC plate was then placed in a jar containing solvent A (i.e Toulene-diaxane-acetic acid) for about 40-50 minutes to let the solvent run through the TLC plate. When the solvent reached the level of solvent front (at 13 cm) the plate was taken out of the jar and dried in the air. The substances separated on the TLC plate was usually paler in color so the 10% sulphuric acid solution was sprayed over the TlC plate and kept in the hot air oven pre- heated at 110° for few minutes until the spots were properly developed.

After the spots were developed, the product was then determined by tallying the colour and position of the product with the charts given by Culberson and Kristinson (1970) and Culbersom (1972).

3.3 Data Analysis

Data entry and data checking were done after the completion of the field work and identification of the lichen specimens thus collected. All the identified lichen species were categorized along with their family, life forms, habitat groups and dominant species type. Among the several ordination techniques, Detrended Correspondence Analysis (DCA) was done in order to know the nature of the species response curve. The gradient length of DCA 1st axis was used as the determiner of further analysis. DCA analysis revealed a gradient length of first axis as 8.01 > 2.5 SD units thus the Canonical Correspondence Analysis (CCA) was performed. Environmental variables such as altitude, dominant species found in the samplings plots and Relative Radiation Index were presented by the CCA.

Relative Radiation Index

The relative radiation index (RRI) is the combined value of the measurements of slope, aspect and latitudes which was calculated by using the formula given by Ôke (1987).

[RRI= Cos (180-Ω). sinβ. sinØ + cosβ. cosØ],

Where Ω is aspect, β is the slope, and Ø is the latitude of each plot.

It gives a relative value of how much solar radiation a particular spot receives at noon at equinox. Its value ranges from +1 to –1.

3.3.1 Software Used

R is free and widely used software program. R version 3.6.3 (R Core Team 2020) and vegan 2.5-6 (Oksanen *et al*., 2020) package were used for this data analysis (ordination and their graphical representation). In addition, Microsoft excel (Microsoft Office 2010) was used for other graphical presentation.

CHAPTER-4

RESULTS

4.1 Enumeration of the Lichens

Altogether 47 species of lichens under 29 genera and 14 families encountered within the study area, Khaptad National Park (Table 1). The family Parmeliaceae was the largest family with 17 species followed by family Graphidaceae with 6 species; Stereocaulaceae, Lobariaceae and Physciaceae with 4 species; Peltigeraceae, Cladionaceae and Ramalinaceae with 2 species and the families Teloschistaceae, Chrysothricaceae, Collemataceae, Coniocybaceae, Lecanoraceae and Umbilicariaceae with a singlespecies each as shown in the following table (Figure 3).

Table 1: List of lichen species found in the study are:

SN	Name of the Species	Name of the Family
1.	*Bulbothrix meizospora* (Nyl.) Hale	Parmeliaceae
2.	*Cetrelia braunsiana* (Müll. Arg.) W.L. Culb. & C.F. Culb.	Parmeliaceae
3.	*Cetrelia olivetorum* (Nyl.) W.L. Culb. & C.F. Culb.	Parmeliaceae
4.	*Dolichousnea longissima* (Ach.) Articus	Parmeliaceae
5.	*Flavoparmelia caperata* (L.) Hale	Parmeliaceae
6.	*Hypotrachyna adducta* (Nyl.) Hale	Parmeliaceae
7.	*Hypotrachyna exsecta* (Taylor) Hale	Parmeliaceae
8.	*Hypotrachyna cirrhata* (Fr.) Divakar, A. Crespo, Sipman, Elix & Lumbsch	Parmeliaceae
9.	*Hypotrachyna nepalensis* (Taylor) Divakar, A. Crespo, Sipman, Elix & Lumbsch	Parmeliaceae
10	*Menegazzia terebrata* (Hoffm.) A. Massal.	Parmeliaceae
11	*Nephromopsis pallescens* (Schaer.) Y.S. Park	Parmeliaceae
12	*Nephromopsis stracheyi* (C. Bab.) Müll. Arg.	Parmeliaceae
13	*Parmotrema nilgherrense* (Nyl.) Hale	Parmeliaceae
14	*Parmelinella wallichiana* (Taylor) Elix & Hale	Parmeliaceae
15	*Parmelina carporrhizans* (Taylor) Hale	Parmeliaceae

16	*Remototrachyna rhabdiformis* (Kurok.) Divakar & A. Crespo	Parmeliaceae
17	*Usnea orientalis Motyka*	Parmeliaceae
18	*Chaenotheca* sp.	Coniocybaceae
19	*Chrysothrix chlorina* (Ach.) J.R. Laundon	Chrysotrichaceae
20	*Cladonia coccifera* (L.) Willd	Cladionaceae
21	*Cladonia corniculate* Ahti & Kashiw.	Cladionaceae
22	*Dendriscosticta platyphylla* (Trevis.) Moncada & Lücking	Lobariaceae
23	*Lobaria pindarensis* Räsänen	Lobariaceae
24	*Lobaria retigera* (Bory) Trevis.	Lobariaceae
25	*Sticta henryana* Müll. Arg.	Lobariaceae
26	*Diorygma hieroglyphicum* (Pers.) Straiger & Kalb	Graphidaceae
27	*Graphis* sp.1	Graphidaceae
28	*Graphis* sp.2	Graphidaceae
29	*Graphis* sp.3	Graphidaceae
30	*Graphis chlorotica* A. Massal	Graphidaceae
31	*Graphis scripta* (L.) Ach.	Graphidaceae
32	*Heterodermia diademata* (Taylor) D.D. Awasthi	Physciaceae
33	*Heterodermia incana* (Stirt.) D.D. Awasthi	Physciaceae
34	*Heterodermia speciosa* (Wulfen) Trevis.	Physciaceae
35	*Polyblastidium togashii* (Kurok.) Kalb	Physciaceae
36	*Ioplaca pindarensis* (Räsänen) Poelt & Hinter.	Teloschistaceae
37	*Lecanora* sp.	Lecanoraceae
38	*Leptogium askotense* D.D. Awasthi	Collemataceae
39	*Lepraria caesioalba* (B. de Lesd.) J.R. Laundon	Stereocaulaceae
40	*Lepraria eburnean* J.R. Laundon	Stereocaulaceae
41	*Lepraria yunnaniana* (Hue) Zahlbr.	Stereocaulaceae
42	*Stereocaulon* sp.	Stereocaulaceae
43	*Peltigera* sp.	Peltigeraceae
44	*Solorina simensis* Hochst. ex Flot	Peltigeraceae

45	*Ramalina conduplicans* Vain.	Ramalinaceae
46	*Ramalina sinensis* Jatta	Ramalinaceae
47	*Umbilicaria nepalensis* Poelt	Umbilicariaceae

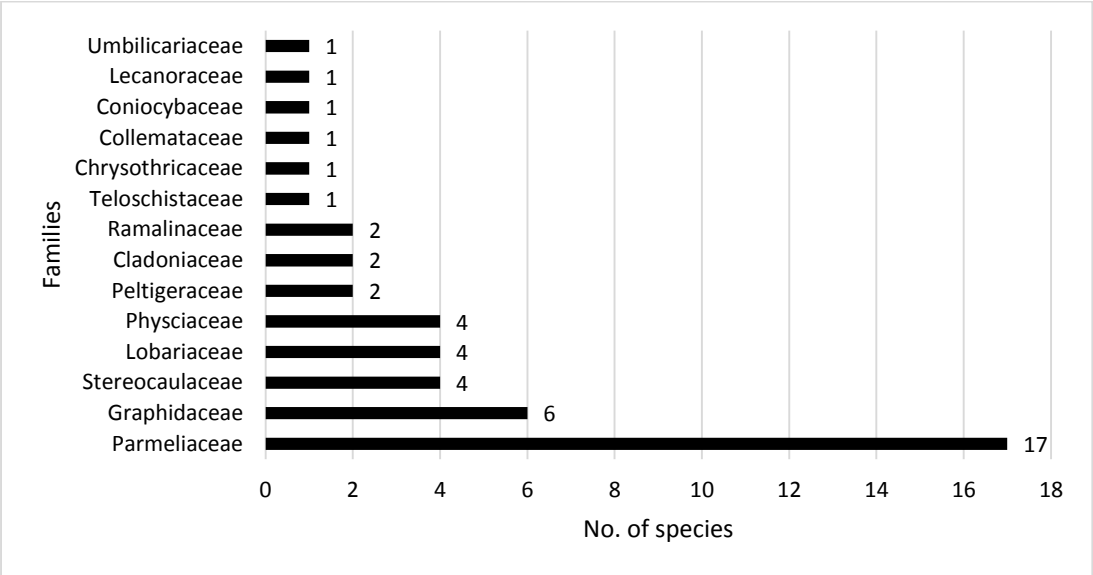

Figure 3. Families with their respective number of lichen species.

Four life forms (growth forms) – crustose, foliose, fruticose and leprose were distinguished among the species found. The foliose growth forms was found to be the dominant life form with 27 (58%) species followed by crustose with 10 species (21 %), fruticose with 7 species (15%) and leprose with 3 species (6%, Figure 4).

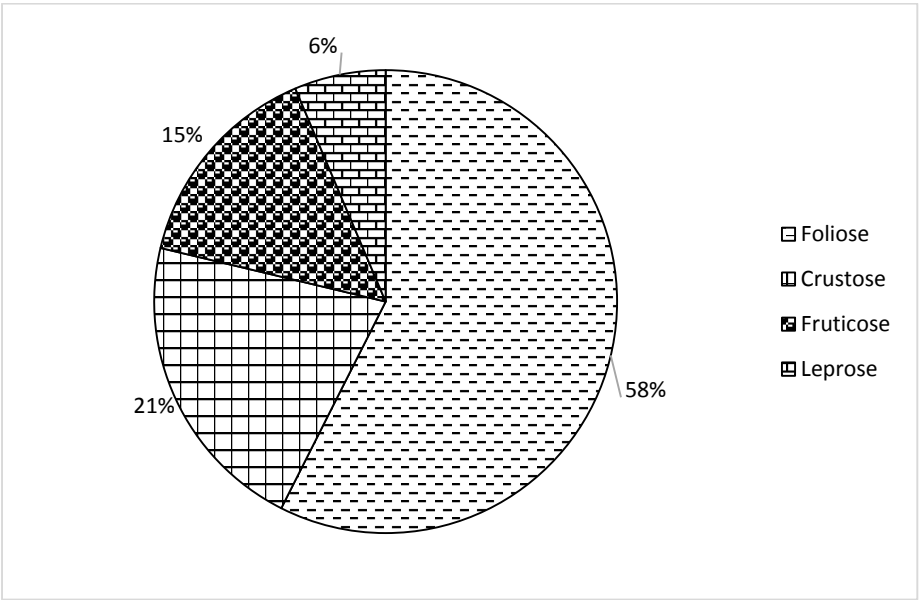

Figure 4. Different life forms with their respective percentages of lichen species.

Lichen species richness at 2250 m and 3200 m was found higher than that at mid elevations (Figure 5). Lichen diversity showed inverse unimodal pattern along the elevation gradient. A certain drop of lichen species richness was seen between the altitude 2500 m to 2600 m. Even after a certain drop, species richness seemed to be increasing with the increase in altitude upto 3200 m.

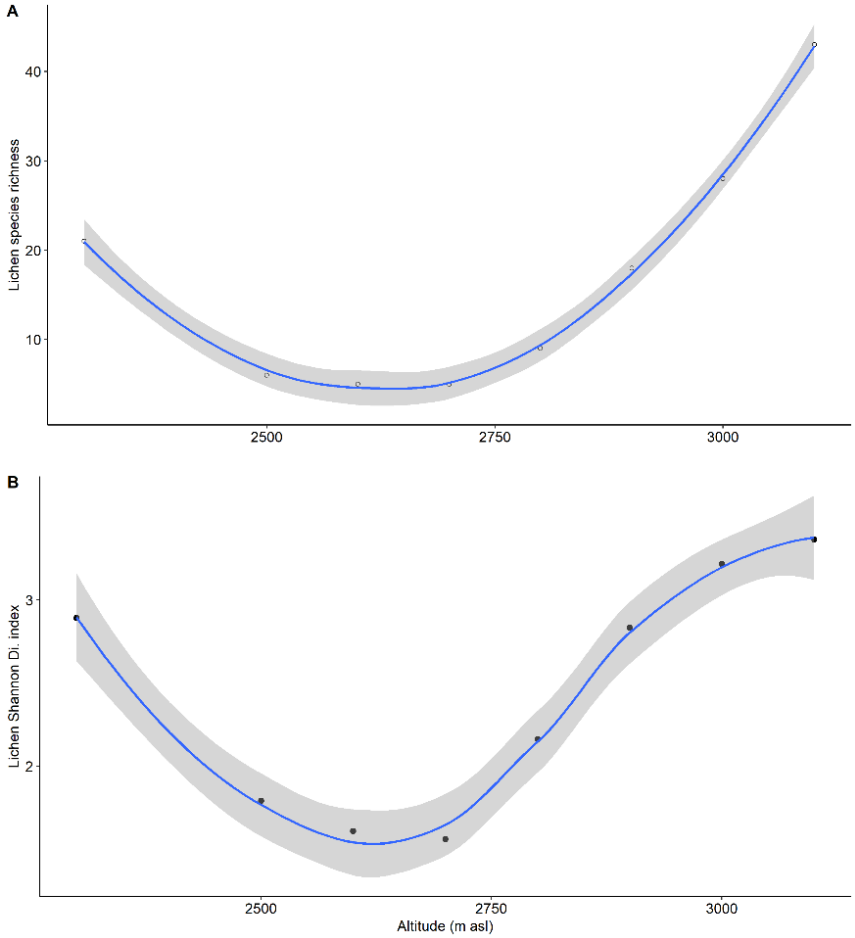

Figure 5. The relationship between lichen species richness vs altitude and lichen Shanon diversity index vs altitude.

4.2 Artificial key to the Families of the Studied Lichens

1a. Thallus Crustose……. 2

1b. Thallus Otherwise…….. 6

2a. Thallus Leprose ……..... 3

2b. Thallus not Leprose……...…… 4

3a. Thallus granular leprose with bright greenish-yellow apothecia..... ..... Chrysothricaceae

3b. Thallus leprose with 'pinhead' like apothecia…….....Coniocybaceae

4a. Apothecia Lirellate…… Graphidaceae

4b. Apothecia lecanorine……. 5

5a. Thallus always crustose……. Lecanoraceae

5b. Thallus may be crustose, foliose or fruticose……..……... Teloschistaceae

6a. Thallus distinctly foliose…… 7

6b. Thallus fruticose……... 12

7a. Photobiont blue-green algae or green algae...……... 8

7b. Photobiont green algae……. 10

8a. Thallus gelatinous, blackish, homoiomerous…….…….. Collemataceae

8b. Thallus surface non-gelatinous, color variable, heteromerous…….9

9a. Pseudocyphellae or cyphellae present on lower surface……. Lobariaceae

9b. Pseusocyphellae or cyphellae lacking on lower surface…… Peltigeraceae

10a. Thallus centrally umbilicate…… Umbilicariaceae

10b. Thallus non-umbilicate…….. 11

11a. Thallus usually small and narrow lobed, adnate to substratum……. Physciaceae

11b. Thallus broad lobed, loosely attached to substratum……... Parmeliaceae

12a. Thallus dimorphic with horizontal squamulose primary thallus and erect podetia or secondary thallus……. 13

12b. Thallus strap-shaped, longitudinal axis without central cord……. Ramalinaceae

13a. Podetia present, hollow with or without squamules……... Cladoniaceae

13b. Pseudopodetia present, solid with squamules….…… Stereocaulaceae

Taxonomic Description of each Family, Genera and Species:

1. **CHRYSOTRICHACEAE** Zahlbr.

Thallus crustose, leprose to byssoid (cotton like) bright yellow colored; ascomata immersed and eventually becoming embedded in thallus; asci clavate.

Chrysothrix Mont., *Annls Sci. Nat., Bot.*, sér. 3 **18**:312 (1852)

Thallus generally leprose, thick to thin, non-cirticated, bright yellow to vivid yellowish-green, thallus coloured throughout, margins absent, without lobes.

Chrysothrix chlorina (Ach.) J.R. Laundon, *Lichenologist* **13**(2): 106 (1981)

Basionym: *Lichen chlorinus* Ach., *Lich. Suec. Prodr*. (Linköping): 6 (1799) [1798]

Thallus crustaceous-leprose, diffuse, forming scattered granules in places, but strongly areolate crust, vivid primary yellow, surface composed entirely of a mass of granules, margin absent, apothecia unknown [**Photo Plate 1(D)**].

Chemistry: Thallus C-, K-, Pd-.

Chemical constituent: Vulpinic acid present (Awasthi, 1991).

Distribution: Scattered throughout the boreal forest regions of upland Europe, Northern Italy, Scandinavia, Himalayas, North America (Laundon, 1981).

Habitat: Found on the bark of *Rhododendron* sp.

Specimen examined: KNP-84 (TUCH-LIC-0001003), KNP-57 (TUCH-LIC-0001051)

2. **CONIOCYBACEAE** Rchb.

Thallus crustose, corticolous or terricolous and poorly differentiated, mazaedia terminal on stipes.

Chaenotheca (Th. Fr.) Th. Fr., *Lich. Arct.* (Uppsala): 250 (1860)

Thallus crustose, granular-verrucose or squamulose, apothecia stalked, stalk short brown, capitulum spherical. **[PHOTO PLATE 9(A)]**

Distribution: Nepal (Awasthi, 1991).

Habitat: Found on the smoth bark of *Lionia*, *Daphne*.

Specimen examined: KNP-75 (TUCH-LIC-0001052)

3. **GRAPHIDACEAE** Dumort.

Thallus crustose, usually corticolous, rarely saxicolous or foliocolous, ascocarps black lirellate, imerged or emergent, photobiont green alga.

Key to genera

1.a. Spores transversely septate…….. *Graphis*

1.b. Spores muriform…… *Diorygyma*

Graphis Adans., *Fam. Pl.* **2**: 11 (1763)

Thallus corticate, if ecorticate then lack secondary substances, mostly whiteish in colour rarely faint greenish, lirellae can be immersed, erumpent, prominent or sessile, labia striate or entire, exciple partially or completely carbonized, ascospores septate or muriform.

Key to species

1.a. Ascospores transversely septate…….....…… 2

1.b. Ascospores muriform…….....…… 4

2.a. Labia entire……...….....…… 3

2.b. Labia striate…… *G. chlorotica*

3.a. Exciple apically carbonized…… *Graphis 1*

3.b. Exciple laterally carbonized…… *G. scripta*

4.a. Stictic acid present……... *Graphis.2*

4.b. No substances…….. *Graphis 3*

Graphis chlorotica A. Massal., in Krempelhuber, *Verh. zool.-bot. Ges. Wien* **21**: 865 (1871)

Thallus shiny gray, thick, lirellae erumpent with lateral thalline margin, labia striate, exciple carbonized apically, ascospores transversely septate. **[PHOTO PLATE 3(A)]**

Chemical constituent: No lichen substances found.

Distribution: India, Nepal and temperate regions of world (Karmacharya *et al*., 2019)

Habitat: found on rough bark of *Quercus* sp.

Specimen examined: KNP-21 (TUCH-LIC-0001013)

Graphis scripta (L.) Ach., *K. Vetensk-Acad. Nya Handl*. **30**: 145 (1809)

Basionym: *Lichen scriptus* L., *Sp. pl*. **2**: 1140 (1753)

Thallus crustose, prominent, long, narrow, curved, fork like lirellae, hymenium clear, labia entire, exciple laterally carbonized, ascospores transversely septate. [**PHOTO PLATE 3(B)]**

Chemical constituent: No lichen substances found

Distribution: India, Nepal and temperate regions of world (Karmacharya *et al*., 2019).

Habitat: found on rough bark of *Quercus* sp., *Rhododenddron* sp.

Specimen examined: KNP-09 (TUCH-LIC-0001014)

***Graphis* sp. 1**

Thallus crustose, lirellae faintly yellowish colour, labia entire, exciple apically carbonized, ascospores transversely septate. **[PHOTO PLATE 2(D)]**

Chemical constituent: Stictic acid present

Habitat: found on rough surface of *Quercus* sp.

Specimen examined: KNP-93 (TUCH-LIC-0001010), KNP-16 (TUCH-LIC-0001054)

***Graphis* sp. 2**

Thallus crustose corticated, lirellae erumpent with lateral thalline margin, labia striate, ascospores medium (45-70 × 16-22 μm) muriform. **[PHOTO PLATE 2(E)]**

Chemical constituent: Stictis acid present.

Habitat: found on rough surface of *Quercus* sp.

Specimen examined: KNP-01 (TUCH-LIC-0001011)

***Graphis* sp. 3**

Thallus crustose, lirellae lack pigments, labia striate, ascospores large, muriform.

Chemical constituent: No substances found. **[PHOTO PLATE 2(F)]**

Habitat: Smooth bark of *Rhododendron* sp.

Specimen examined: KNP-07 (TUCH-LIC-0001012)

Diorygyma Eschw.

Diorygma hieroglyphicun (Pers.) Straiger & Kalb, in Kalb et al., *Symb. Bot. upsal*. **34**(1):151 (2004)

Basionym: *Opegrapha hieroglyphica* Pers., *Ann. Wetter. Gesellsch. Ges. Naturk*. **2**:16 (1811) [1810]

Thallus corticolous, crustose, greenish-white, uneven, ascomata lirellate, lirellae emergent, white, curved, ascospores hyaline, muriform. **[PHOTO PLATE 2(B)]**

Chemistry: Thallus K+ yellow, Pd+ red.

Chemical constituent: Stictic acid present.

Distribution: Nepal, India, Vietnam, Australia, Cameroon, New Caledonia, Tanzania, Indonesia, Singapore, Papua New Guinea, Philippines (Karmacharya *et al*., 2019).

Habitat: Found on smooth surface of tree *Lionia* sp. and *Rhododendron.*

Specimen examined: KNP-10 (TUCH-LIC-0001008), KNP-14 (TUCH-LIC-0001057)

4. **LECANORACEAE** Körb.

Thallus crustose, saxicolous or corticolous; rhizines absent; fertile thallus; photobiont green alga; apothecia lecanorine.

Lecanora Ach., in Luyken, *Tent. Hist. Lich*.: 90 (1809)

Thallus crustose, adnate, granular, placodiod, areolate, surface white, medulla white, apothecia sessile, apothecia lecanorine, 8-spored asci with colourless, non-septate ascospores. **[PHOTO PLATE 9(C)]**

Chemical constituent: Atranorin acid present.

Distribution: Cosmopolitan in distribution recorded from all continents, upper temperate to alpine regions of the Himalayas (Nayaka, 2004).

Habitat: Found on the rocks, dead logs of *Quercus* sp.

Specimen examined: KNP-81 (TUCH-LIC-0001022)

5. **TELOSCHISTACEAE** Zahlbr.

Thallus crustose, foliose to fruticose; thallus or ascomata usually characteristicaqlly orange colored by presence of the secondary product parietin (an anthraquinone); ascospores 1-septate.

Ioplaca Poelt, *Khumbu Himal* **6**:443 (1977)

Thallus crustose, saxicolous, areolate to subsquamulose, upper side orange, isidia and soredia absent, dark under surface, apothecia immersed, orange to blakish brown disc.

Ioplaca pindarensis (Räsänen) Poelt & Hinter., *Biblthca Lichenol*. **50:** 235 (1993)

Basionym: *Callopisma pindarense* Räsänen, *Ann. Soc. Zool.-Bot. fenn. Vanamo* **6**(no. 2): 83 (1952)

Thallus crustose, saxicolous, often coalescing with other thalli to cover large areas, subsquamulose, upper surface yellow to yellowish-orange to orange, under surface black, apothecia numerous. **[PHOTO PLATE 4(F)]**

Chemistry: Thallus K+ purple, C-, Pd- and I-.

Chemical constituent: Parietin and lecanoric acid present.

Distribution: Nepal, India and Tibet. (Awasthi, 1991)

Habitat: Found on rocks.

Specimen examined: KNP-85 (TUCH-LIC-0001021)

6. **COLLEMATACEAE** Zenker

Thallus gelatinous, blackish, homoiomerus, foliose, isidiate. Apothecia sessile.

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

Thallus commonly foliose, squamulose or fruticose, lobate, gelatinous, upper side smooth or wrinkled, with or without isidia, soredia absent, lower side with or without tomentum.

Leptogium askotense D.D. Awasthi, in Awasthi & Aklitar, *Norw. Jl Bot*. **24**(2): 63 (1977)

Thallus corticolous, adnate, orbicular lobes, upper side dark brown/ grey brown, wrinkled, isidia lacking, lower side pale with pale brown tomentose, apothecia subpedicellate, disc brown. [**PHOTO PLATE 4(D)]**

Distribution: Indi, Nepal and Sri Lanka (Awasthi, 2007).

Habitat: Rough bark of *Quercus* sp.

Specimen examined: KNP-89 (TUCH0LIC-0001023)

7. **LOBARIACEAE** Chevall.

Thallus foliose, heteromerous, corticated on both sides; photobiont blue green alga.

Key to genera

1.a. Thallus with cyphellae on the lower side……..……. *Sticta*

1.b. Thallus lacking cyphellae…….……. *Lobaria*

***Sticta* (Schreb.) Ach.**

Thallus foliose, lobate, horizontally spreading, lobes dichotomously or lobes irregularly branched, thick or thin, upper side smooth, wrinkled, ridged, with or without isidia or soredia, pseudocyphellae absent, lower side pale or dark, tomentose, sometimes rhizinate, cyphellae present, thallus heteromerous, corticated on both side, medulla white.

Key to species

1.a. Medulla KC+ red…….…… *S. nylanderiana*

1.b. Medulla KC-…….……... *S. henryana*

Sticta henryana Müll. Arg., *Flora*, Regensburg **74**(3): 374 (1891)

Thallus corticolous, horizontally spreading, sinuate lobate, upper side yellowish-grey, smooth, lacking isidia or soredia, lower side brownish, cyphellae present. **[PHOTO PLATE 8(D)]**

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

Distribution: China, temperate regions of India, Nepal (Awasthi, 2007).

Habitat: Found on rough bark of *Abies.*

Specimen examined: KNP-80 (TUCH-LIC-0001043), KNP-OP02 (TUCH-LIC-0001074)

Sticta nylanderiana Zahlbr., *Cat. Lich. Univers*. **3**: 365 (1925)

Current name: *Dendriscostica platyphylla* (Trevis.) Moncada & Lücking, *Lichenologist* **45**(2): 222 (2013)

Thallus corticolous, horizontal, loosely adnate, upper side pale grey to darker, lacking isidia or soredia, lower side pale brown to brown, cyphellae present. **[PHOTO PLATE 2(A)]**

Chemistry: Cortex K+ yellow, medulla K-, KC+ red.

Distribution: Temperate regions of India and Nepal, China (Awasthi, 2007).

Habitat: Rough bark of *Abies*.

Specimen examined: KNP-48 (TUCH-LIC-0001006)

***Lobaria* (Schreb.) Hoffm.**

Thallus foliose, dorsiventral, usually dichotomously or irregularly large lobed, upper side grey- brown to dark brown or blackish, smooth or rugose with reticulate ridges, isidia and soredia present or absent, lower side smooth to netted, tomentose and rhizinate, lack cyphellaeand pseoducyphellae, thallus heteromerous, corticated on both sides, medulla usually white.

Key to species

1.a. Photobiont green algae …….. *L. pindarensis*

1.b. Photobiont cynobacterium……... *L. retigera*

Lobaria pindarensis Räsänen, *Arch. Soc. Zool. Bot. Fenn. Vanamo*. **VI** (2):84 (1952)

Thallus corticolous, loosely adnate, lobes flat, upper side pale brown to brown, reticulately ridged, isidia on ridges, lower side brown, tomentose sparsely rhizinate, photobiont green alga. **[PHOTO PLATE 5(A)]**

Chemistry: Upper cortex K-, medulla K+ yellow, C-, KC+ red.

Chemical constituent: Gyrophoric, norstictic, stictic acids in medulla (Awasthi, 2007).

Distribution: Upper temperate regions of India and Nepal, Japan, Java, Malaya, Philippines, Pacific Islands, Australia (Awasthi, 2007).

Habitat: Found on the bark of *Lionia* sp., *Quercus* sp.

Specimen examined: KNP-86 (TUCH-LIC-0001024)

Lobaria retigera (Bory) Trevis, *Lichenoth. Veneta*: 75 (1869)

Basionym: *Lichen retiger* Bory, *Voyag. Princip. Iles Mers. D'Afr.* **1**:391 (1804)

Thallus corticolous, loosely adnate, upper side pale brown to darker at margins, reticulately ridged, lower side dark brown to black, tomentose sparsely rhizinate, photobiont cyanobacterium. **[PHOTO PLATE 5(B)]**

Chemistry: Upper cortex K-, medulla K-, C-, KC-, P-.

Chemical constituent: Thelephoric acid reported in tomentum (Awasthi, 2007).

Distribution: Lower temperate to upper temperate regions of India, Nepal and Sri Lanka, Japan, West Pacific Islands, Australia, New Zealand, South Africa, North America and Alaska (Awasthi, 2007).

Habitat: Found on the Rough surface of *Lionia* sp.

Specimen examined: KNP-87 (TUCH-LIC-0001025), KNP-47 (TUCH-LIC-0001062).

8. **PELTIGERACEAE** Dumort.

Thallus foliose, corticated only on upper side, heteromerous; photobiont blue green alga; lower surface have vein or rhizines, tomentose; apothecia marginal on upper side.

Key to genera

1.a. Thallus large lobed, lower side veined, ascospores colourless, usually 3 septate……..…… *Peltigera*

1.b. Thallus medium sized, corticted below apothecia, ascospores brown and 2 celled…….....…….. *Solorina*

Peltigera Willd., *Fl. berol. Prodr. :* 347 (1787)

Thallus foliose, loosely adnate, usually large, lobes thin or thick, upper side brownish or reddish brown, smooth, scrobiculate, with or without tomentum, soredia, isidia present or absent, lower side veined and rhizinate, brown to black in colour, rhizines simple, medulla white or brownish. **[PHOTO PLATE 7(D)]**

Distribution: Asia, Europe, N. America, S. America, Africa, Australia and New Zealand (Awasthi, 2007).

Habitat: Found on the dead log of *Rhododendron*.

Specimen examined: KNP-30 (TUCH-LIC-0001038)

Solorina Ach., *K. Vetensk-Acad. Nya Handl*. **29**: 228 (1808)

Thallus terricolous, foliose, lobate, lobes rounded, upper side greenish grey to brown, lower side tomentose, rhizinate, thallus heteromerous, corticated on upper side.

Solorina simensis Hochst. Ex flot., *Linnaea* **17**: 17 (1843)

Thallus terricolous, lower side pale yellow veined, photobiont cyanobacterium. **[PHOTO PLATE 8(C)]**

Distribution: reported from the temperate regions of India, Nepal (Awasthi, 2007).

Habitat: Found on rocks.

Specimen examined: KNP-65 (TUCH-LIC-0001045)

9. **UMBILICARIACEAE** Chevall.

Thallus mono- or poly-phyllous, often lobed, black or dark leathery orbicular attached to substratum by central holdfast (umbilicus); rhizines scattered or grouped; apothecia circular, sessile or shortly stalked.

Umbilicaria Hoffm., *Descr. Adumb. Plant. Lich*. **1**(1): 8 (1789) [1790]

Thallus mono to poly-phyllous; apothecia with conspicuous gyri when mature.

Umbilicaria nepalensis Poelt, *Khumbu Himal* **6**(3): 426 (1977)

Thallus saxicolous, umbilicate, margins are curled backwards, no cilia, upper side grey, smooth, wrinkled at umbo, lower side brownish black, rhizinomorph present, apothecia gyrodiscus. **[PHOTO PLATE 8(F)]**

Chemical constituent: Gyrophoric acid

Distribution: Temperate to alpine regions of India and Nepal. Endemic to Himalayas.

Habitat: Found on the rocks (Awasthi, 2007).

Specimen examined: KNP-91 (TUCH-LIC-0001046), KNP-OP04 (TUCH-LIC-0001075)

10. **PHYSCIACEAE** Zahlbr.

Thallus foliose, usually small and narrow lobed, grey or rarely brown, yellow or yellowish green in colour, ecorticated to corticated, heteromerous, corticolous or saxocolous or terricolous or muscicolous; photobiont green alga; apothecia sessile, lecanorine or biatorine.

Key to genus

1.a. Lower cortex or pseudocortex present, often with rhizines…… *Heterodermia*

1.b. Lower cortex absent, rarely or never with rhizines…… *Polyblastidium*

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

Thallus foliose, adnate, suberect, rosulate to pendulous, dichotomously or irregular branched, heteromerous, corticated on both sides or only on upper side, lower side corticated and rhizinate or ecoerticated and then rhizines arising from corticated margins.

Key to species

1.a. Thallus corticated on both sides …….....…… 2

1.b. Thallus corticated on upper side…….....…….. *H. incana*

2.a. Thallus sorediate …….....……. *H. speciosa*

2.b. Thallus lacking soredia …….....…... *H. diademata*

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

Basionym: *Parmelia diademata* Taylor, *London J. Bot*. **6**: 165 (1847)

Thallus corticolous, corticated on both sides, upper side greyish white, lacking isidia or soredia, lower side pale brown, rhizines sparse, apothecia numerous. **[PHOTO PLATE 3(C)]**

Chemistry: Medulla K+ yellow, C-.

Distribution: Widely distributed in China, Japan, Taiwan, Africa, Central and South America, subtropical to temperate regions of India, Nepal and Sri Lanka (Awasthi, 2007).

Habitat: Found on smooth surface of dead log.

Specimen examined: KNP-29 (TUCH-LIC-0001018), KNP-58 (TUCH-LIC-0001061)

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

Basionym: *Physcia incana* Stirt., *Proc. Roy. Phil. Soc. Glasgow* **11**:322 (1879) [1878]

Thallus corticolous, branched, lobes spathulate, corticated on upper side, upper side white to whitish grey lacking isidia and soredia, lower side white veined with marginal rhizines. **[PHOTO PLATE 3(D)]**

Chemistry: Medulla K+ yellow, C-.

Distribution: Subtropical to lower temperate regions of India, Nepal and Sri Lanka, China, Taiwan, Thailand (Awasthi, 2007).

Habitat: Found on rough bark of *Quercus*.

Specimen examined: KNP-24 (TUCH-LIC-0001019)

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

Basionym: *Lichen speciosus* Wulfen, in Jacquin, *Collnea bot*. **3**: 119 (1791) [1789]

Thallus corticolous or saxicolous, lobes plane, corticated on both sides, upper side greyish white, lower side brownish, rhizinate. **[PHOTO PLATE 4(A)]**

Chemistry: Medulla K+ yellow, C-, Pd+ yellow.

Distribution: India, Nepal and tropical regions of the world (Awasthi, 2007).

Habitat: Found on the bark of *Betula* sp.

Specimen examined: KNP-19 (TUCH-LIC-0001020)

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

Similar to *Heterodermia* s. str., but differ in having arachnoid lower surface.

Polyblastidium togashii (Kurok.) Kalb, in Mongkolsuk, Meesim, Poengsungnoen, Buaruang, Schumm & Kalb, *Phytotaxa* **235**(1): 47 (2015)

Synonym*: Heterodermia togashii* (Kurok.) D.D. Awasthi, *Geophytology* **3**(1): 114 (1973)

Basionym: *Anaptychia togashii* Kurok.*Beih. Nova Hedwigia* **6**: 68 (1962)

Thallus adnate, corticated on upper side lacking soredia, lower side white, apothecia with lobulated margin. **[PHOTO PLATE 7(E)]**

Chemistry: Medulla K+ yellow.

Distribution: Upper temperate to Alpine regions of India and Nepal, China (Awasthi, 2007).

Habitat: Rough bark of *Lionia* sp.

Specimen examined: KNP-34 (TUCH-LIC-0001032)

11. **PARMELIACEAE** F. Berchtold & J. Presl

Thallus foliose, corticolous, muscicolous, saxocolous, rarely terricolous, corticated on both side; rhizines present rarely absent, cyphellae or pseudocyphellae or tomentum absent, medulla not hollow; apothecia laminal or marginal, asci with strong amyloid thallus, 8 spored.

Key to genera

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

1.b. Thallus foliose……..... 2

2.a. Medulla hollow ……..... *Menegazzia*

2.b. Medulla solid ……... 3

3.a. Thallus with pseudocyphellae ……..... 4

3.b. Thallus lacking pseudocyphellae ……..... 5

4.a. Pseudocyphellae on upper and lower sides ……..... *Cetrelia*

4.b. Pseudocyphellae on lower side ……... .*Nephromopsis*

5.a. Thallus lobes with marginal bulbate cilia…….. *Bulbothrix*

5.b. Thallus lobes lack marginal bulbate cilia ……... 6

6.a. Thallus yellow-green, upper cortex K- …… *Flavoparmelia*

6.b. Thallus grey to darker, upper cortex K+…….....7

7.a. Upper side densely maculate ……... *Parmotrema*

7.b. Upper side emaculate ……..... 8

8.a. Medulla white, cilia in axils ……..... *Parmelinella*

8.b. Medulla yellow-orange, cilia rarely present……..... 9

9.a. Rhizines dichotomously branched……..... 10

9.b. Rhizines simple or squarrosely branched……..... *Parmelina*

10.a. Rhizines long, lobes narrow, sublinear to linear,elongate, subdichotomously or dichotomously branched……... *Hypotrachyna*

10.b. Rhizines short, lobes broad, subirregular, rotund, irregularly branched……... *Remototrachyna*

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

Thallus fruticose, erect, shrubby, procumbent to pendulous, attached by a discoid holdfast, greenish grey or yellowish grey in colour, heteromerous, corticated, medulla white.

Key to species

1.a. Thallus pendulous, main branches filamentose with lateral branchlets arising at right angles to axis…… *U. longissima*

1.b. Thallus erect bushy, branching sympodial or subsympodial with secondary branches……... *U. orientalis*

Usnea longissima A*ch., Lich. Univ.: 626 (1810)*

Current name: ***Dolichousnea longissima*** (Ach.) Articus, Taxon 53: 932 (2004)

Thallus corticolous, pendulous, filamentose, pale yellow to greyish green, lateral branchlets dense, perpendicular, surface of filamentoose branches usually decorticated, central axis solid, colourless, apothecia rare, margin ciliate. **[PHOTO PLATE 9(E)]**

Chemical constituent: Barbatic acid, fumarprotocetraric acid present.

Distribution: Nepal, India, China, Japan, Europe, North America (Awasthi, 2007).

Habitat: Found on the *Abies*.

Specimen examined: KNP-62 (TUCH-LIC-0001047)

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

Thallus corticolous, erect, greenish grey to yellowish grey, branching sympodial, branches somewhat irregularly swollen, densely branched, dispersed, soredia, isidia, psydocyphallae absent, axis solid, apothecia upto 10 mm in diameter. **[PHOTO PLATE 9(D)]**

Chemistry: Medulla K+ orange, KC+ yellow, Pd+ yellow.

Chemical constituent: Usnic acid and salacinic acid present.

Distribution: Nepal, India, China, Bhutan, Japan (Awasthi, 2007).

Habitat: Found on the twigs of *Abies*, *Drepanostachyum.*

Specimen examined: KNP-56 (TUCH-LIC-0001048)

Menegazzia A. Massal., *Neagenea Lich*.: **3** (1854)

Thallus foliose, suborbicular or rosettiform, dorsiventral, radiately lobate, upper side grey to grey-brown, perforated, lower side brown-black, lacking rhizines, thallus heteromerous, corticated on both sides, medulla white.

Menegazzia terebrata (Hoffm.) A. Massal., *Neagenea Lich*: 1 (1854)

Basionym: *Lobaria terebrata* Hoffm., *Deutschl. Fl.*, Zweiter Theil (Erlangen): 151 (1796) [1795]

Thallus corticolous, suborbicular, adnate, lobes branched, upper side grey to grey brown with round perforations, lower side brown-black. **[PHOTO PLATE 6(B)]**

Chemistry: Medulla K+ yellow, P+ orange.

Chemical constituent: Stictic acid complex present.

Distribution: Single species from northern hemisphere reported from temperate region of Nepal and India, others on the southern hemisphere (Awasthi, 2007).

Habitat: Found on the rough surface of *Quercus.*

Specimen examined: KNP-55 (TUCH-LIC-0001029)

Cetrelia W.L. Culb. & C.F. Culb., *Contr. U.S. natnl. Herb.* **34**:490 (1968)

Thallus foliose, heteromerous, pseudocyphellae on one or both sides, with or without isidia and soredia, lower side rhizinate, corticated on both sides.

Key to species

1.a. Thallus lacking soredia, isidiate……..… *C. braunsiana*

1.b. Thallus marginally sorediate, isidia absent…….. *C. olivetorum*

Cetrelia braunsiana (Müll. Arg.) W.L. Culb. & C.F. Culb., *Contr. U.S. natnl. Herb*. **34**: 493 (1968)

Basionym: *Parmelia braunsiana* Müll. Arg., *Flora*, Regensburg **64**: 506 (1881)

Thallus corticolous or saxicolous, upper side grey to greenish brown, isidiate, lower side blackwith black rhizines. **[PHOTO PLATE 1(C)]**

Chemistry: Medulla K-, C-, KC+ pink, Pd-.

Distribution: Temperate regions of Nepal and India, China, Japan Taiwan and Philippines (Awasthi, 2007).

Habitat: Found on the rough surface of *Quercus.*

Specimen examined: KNP-71 (TUCH-LIC-0001001)

Cetrelia olivetorum (Nyl.) W.L. Culb. & C.F. Culb., *Contr. U.S. natnl. Herb*. **34**: 515 (1968)

Basionym: *Parmelia olivetorum* Nyl, *Not. Sällsk. Fauna et Fl. Fenn. Förh*., Ny Ser. **8**: 180 (1866)

Thallus corticolous, upperside greyish white to tan brown, lobed margins with farinose soredia, lower side black with few rhizines. **[PHOTO PLATE 1(B)]**

Chemistry: Medulla C+ pink.

Distribution: Temperate regions of Nepal and India, China, Japan, Europe and North America (Awasthi, 2007).

Habitat: Found on the rough bark of *Abies*.

Specimen examined: KNP-45 (TUCH-LIC-0001002)

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

Thallus foliose, heteromerous, large, irregularly lobate,upper side greenish yellow, smooth, rugose to reticulate, lacking isidia, soredia and pseudocyphellae, lower side dark brown or black, pseudocyphellate, medulla white or pigmented, apothecia of 2 types: (i) laminal, submarginal to marginal, (ii) marginal.

Key to species

1.a. Thallus loosely adnate, apothecia laminal to submarginal…….. *N. pallescens*

1.b. Thallus loosely attached, apothecia marginal on lower sides of lobes..... .....*N. stracheyi*

Nephromopsis pallescens (Schaer.) Y.S. Park, *Bryologist* **93**(2): 122 (1990)

Basionym: *Cetraria pallescens* Schaer., in Moritzi, *Syst. Verz.*: 129 (1846) [1845-46]

Thallus corticolous, loosely adnate, lobes convolute, upper side greenish yellow, lower side yellowish grey, rhizines short, medulla white, apothecia laminal to submarginal. **[PHOTO PLATE 6(C)]**

Chemistry: Medulla KC+ red.

Distribution: Temperate parts of Nepal and India, commonly occurring in the temperate parts of the Himalayan region (Awasthi, 2007).

Habitat: Found on the rough surface of *Quercus.*

Specimen examined: KNP-61 (TUCH-LIC-0001031)

Nephromopsis stracheyi (C. Bab.) Müll. Arg., *Flora*, Regensburg **74**(3): 374 (1891)

Basionym: *Cetraria stracheyi* C. Bab., *J. Bot. (Hooker)* **4**: 245 (1852)

Thallus corticolous, loosely adnate, coriaceous, upper side greenish yellow, slightly scrobiculate-lacunose, lower side yellowish brown, reticulately nervosa-rugose, pseudocyphellae rarely raised, rhizines short, medulla white, apothecia marginal on lower side of lobes. **[PHOTO PLATE 6(D)]**

Chemistry: upper cortex K-, medulla K-, C+ red, KC+ red.

Distribution: Temperate regions of Nepal and India, China and Taiwan (Awasthi, 2007).

Habitat: Found on the smooth surface of *Daphne.*

Specimen examined: KNP-53 (TUCH-LIC-0001030)

Bulbothrix Hale, *Phytologia* **28**(5): 479 (1974)

Thallus foliose, heteromerous, closely adnate, irregular lobe margins with bulbate cilia, corticated on both sides, medulla usually white, apothecia laminal, lecanorine, imperforate.

Bulbothrix meizospora (Nyl.) Hale, *Phytologia* **28**(5): 480 (1974)

Basionym: *Parmelia tiliacea* var *meizospora* Nyl., *Syn. meth. lich*. (Parisiis) **1**(2): 383 (1860)

Thallus corticolous, adnate, bulbate cilia mostly in axils, isidia and soredia absent, lower side black with brownish at margins densely rhizinate, medulla white. **[PHOTO PLATE 1(A)]**

Chemistry: Medulla K+ red

Chemical constituent: Salazinic acid present.

Distribution: Subtropical to lower temperate regions of Nepal, India and Sri Lanka, Pakistan and Africa (Awasthi, 2007).

Habitat: Smooth Bark of *Lionia* sp.

Specimen examined: KNP-69 (TUCH-LIC-0001000)

Flavoparmelia Hale, *Mycotaxon* **25**(2): 604 (1986)

Thallus foliose, closely adnate, lobes rotund to subrotund with eciliate margins, upper side yellow-green to green with or withouit isidia, soredia and pustules, lower side black with simple or dichotomously branched rhizines.

Flavoparmelia caperata (L.) Hale, *Mycotaxon* **25** (2): 604 (1986)

Basionym: *Lichen caperatus* L., *Sp. pl*. **2**: 1147 (1753)

Thallus corticolous, adnate, upper side crumpled, pustules on the ridges, soredia granular, lower side black, narrow marginal zone brownish ans shiny, medulla white. **[PHOTO PLATE 2(C)]**

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

Chemical constituent: Protocetraric acid present.

Distribution: Subtropical to lower temperate regions of Nepal, India and Sri Lanka, China, Japan and widely distributed in lower temperate regions of the world (Awasthi, 2007).

Habitat: Rough bark of *Quercus* sp.

Specimen examined: KNP-23 (TUCH-LIC-0001009)

Parmotrema A. Massal., *Atti Inst. Veneto Sci. lett.*, ed Arti, Sér. 3 **5**: 248 (1860) [1859-60]

Thallus foliose, usually loosely attached to substratum, large, lobes apically rotund, margins with or without cilia, upper side pale grey to grey-green with or without white-maculae, isidia and soredia, pseudocyphellae absent, lower side brown to black, rhizines simple or branched mostly in xcentral part, thallus heteromerous, corticated on both sides, medulla white or pigmented, apothecia laminal, lecanorine generally pedicellate.

Parmotrema nilgherrense (Nyl.) Hale, *Phytologia* **28** (4): 338 (1974)

Basionym: *Parmelia nilgherrensis* Nyl., *Flora*, Regensburg **52**: 291 (1869)

Thallus corticolous, lobes ciliate, upper side pale grey to darker, lacking isidia and soredia, lower side black at center and brown at the margin, medulla white. **[PHOTO PLATE 7(A)]**

Chemistry: Medulla KC+ red

Distribution: China, Thailand, East Africa and temperate regions of Nepal, India and Sri Lanka (Awasthi, 2007).

Habitat: Found on dead log of *Abies.*

Specimen examined: KNP-25 (TUCH-LIC-0001033), KNP-44 (TUCH-LIC-0001034)

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

Thallus foliose, coriaceous, adnate, irregularly or sundichotomously sinuate lobate, lobes wide, rotund, cilia simple, upper side yellowish to greenish grey with or without

isidia and soredia, lower side black with rhizines in central part, thallus heteromerous, corticated on both sides, apothecia laminal.

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

Basionym: *Parmelia wallichiana* Taylor, *London J. Bot*. **6**: 176 (1847)

Thallus corticolous, closely adnate, coriaceous, lobes subrotund, ciliatein axils, upper side grey, rugulose in center and shiny at periphery, isidiate, lower side black, centrally rhizinate, margin shiny brown. **[PHOTO PLATE 7(B)]**

Chemistry: Medulla K+ red, P+ orange.

Chemical constituent: Salazinic acid present.

Distribution: China, Japan, South East Asia, Africa, Australia and tropical to lower temperate regions of Nepal, India and Sri Lanka (Awasthi, 2007).

Habitat: Found on bark of *Rhododendron, Acer*.

Specimen examined: KNP-32 (TUCH-LIC-0001035), KNP-22 (TUCH-LIC-0001036)

Parmelina Hale, *Phytologia* **28**(5): 481 (1974)

Thallus foliose, adnate, dichotomously or irregularly lobate, lobes sublinear, apically subrotund, simple cilia in axils of lobes, upper side greyish green, with or without isidia and soredia, lower side brown-black, rhizines simple.

Parmelina carporrhizans (Taylor) Hale, *Phytologia* **28**(5): 482 (1974)

Basionym: *Parmelia carporrhizans* Taylor, *London J. Bot*. **6**: 163 (1847)

Thallus corticolous, adnate, sublinear lobes, black rimmed, upper side olive-grey, isidia & soredia lacking, lower side brown, medulla white. **[PHOTO PLATE 7(C)]**

Chemistry: Medulla C+ red, KC+ red.

Chemical constituent: Lecanoric acid, atranorin acid.

Distribution: Asia, Europe, Western North America, Australia (Awasthi, 2007).

Habitat: Smooth Bark of *Rhododendron* sp.

Specimen examined: KNP-03 (TUCH-LIC-0001037)

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

Thallus foliose, adnate, dichotomously or sub dichotomously branched lobes with truncate apices, upper side grey to yellow green, with or without isidia, soredia nad pustules, lower side black, sparsely or richly dichotomously branched rhizines,

Key to species

1.a. Thallus foliose dichotomously or subdichotomously branched, ciliate…… 2

1.b. Thallus foliose subdichotomously or irregularly sinute-lobate, rarely ciliate……3

2.a. Lower side uniformly rhizinate, rhizines short……..… *H. cirrhata*

2.b. Lower side nude or irregularly scattered long rhizines……. *H. nepalensis*

3.a. Thallus isidiate, postulate-sorediate or sorediate…..……..... *H. exsecta*

3.b. Thallus lacking isidia, pustules & soredia ……... *H. adducta*

Hypotrachyna adducta (Nyl.) Hale, *Phytologia* **28**(4): 340 (1974)

Basionym: *Parmelia adducta* Nyl., *Flora,* Regensburg **68**: 610 (1885)

Thallus corticolous, upper side ashy grey, lacking isidia and soredia, lower side black with rhizines, medulla white. **[PHOTO PLATE 9(B)]**

Chemistry: Medulla K-, C-, KC-, Pd+ red.

Distribution: China, Taiwan, subtropical to lower temperate regions of India and Nepal (Awasthi, 2007).

Habitat: Found on the rough surface of twig.

Specimen examined: KNP-77 (TUCH-LIC-0001050)

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

Basionym: *Parmelia cirrhata* Fr., *Syst. orb. veg*. (Lundae) **1**: 283 (1825)

Thallus corticolous, suberect, upper side grey to dark grey, lacking soredia and isidia, lowerside black-brown, rarely with much elongated rhizinal structures. **[PHOTO PLATE 4(C)]**

Chemistry: Medulla K+ brown-red, C-, Pd+ orange-red.

Chemical constituent: Salazinic acid present.

Distribution: Subtropical to mostly lower temperate regions of Nepal, India and Sri Lanka, and widely distributed in Japan, Taiwan, South China, Central and South America (Awasthi, 2007).

Habitat: Smooth surface of *Rhododendron* sp.

Specimen examined: KNP-26 (TUCH-LIC-0001016)

Hypotrachyna exsecta (Taylor) Hale, *Phytologia* **28**(4): 341 (1974)

Basionym: *Parmelia exsecta* Taylor, *London J. Bot.* **6**: 166 (1847)

Thallus corticolous, adnate, branched, upper side dark grey, apically postulate, soredia granular, lower side black with dichotomously branched rhizines, medulla white. **[PHOTO PLATE 4(B)]**

Chemistry: Medulla K-, C-, KC+ red.

Chemical constituent: Barbatic acid present.

Distribution: South East Asia, Australia, Papua New Guinea, tropical to lower temperate regions of India, Nepal and Sri Lanka (Awasthi, 2007).

Habitat: Rough surface of *Quercus* sp.

Specimen examined: KNP-27 (TUCH-LIC-0001015)

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

Basionym: *Parmelia nepalensis* Taylor, *London J. Bot.* **6**: 172 (1847)

Thallus corticolous, upper side grey to dark grey or brownish lacking isidia and soredia, lower side black-brown with simple or branched rhizines. **[PHOTO PLATE 4(E)]**

Chemistry: Medulla K+ yellow turning red, Pd+ orange red.

Chemical constituent: Salazinic acid and protoloschesterinic acid present.

Distribution: Subtropical and temperate regions of India and Nepal, and widely distributed in pantropical to temperate parts of Asia (Awasthi, 2007).

Habitat: Found on the twig of *Daphne* sp.

Specimen examined: KNP-64 (TUCH-LIC-0001017)

Remototrachyna Divakar & A. Crespo, in Divakar, lumbsch, Ferencová, Prado & Crespo, *Am. J. Bot.* **97**(4): 584 (2010)

Thallus foliose, adnate, subirregular lobes with rounded apices, short, mostly dichotomously branched rhizines, a large ellipsoid ascospores.

Remototrachyna rhabdiformis (Kurok.) Divakar & A. Crespo, in Divakar, lumbsch, Ferencová, Prado & Crespo, *Am. J. Bot.* **97**(4): 586 (2010)

Synonym: *Hypotrachyna rhabdiformis* (Kurok.) Hale, *Smithson. Contr. bot*. **25**: 62 (1975)

Basionym: *Parmelia rhabdiformis* Kurok., *Contr. U.S. natnl. Herb*. **36**: 183 (1964)

Thallus corticolous, adnate, lobes sublinear, upper side pale grey, isidiate, isidia club shaped, simple, lower side black with dense dichotomously branched rhizines, medulla white. **[PHOTO PLATE 8(B)]**

Chemistry: Medulla K+ red, C-, P+ orange-red

Chemical constituent: Norstictic, stictic complex and atranorin acid present.

Distribution: South-East Asia, Panama, Peru (Awasthi, 2007).

Habitat: Rough bark of *Abies* sp.

Specimen examined: KNP-67 (TUCH-LIC-0001042)

12. **RAMALINACEAE** C. Agardh

Thallus fruticose, erect to procumbent, branched, branches round or strap shaped or lobes flattened; corticated on all sides; photobiont green alga; apothecia lecanorine.

Ramalina Ach., in Luyken, *Tent. Hist. Lich*.: 95 (1809)

Thallus fruticose, erect or pendulous, variously branched, narrow strap shaped or wide lobed, greenish grey, yellowish grey to yellowish brown, pseudocyphellae present or

absent, thallus heteromerous, corticated on all sides, medulla loose or arachnoid, solid or hollow.

Key to genus

1.a. Thallus broad lobed, medulla lacking lichen substance…….... *R. sinensis*

1.b. Thallus usually narrow lobed, medulla usually with lichen substance……..... .....*R. conduplicans*

Ramalina conduplicans Vain., *Ann. bot. Soc. Zool.-Bot. fenn. Vanamo* **1**(3): 35 (1921)

Thallus corticolous, erect, greenish grey, branched, upper side smooth scarcely pseudocyphellate, lower side rugose, medulla solid. **[PHOTO PLATE 7(F)]**

Chemical constituent: Usnic acid and salazinic acid present.

Distribution: Lower temperate regions of India and Nepal, Eastern Asia (Awasthi, 2007).

Habitat: Found on Rough bark of *Abies.*

Specimen examined: KNP-08 (TUCH-LIC-0001039), KNP-28 (TUCH-LIC-0001040)

Ramalina sinensis Jatta, *G. bot. ital*., n.s. **9**: 462 (1902)

Thallus corticolous, erect (4-5 cm long), yellowish green to greyish, upper side longitudinally wrinkled, lower side white and ridged, medulla solid. Apothecia upto 9 mm in diameter. **[PHOTO PLATE 8(A)]**

Distribution: India, Nepal, China, South East Asia and Europe (Awasthi, 2007).

Habitat: Found on smooth surface of dead log, Rough bark of *Abies.*

Specimen examined: KNP-63 (TUCH-LIC-0001041)

13. **CLADONIACEAE** Zenker

Thallus dimorphic with squamulose or crustose as primary thallus and podetium or pseudopodetium as secondary fruticose thallus; apothecia terminal; photobiont green alga.

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

Thallus dimorphic, terricolous, on mosses over rocks, primary thallus horizontal, either crustose or squamules to foliose, adpressed or suberect, rounded to elongate,

crenate to lobate, upper side grey-green, olive-grey to brownih, corticated; secondary thallus a podetium, arising from primary thallus, scyphose or simple or variously branched cylindrical structures, hymenial discs (apothecia) developing on margin of scyphi or terminal of podetia tips red, red-brown.

Key to species

1.a. Podetia always scyphose, scyphi well developed …….. *C. coccifera*

1.a. Podetia cylindrical, always escyphose, scyhi then normal…… *C. corniculata*

Cladonia coccifera (L.) Willd., *Fl. berol. prodr*. : 361 (1787)

Basionym: *Lichen cocciferus* L., *Sp. pl.***2**: 1151 (1753)

Squamuls of primary thallus small to medium sized, orange yellow at basal part, podetia greenish yellow to grey (5-15 mm tall), scyphose, scyphi goblet-shaped, imperforate, hymenial disc red on margin of scyphi. **[PHOTO PLATE 1(F)]**

Chemical: Podetia K-, KC+ yellow, Pd-.

Chemical constituent: Calycin acid and zeorin acid present.

Distribution: Temperate regions of India and Nepal, Bhutan, Asia, Europe, North and South America (Awasthi, 2007).

Habitat: Found on rocks.

Specimen examined: KNP-88 (TUCH-LIC-0001004)

Cladonia corniculata Ahti & Kashiw., in Inoue, *Studies on Cryptogams in Southern Chile* (Tokyo): 136 (1984)

Squamules of primary thallus small, sorediate, brownish on upper side, podetia white to yellow-grey (10-15 mm tall), branched in apical region, always escyphose. **[PHOTO PLATE 1(E)]**

Chemical: K-, Pd+ red.

Chemical constituent: Protocetraric acid present.

Distribution: Lower temperate regions of India, South East Asia, South Africa, Central and South America and Australia (Awasthi, 2007).

Habitat: Found on rough bark of *Abies*, rocks.

Specimen examined: KNP-82 (TUCH-LIC-0001005)

14. **STEREOCAULACEAE** Chevall.

Thallus dimorphic with crustose or foliose as primary thallus and a fruticose secondary thallus (stipes) bearing hymenia, dominated pseudopodetia, usually

terricolous or saxicolous; apothecia lecideine, ascospores multiseptate, sometime aseptate.

Key to genera

1.a. Thallus crustose to subfoliose with powdery appearance……..... *Lepraria*

1.b. Thallus dimorphic with primary thallus crustose to secondary thallus fruuticose…… *Stereocaulon*

Lepraria Ach., Methodus, Secti 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.

Key to species

1.a. Protocetraric acid present…….…….. *L. caesioalba*

1.b. Protocetraric acid absent……..... 2

2.a. Alectorialic acid present…….. *L. eburnea*

2.b. Alectorialic acid absent…… *L. yunnaniana*

Lepraria caesioalba (B. de Lesd.) J.R. Laundon, *Lichenologis*t **24**(4): 324 (1992)

Basionym: *Crocynia caesioalba* B. de Lesd., *Bull. Soc. bot. Fr*. **61**: 84 (1914)

Thallus leprose, granular, margin usually delimited, sometimes diffuse, lobes sometimes present, medulla present, white, hypothallus usually absent, soredia abundant. **[PHOTO PLATE 5(D)]**

Chemical constituent: Atranorin, protocetraric acid present.

Distribution: Asia, Europe, North and South America, Greenland. In India, found between altitudes of 450 to 3400 m (Saag *et al*., 2009).

Habitat: Found on rough bark of *Quercus*.

Specimen examined: KNP-40 (TUCH-LIC-0001026)

Lepraria eburnea J.R. Laundon, *Sommerfeltia* **14**: 196 (1992)

Thallus leprose, powdery to cottony, medulla usually present, thick, white, hypothallus usually not distinct, thallus surface without soredia often present. **[PHOTO PLATE 5(C)]**

Chemical constituent: Alectorialic acid present.

Distribution: North America, Australia, Greenland, India (between 1000-2000 m altitude) (Saag *et al*., 2009).

Habitat: Found on rough bark of *Abies.*

Specimen examined: KNP-42 (TUCH-LIC-0001027)

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

Basionym: *Crocynia yunnaniana* Hue, *Bull. Soc. bot. Fr*. **71**: 396 (1924)

Thallus leprose, of cottony hypothallus, powdery soredia, margin diffuse, lobes usually absent, rarely indistinct, medulla sometimes present, white. **[PHOTO PLATE 6(A)]**

Chemistry: K-, C-, KC+ pink.

Chemical constituent: Divanicatic acid present.

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

Habitat: Found growing with the moss on rock.

Specimen examined: KNP-74 (TUCH-LIC-0001028)

Stereocaulon (Schreb.) Schrad., *Spicil. fl. germ.***1**:113 (1794)

Thallus dimorphic, primary thallus crustose, granular, secondary thallus vertical, fruticose, pdeudopodetia corticated, brownish at basal part and whitish grey at tip, granulose. **[PHOTO PLATE 8(E)]**

Distribution: India, Nepal and Sri Lanka (Awasthi, 2007).

Habitat: Found on the rough bark of *Abies*, rocks.

Specimen examined: KNP-72 (TUCH-LIC-0001044)

4.3 Species Composition

The Detrended Correspondence Analysis (DCA) table (Table 2) showed that the value of the first axis length to be 8.01 SD units. The eigenvalue of first axis was 0.724 which is greater than 0.5 that signifies the stronger strength in the data matrix.

Table 2: Summary of DCA

	DCA1	DCA2	DCA3	DCA4
Eigenvalues	0.7243	0.6546	0.5688	0.5296
Decorana values	0.791	0.6247	0.5505	0.5023
Axis lengths	8.0143	4.8114	4.239	5.0184

The CCA analysis showed that the constrained analysis only explained 13 % of 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 III).

Table 3: CCA model test

	Inertia	Proportion	Rank
Total	15.6978	1	
Constrained	2.0034	0.1276	13
Unconstrained	13.6945	0.8724	46

The environment-species composition (Figure 5) showed that the altitude had strong effect on the lichen species composition than relative radiation index, RRI, (Appendix IV and V). As the altitude increases the number of lichen species seems to increase. With the increase in altitude the species like *Daphne, Rhododendron, Acer* seemed to be dominant whereas the *Quercus* seemed to be found in lower altitude i.e. *Quercus* showed strong negative relationship with the altitude. The host dominant species *Quercus* shows a very strong effect on the lichen species composition. The relative radiation index (RRI) was significantly represented by axis I. The dominant species like *Betula, Persea* and *Picea* were positively related to the RRI. Species like *Hypotrachyna exsecta, Graphis* sp. *3, Hypotrachyna cirrhata, Ioplaca pindarensis, Leptogium askotense, Diorygma hieroglyphicum, Peltigera* sp., *Grphis scripta, Menegazzia terebrata* showed high abundance in *Quercus* habitat while the species like *Parmotrema nilgrerrense, Diorygma hieroglyphicum, Parmelina carporrhizans* found on the *Aesculus* habitat. Likewise *Usnea longissima, Usnea oreintalis Hypotrachyna nepalensis, Ramalina sinesis, Ramalina conduplicans, Remototrachyna rhabdiformis, Sticta henryana, Cetralia olivetorum* etc species were more abundant on the higher altitude on the dominant species like *Daphne, Rhododendron, Acer,* and some on meadows or grassland. Some species like *Nephromopsis stracheyi, Cladonia coccifera, Lobaria retigera, Dendriscosticta platyphylla* showed abundance in the host species *Picea,* likewise *Leconora* sp., *Bulbothrix meizospora, Polyblastidium togashii* were found on the species *Persea.*

Similarly, species like *Nephromopsis pallscens*, *Ramalina conduplicans*, *Cetralia braunsiana* were some species found on the twigs and branches of *Drepanostachyum* and *Berberis* on the higher altitude.

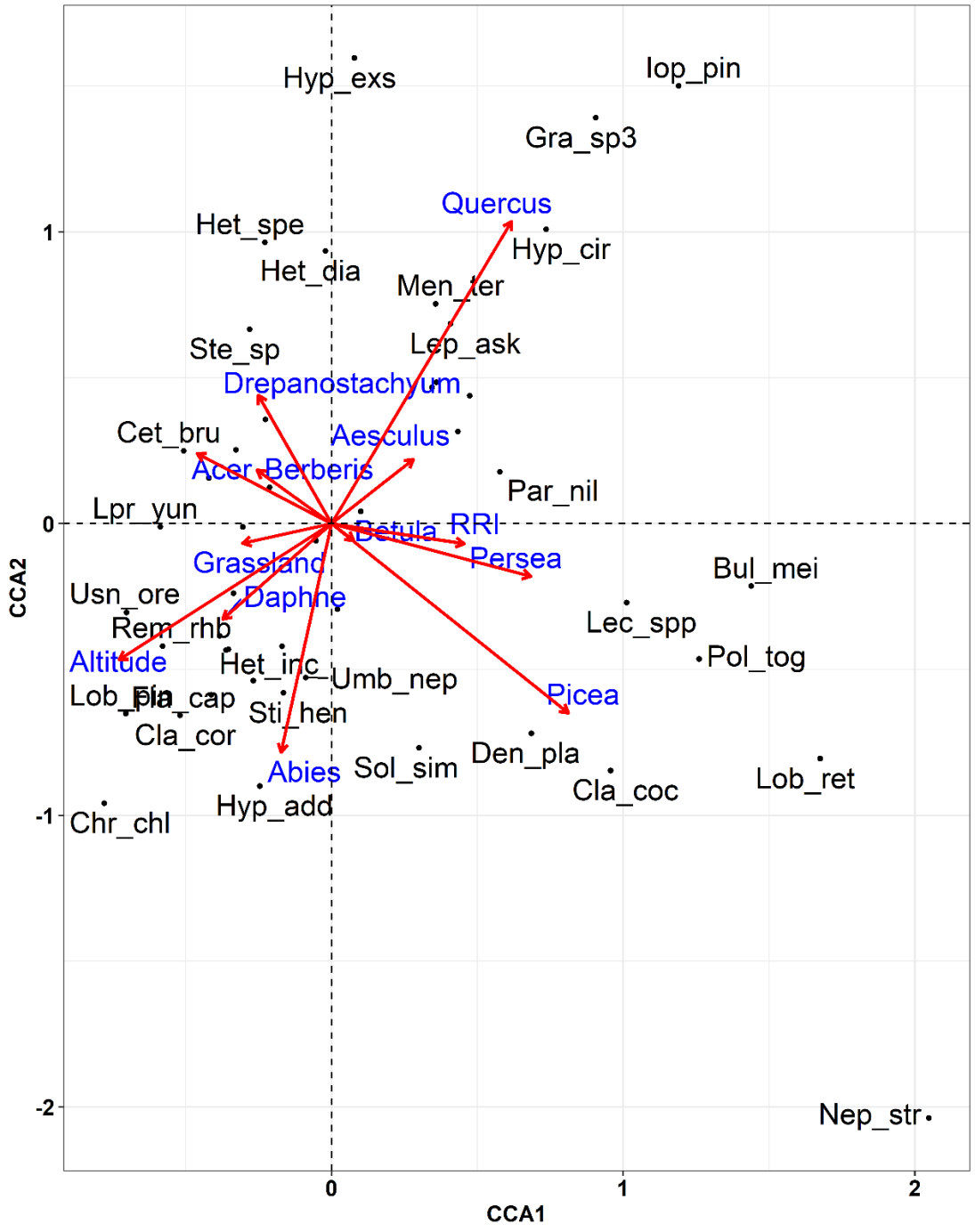

Figure 6: CCA plot showing lichen composition constraint by altitude, RRI and dominant host species.

CHAPTER-5
DISCUSSION

The present study was carried out from an altitude of 2250 m to 3200 m asl in the Khaptad National Park, Western Nepal. Lichen species traced in the present study have previously been also reported from the adjacent regions, such as India (Mishra & Upreti, 2014) and also other parts of Nepal, Devkota (2008), Baniya *et al* (2010), Baral (2015), Devkota *et al* (2017), Baniya *et al* (2017), Jha *et al* (2017), Chongbang *et al*. (2018) etc. *Cetrelia braunsiana, Cetrelia pseudolivetorum, Chaenotheca* sp., *Chrysothrix chlorine, Cladonia coccifera, Cladonia corniculata, Flavoparmelia caperata, Graphis* sp., *Heterodermia diademata, Heterodermia incana, Heterodermia speciosa, Hypotrachyna adducta, Hypotrachyna exsecta, Hypotrachyna cirrhata, Hypotrachyna nepalensis, Lecanora* sp., *Leptogium askotense, Lobaria pindarensis, Lobaria retigera, Menegazzia terebrata, Parmotrema nilgherrense, Peltigera sp., Ramalina conduplicans, Ramalina sinensis, Stereocaulon* sp. and *Usnea longissima* were common species recorded by Chongbang *et al* (2018) and species identified from the present study sites of Khapad National Park. Jha *et al* (2017) had reported 84 lichen species from Annapurna Conservation Area (ACA), among which 11 species that were recorded in their study were also found in present study site. These were *Cladonia coocifera, Lepraria* sp., *Leptogonium* sp., *Peltigera polydactyla, Usnea* sp., *Lobaria retigera, Parmotrema* sp., *Heterodermia diademeta, Hypotrachyna cirrhata, Hypotrachyna nepalensis* and *Ramalina conduplicans*.

Baral (2015) in his study on lichen diversity in Manaslu Conservation Area and Sagarmatha National Park, had reported the occurrence of a total of 13 species of lichen from Manaslu Conservation Area (belonging to 4 families). Among these species *Bulbothrix* sp., *Cladonia* sp, *Hypotrachyna nepalensis, Flavoparmelia caperata, Heterodermia diademata, H. incana, Leconara* sp., *Leptogium* sp, *Parmotrema nilgherrense, Pelgigera polydactyla, Ramalina sinensis, Sterocaulon* sp., *Usnea longissima* and *Usnea orientalis*which were reported in Sagarmatha National Park and *Hypotrachyna nepalensis, Lobaria pindarensis* and *Usnea longissima* were reported from Manaslu Conservation Area were also identified from specimen collected from the study sites of Khaptad National Park. Similarly in a taxonomic study of Lichens of Phulchowki hills, Lalitpur district, Devkota (2008)

identified thirty-two species of lichens from different altitudinal gradient ranges from 1500-2700 m above sea level of Phulchowki hill. Out of those thirty two species *Flavoparmelia caperata, Hypotrachyna cirrhata, Hypotrachyna nepalensis, Heterodermia diademata, Heterodermia incana, Heterodermia speciosa, Leptogium* sp., *Lobaria* sp., *Parmotrema nilgherrensis, Peltigera* sp., *Ramalina sinensis, Sterocaulon* sp., *Usnea longissima* and *Usnea orentalis* reported by Devkota (2008) were also identified from present study area which could be possible due to the cosmopolitan distribution of those lichens species. Out of 47 lichen species reported in this study 19 species were also reported from the Kumaun Himalaya Uttarakhand by Mishra & Upreti (2014).

Baral (2015) had reported *Quercus* and *Rhododendron* species as host plant for *Usnea longissima*; *Betula* sp. as host plant for *Ramalina sinensis*; *Malus domestica* as host plant for *Hypotrachyna nepalensis; Lobaria pindarensis* was reported from rocks. In contrast, the present study had found *Usnea longissima* on *Abies* sp.; *Hypotrachyna nepalensis* on *Daphne; Ramalina sinesis* on *Abies* and *Lobaria pindarensis* on *Lionia* sp. *Lobaria pindarensis* which was found growing on bark of *Quercus* in my study area was reported on different substratum from different parts of Nepal. Sharma *et al* (2009) reported *Lobaria pindarensis* on branch of *Berberis* sp.; Devkota *et al* (2019), on trunk of *Abies spectabilis*; on trunk of *Rhus wallichi, Abies spectabilis*, on bark of *Viburnum nervosum*on branch of *Rosa macrophylla, Rhodendron campanulatum* and *Berberis* sp. Similarly, they also reported *Lobaria pindarensis* on trunk of *Pinus* wallichiana, *Mahonia nepalensis, Abies spectabilis, Arundinaria* sp. In Nepal, temperate to subalpine zone (2036 m - 4000 m) was found favourable for growth of *Lobaria pindarensis* which was also supported by this study done in Khapad National Park. Similarly *Lobaria retigera* was reported on trunk of *Abies spectabilis, Machelus* sp. and *Rhododendron* sp.; on trunk of *Quercus semicarpifolia* by Devkota *et al* (2017).

However the present study found *Lobaria retigera* from *Lionia* only. In addition, *Sticta henryana* which was reported on bark of *Abies spectabilis* in this study was supported by Devkota *et al* (2017). Sharma (1979) reported *Sticta platyphylloides, Sticta praetextata, Lobaria discolor* and *Lobaria retigera* from Khaptad, Doti while in this study *Sticta platyphylloides, Sticta praetextata, Lobaria discolor* were missing

and might be present in other part of National Park which was not included under present study sites.

Forests are habitats with complex ecological gradients that provide habitat for a rich assemblage of epiphytic angiosperms (Mondragon *et al*., 2015) as well as various cryptogams, such as lichens. Total lichen species richness in Nepal varies strongly with elevation in line with previous findings (Bruun *et al*., 2006; Grytnes *et al*., 2006; Baniya *et al*., 2010, 2012; Chongbang *et al*., 2018; Cobanoglu and Sevgi 2009). In addition lichen communities change as a forest changes along elevation. The number of species, as well as other higher ranks of taxonomic organization in a site (e.g. species richness or alpha diversity), and their compositional change across different habitat types (species turnover or beta-diversity) within a landscape, are important measures of biodiversity that have wide applications, such as environmental monitoring and conservation evaluation (Negi 1999). Similarity in recorded lichen species in previous studies and in this study might be because of similar elevation range included in studies which in turn provide similar substrate and microhabitat for lichen species. The number of lichen species can be affected by the altitude or the types of vegetation on which they grow. The effect of slope, latitude, longitude, aspects combinedly measured as relative radiation index could not be seen impressive.

Among the lichen habitat groups, the corticolous species were found dominant in the study area which is a natural forest and have plenty of substratum and high moisture. This was supported by the result of Pinokiyo *et al* (2008). Similar result as seen by Stofer *et al* (2006), the lichen species was found decreasing from the forest as we went towards the open meadows. The low lichen species in the open meadows could be the result of the grazing of the livestock in the area. Though meadows have low lichen species, the lichen species found in there were on rocks. It might be due to rocks as substrate which provide relatively stable and fertile substrate for growth of lichens as concluded by Negi and Upreti (2000).

In Nepal, lichen species richness show strong variation with elevation (Baniya *et al.*, 2010). This findings has been also supported by the studies in other countries (Bruun *et al.*, 2006, Grytness *et al.*, 2006, Pinokiyo *et al.*, 2008). The present study also showed a distinct variation with altitude but differed by reverse unimodal relationship. Former studies by Bruun *et al* (2006), Baniya *et al* (2010, 2012) were from a larger

geographical space whereas my study covers above 2250 m elevation. It lacks data from low altitudes which may be the result for reverse unimodal pattern and do not support their findings. Zhang *et al* (2016) and Gebrehiwot *et al* (2019) also found the inveted hump-shaped pattern of species diversity with the altitude due to the changes in the microenvironment such as disturbances and canopy cover. This findings support my finding as the present study sites have dense forest communities and have more canopy cover lacking the sufficient sunshine in the understory. Though the relationship between the lichen diversity and the altitude have positive correlation i.e. inspite of a certain drop in the number of lichen species in a certain elevation, the number of lichen species seemed to be increased upto an elevation of 3100 m. This positive correlation can be justified by the findings of Svoboda *et al* (2011).

In the present study, crustose lichens were dominantly found on the lower study sites of the study area and fruticose were maximum at higher study sites, whereas foliose were found commonly on every elevation. This was found common with the result reported by Pinokiyo *et al* (2008) and Baniya *et al* (2010).In the lower altitude of the study area, *Quercus* sp. was found to be dominant host species for the lichens. It may be due to the pH, roughness and water retention capacity of *Quercus* sp. Showed by the result of Chatterjee (1999) and Nag *et al* (2012). Their study also concluded that the species richness was found to be highest in the substratum *Picea abies*, which also supported this study's result in which *Picea* sp. and *Abies* sp. species found in the higher altitude of the study area had high number of lichen species. In the higher altitude of the study area, the forest became moist and the number of epiphytic lichens increases substantially. Similar finding was reported by the Nash (1977). As the altitude rises, the variation on the other environment variables such as temperature, precipitation, soil pH, moisture content, vegetation, humidity etc. determine the diversity of different organism. Apart from these environmental variables anthropogenic factors also effect the diversity of the different plant species (Tu *et al.,* 2010). Khaptad National Park is also religious place hence the anthropogenic activities can also be seen there which can be a factor to alter the lichen species diversity.

CHAPTER-6
CONCLUSION AND RECOMMENDATIONS

CONCLUSION

Khaptad National Park is a diverse and beautiful landscape with magnificent vegetation but less explored. This study explored a total of 47 lichen species belonging to 29 genera and 14 families of different life-forms within 98 plots, from 2200 m to 3200 m asl. Among these species found Parmeliaceae was the largest family possessing 17 species and the foliose lichen was found as the dominant life-form. Only three leprose forms were found. Lichen species richness found to have positive correlation with the elevation. The number of lichen species increased as the altitude increased. At the lower altitude *Quercus* was found to be the dominant host species for lichens whereas *Abies, Picea, Rhododendron* were the dominant host species at the higher altitude. However, the species richness didn't vary significantly along the dominant host species. Relative radiation index could not show any impressive effect in the distribution of the lichen. The present study clearly showed that the effect of altitude and the host influence the lichen richness and the composition, however, there are other unknown factors that also influenced the lichen diversity in the study area. Hence, further research in the Khaptad National Park can help to aid in the Nepal's lichen study.

RECOMMENDATIONS

Khaptad National Park is extended in 4 districts of the western Nepal. Among which the present study was only able to cover the 2 districts i.e. Doti and Bajhang and still lacks a complete data from the remaining sites. Hence, I strongly recommend that further study of lichens should be carried out in those remaining parts of the national park.

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APPENDICES

Appendix I: Table showing the altitude, latitude, longitude, dominant tree species, slopes, aspect and Relative Radiation Index (RRI) of each plot of the study area.

Plot	Altitude	Laitude	Longitude	Dominant_tree	Slope(in °)	Aspect	RRI
1	2280	29.34197	81.04892	*Quercus*	7	SE	-0.74358
2	2271	29.34208	81.04915	*Quercus*	32	N	0.038003
3	2273	29.34232	81.05097	*Quercus*	2	N	0.997261
4	2286	29.34219	81.05091	*Rhododendron*	18	N	-0.36771
5	2273	29.34188	81.0524	*Rhododendron*	24	NE	-0.909
6	2265	29.34168	81.05298	*Rhododendron*	29	NE	0.91904
7	2264	29.34178	81.05303	*Rhododendron*	12	SW	-0.46719
8	2266	29.34164	81.05296	*Quercus*	25	SW	-0.38153
9	2297	29.34185	81.05357	*Quercus*	31	SE	-0.62444
10	2301	29.34199	81.05349	*Rhododendron*	35	S	0.805572
11	2334	29.34253	81.05372	*Persea*	35	NW	0.506279
12	2338	29.34243	81.05376	*Rhododendron*	31	NW	-0.1738
13	2480	29.34365	81.05638	*Quercus*	35	W	0.379796
14	2514	29.34396	81.05718	*Quercus*	37	SW	-0.84131
15	2576	29.34446	81.05836	*Quercus*	41	NW	0.600214
16	2614	29.34453	81.05873	*Rhododendron*	18	S	0.341913
17	3060	29.39851	81.1349	*Abies*	12	SE	-0.15147
18	3054	29.39836	81.13518	*Abies*	15	SE	-0.12065
19	3025	29.40002	81.13571	*Picea*	34	E	0.817515
20	3028	29.4	81.13531	*Abies*	15	N	0.678351
21	3025	29.40037	81.13648	*Rhododendron*	44	SW	-0.41786
22	3033	29.40039	81.13665	*Rhododendron*	33	SW	0.771669
23	3005	29.40203	81.13716	*Acer*	23	NE	-0.5353
24	3013	29.40208	81.1369	*Acer*	24	NE	-0.99919
25	2964	29.40375	81.13746	*Acer*	36	NE	0.784765
26	2971	29.40376	81.13733	*Acer*	21	NE	-0.48012
27	2917	29.40447	81.1376	*Acer*	36	N	0.895996
28	2913	29.4046	81.13733	*Acer*	43	N	0.213566
29	2897	29.40527	81.13678	*Abies*	24	NE	-0.44758
30	2900	29.40522	81.13676	*Abies*	27	NE	0.988882
31	2871	29.40608	81.13646	*Aesculus*	25	NE	-0.49472
32	2875	29.40605	81.1364	*Aesculus*	28	N	0.528664
33	2843	29.40727	81.13577	*Rhododendron*	44	NE	-0.42969
34	2848	29.40715	81.13572	*Rhododendron*	17	NE	-0.75228
35	3051	29.39007	81.13958	*Abies*	10	W	-0.11712
36	3068	29.39018	81.13986	*Abies*	10	SW	-0.10171

37	3080	29.38931	81.14156	*Abies*	32	N	-0.66355
38	3077	29.38943	81.14158	*Abies*	10	SW	0.685289
39	3092	29.38687	81.14282	*Quercus*	40	SW	0.30392
40	3094	29.387	81.14268	*Quercus*	40	SW	0.303843
41	3103	29.38634	81.14122	*Abies*	27	N	0.883689
42	3108	29.38628	81.14117	*Rhododendron*	35	N	0.062555
43	3100	29.38508	81.14063	*Daphne*	32	SW	-0.50214
44	3105	29.38513	81.14061	*Daphne*	20	SW	0.278944
45	3107	29.38557	81.13922	*Rhododendron*	25	SW	-0.3407
46	3111	29.38556	81.13912	*Abies*	20	SW	0.058025
47	3137	29.3864	81.13779	*Abies*	12	S	-0.17734
48	3134	29.38625	81.13789	*Abies*	9	SW	0.650007
49	3149	29.38599	81.1368	*Abies*	18	SW	-0.67129
50	3144	29.38584	81.1368	*Abies*	20	S	0.602776
51	3027	29.37512	81.12112	*Abies*	36	N	0.88736
52	3037	29.37521	81.12101	*Abies*	27	E	0.921167
53	3057	29.37446	81.1197	*Daphne*	25	S	-0.38576
54	3064	29.37454	81.11959	*Rhododendron*	23	SE	0.357937
55	3066	29.37325	81.11795	*Abies*	30	SE	-0.65706
56	3074	29.3735	81.11789	*Abies*	26	SW	-0.30895
57	3058	29.3728	81.11672	*Rhododendron*	12	N	-0.15485
58	3063	29.37285	81.11657	*Acer*	10	NE	0.621457
59	3091	29.37154	81.11614	Grassland	27	N	0.965227
60	3092	29.37173	81.11599	*Abies*	10	SE	-0.0786
61	3070	29.37124	81.11482	*Abies*	7	NW	-0.82
62	3065	29.37104	81.11478	Grassland	28	S	0.641697
63	3082	29.36802	81.11234	*Betula*	30	E	0.738181
64	3082	29.36776	81.11243	Grassland	12	N	-0.42351
65	3111	29.36774	81.1105	*Quercus*	28	SE	0.60276
66	3105	29.36758	81.11052	*Quercus*	34	SE	0.703392
67	3114	29.36762	81.10814	*Berberis*	32	S	-0.86882
68	3110	29.36753	81.10816	*Drepanostachyum*	20	SE	0.342388
69	3118	29.36675	81.10627	*Drepanostacyum*	32	E	0.097845
70	3122	29.36689	81.10623	*Berberis*	33	E	-0.81215
71	3118	29.365	81.1051	*Drepanostacyum*	28	E	0.518877
72	3115	29.36485	81.10512	*Rhododendron*	28	SE	0.318536
73	3111	29.36278	81.10304	*Daphne*	20	NE	0.618697
74	3110	29.36271	81.10311	*Daphne*	18	W	0.32547
75	3090	29.36164	81.10159	*Rhododendron*	22	SE	0.459625
76	3098	29.36185	81.10155	*Quercus*	35	S	0.101805
77	3094	29.36193	81.09997	*Rhododendron*	31	S	-0.72521
78	3089	29.36183	81.09985	*Quercus*	30	S	0.285339
79	3107	29.36262	81.09885	*Acer*	32	S	-0.87126
80	3113	29.36268	81.09903	*Acer*	36	S	0.937947

81	3148	29.35624	81.06893	*Rhododendron*	17	S	0.899446
82	3144	29.35602	81.06894	*Rhododendron*	22	W	0.472304
83	3116	29.35575	81.0671	*Abies*	7	S	-0.43368
84	3110	29.35549	81.06687	*Abies*	4	W	-0.02823
85	3065	29.35444	81.06545	*Quercus*	33	E	-0.6377
86	3060	29.35434	81.06557	*Quercus*	33	NE	-0.39585
87	3024	29.35286	81.0654	*Quercus*	29	S	0.884258
88	3020	29.35277	81.06531	*Acer*	27	SE	0.768542
89	2996	29.35102	81.06484	*Rhododendron*	27	SE	0.768399
90	2997	29.35082	81.06486	*Rhododendron*	9	NW	0.784744
91	2950	29.34942	81.06417	*Rhododendron*	22	SE	0.482647
92	2948	29.34931	81.0642	*Aesculus*	23	SE	0.874424
93	2919	29.34905	81.06148	*Quercus*	27	SW	0.7876
94	2920	29.34899	81.0615	*Quercus*	24	NW	-0.27581
95	2846	29.34839	81.05964	*Quercus*	21	W	0.685435
96	2841	29.34835	81.05967	*Quercus*	28	S	0.330101
97	2706	29.34613	81.05953	*Betula*	35	SW	0.545473
98	2701	29.34599	81.05965	*Quercus*	35	W	0.243643

Appendix II: List of Lichen species on which Thin Layer Chromatography was performed.

S.N.	Name of the lichen species	Life form
1	*Bulbothrix meizospora* (Nyl.) Hale	Foliose
2	*Cladonia coccifera* (L.) Willd	Fruticose
3	*Cladonia corniculata* Ahti & Kashiw.	Fruticose
4	*Diorygma hieroglyphicum* (Pers.) Staiger & Kalb	Crustose
5	*Dolichousnea longissima* (Ach.) Articus	Fruticose
6	*Flavoparmelia caperata* (L.) Hale	Foliose
7	*Graphis sp.1*	Crustose
8	*Graphis sp. 2*	Crustose
9	*Graphis sp. 3*	Crustose
10	*Graphis chlorotica* A. Massal.	Crustose
11	*Graphis scripta (L.) Ach.*	Crustose
12	*Hypotrachyna exsecta* (Taylor) Hale	Foliose
13	*Hypotrachyna cirrhata* (Fr.) Divakar, A. Crespo, Sipman, Elix & Lumbsch	Foliose
14	*Hypotrachyna nepalensis* (Taylor) Divakar, A. Crespo, Sipman, Elix & Lumbsch	Foliose
15	*Ioplaca pindarensis* (Räsänen) Poelt & Hinter.	Crustose
16	*Lecanora sp.*	Crustose
17	*Lepraria caesioalba* (B. de Lesd.) J.R. Laundon	Leprose
18	*Lepraria eburnea* J.R. Laundon	Leprose
19	*Lepraria yunnaniana* (Hue) Zahlbr.	Leprose
20	*Menegazzia terebrata* (Hoffm.) A. Massal.	Foliose
21	*Parmelinella wallichiana* (Taylor) Elix & Hale	Foliose
22	*Parmelina carporrhizans* (Taylor) Hale	Foliose
23	*Remototrachyna rhabdiformis* (Kurok.) Divakar & A. Crespo	Foliose
24	*Ramalina conduplicans* Vain.	Fruticose
25	*Umbilicaria nepalensis* Poelt	Foliose
26	*Usnea orientalis* Motyka	Fruticose

Appendix III: List of Lichen species, their short name, life form, frequency of occurences in the study area and CCA scores of each of the species.

S.N.	Name of lichen species	Short name	Life form	Frequency	CCA1	CCA2
1	*Bulbothrix meizospora*	Bul_mei	F	3	1.44	-0.21
2	*Cetrelia braunsiana*	Cet_bru	F	2	-0.51	0.25
3	*Cetrelia olivetorum*	Cet_oli	F	2	-0.35	-0.43
4	*Chaenotheca* sp.	Cha_spp	Cr	5	0.10	0.04
5	*Chrysothrix chlorine*	Chr_chl	Cr	3	-0.78	-0.96
6	*Cladonia coccifera*	Cla_coc	Fr	2	0.96	-0.85
7	*Cladonia corniculata*	Cla_cor	Fr	3	-0.52	-0.66
8	*Dendriscosticta platyphylla*	Den_pla	F	4	0.69	-0.72
9	*Diorygma hieroglyphicum*	Dio_hie	Cr	2	0.43	0.32
10	*Flavoparmelia caperata*	Fla_cap	F	3	-0.41	-0.59
11	*Graphis* sp.1	Gra_sp1	Cr	3	-0.23	0.36
12	*Graphis* sp. 2	Gra_sp2	Cr	3	-0.38	-0.38
13	*Graphis* sp.3	Gra_sp3	Cr	2	0.91	1.39
14	*Graphis chlorotica*	Gra_chl	Cr	4	-0.21	0.12
15	*Graphis scripta*	Gra_scr	Cr	5	0.34	0.47
16	*Heterodermia diademata*	Het_dia	F	5	-0.02	0.93
17	*Heterodermia incana*	Het_inc	F	3	-0.27	-0.54
18	*Heterodermia speciosa*	Het_spe	F	2	-0.23	0.96
19	*Hypotrachyna adducta*	Hyp_add	F	2	-0.25	-0.90
20	*Hypotrachyna exsecta*	Hyp_exs	F	2	0.08	1.60
21	*Hypotrachyna cirrhata*	Hyp_cir	F	2	0.74	1.01
22	*Hypotrachyna nepalensis*	Hyp_nep	F	2	-0.34	-0.24
23	*Ioplaca pindarensis*	Iop_pin	Cr	4	1.19	1.50
24	*Lecanora* sp.	Lec_spp	Cr	2	1.01	-0.27
25	*Leptogium askotense*	Lep_ask	F	3	0.41	0.69
26	*Lobaria pindarensis*	Lob_pin	F	4	-0.70	-0.65

27	*Lobaria retigera*	Lob_ret	F	2	1.68	-0.81
28	*Lepraria caesioalba*	Lpr_cas	L	3	0.02	-0.29
29	*Lepraria eburnean*	Lpr_ebu	L	3	-0.17	-0.42
30	*Lepraria yunnaniana*	Lpr_yun	L	3	-0.59	-0.01
31	*Menegazzia terebrata*	Men_ter	F	3	0.36	0.75
32	*Nephromopsis pallescens*	Nep_pal	F	2	-0.30	-0.01
33	*Nephromopsis stracheyi*	Nep_str	F	2	2.05	-2.04
34	*Parmotrema nilgherrense*	Par_nil	F	3	0.58	0.18
35	*Parmelinella wallichiana*	Pmn_wal	F	3	-0.05	-0.06
36	*Parmelina carporrhizans*	Prm_car	F	2	0.36	0.48
37	*Peltigera sp.*	Pel_spp	F	4	0.47	0.44
38	*Polyblastidium togashii*	Pol_tog	F	3	1.26	-0.46
39	*Ramalina conduplicans*	Ram_con	Fr	3	-0.33	0.25
40	*Ramalina sinensis*	Ram_sin	Fr	3	-0.36	-0.43
41	*Remototrachyna rhabdiformis*	Rem_rhb	F	4	-0.58	-0.42
42	*Sticta henryana*	Sti_hen	F	3	-0.16	-0.58
43	*Stereocaulon sp.*	Ste_sp	Fr	3	-0.28	0.67
44	*Solorina simensis*	Sol_sim	F	4	0.30	-0.77
45	*Umbilicaria nepalensis*	Umb_nep	F	3	-0.09	-0.53
46	*Dolichousnea longissima*	Usn_lon	Fr	3	-0.42	0.16
47	*Usnea orientalis*	Usn_ore	Fr	3	-0.70	-0.30

(F = Foliose, Cr = Crustose and Fr = Fructicose)

Appendix IV: Environmental biplot scores for constrained variables

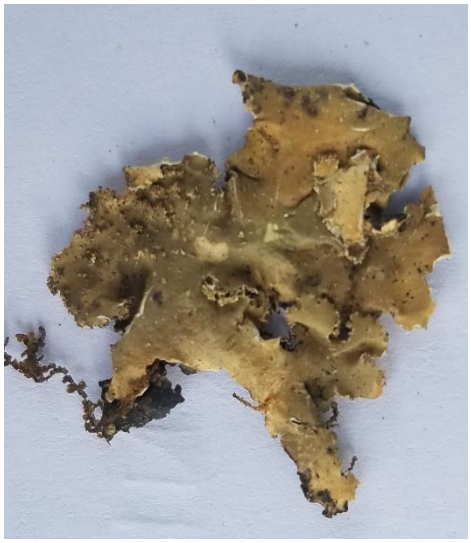
S. No.	Variables	CCA1	CCA2
1	*Abies*	-0.12	-0.52
2	*Acer*	-0.31	0.16
3	*Aesculus*	0.19	0.15
4	*Berberis*	-0.17	0.12
5	*Betula*	0.05	-0.04
6	*Daphne*	-0.25	-0.22
7	*Drepanostachyum*	-0.17	0.29
8	Grassland	-0.20	-0.04
9	*Persea*	0.46	-0.12
10	*Picea*	0.54	-0.43
11	*Quercus*	0.41	0.69
12	Altitude	-0.49	-0.31
13	RRI	0.30	-0.05

Appendix V: ANOVA of environmental variables during CCA

S. No.	Variables	Df	ChiSquare	F	Pr(>F)
1	*Abies*	1	0.20	1.20	0.16
2	*Acer*	1	0.14	0.84	0.76
3	*Aesculus*	1	0.15	0.89	0.55
4	*Berberis*	1	0.08	0.50	0.95
5	*Betula*	1	0.10	0.64	0.84
6	*Daphne*	1	0.14	0.88	0.59
7	*Drepanostachyum*	1	0.15	0.93	0.52
8	Grassland	1	0.12	0.76	0.73
9	*Persea*	1	0.21	1.27	0.21
10	*Picea*	1	0.24	1.47	0.13
11	*Quercus*	1	0.20	1.22	0.12
12	Altitude	1	0.14	0.88	0.71
13	RRI	1	0.13	0.80	0.84
14	Residual	84	13.69		

PHOTO PLATE 1

A. *Bulbothrix meizospora*



B. *Cetrelia olivetorum*

C. *Cetrelia braunsiana*

D. *Chrysothrix chlorina*

E. *Cladonia corniculata*

F. *Cladonia coccifera*

PHOTO PLATE 2

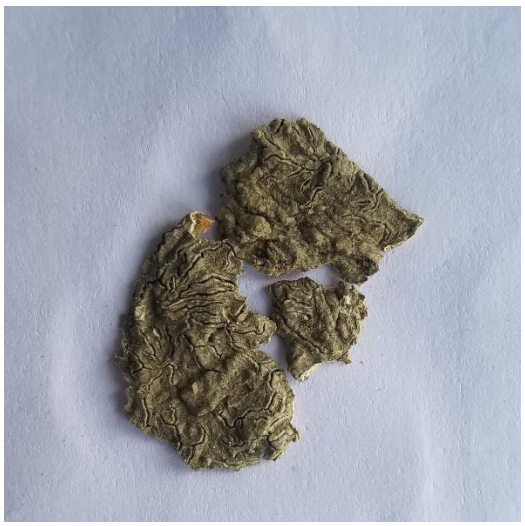
A. *Dendriscosticta platyphylla*

B. *Diorygma hieroglyphicum*

C. *Flavoparmelia caperata*

D. *Graphis* sp.1

E. *Graphis* sp.2

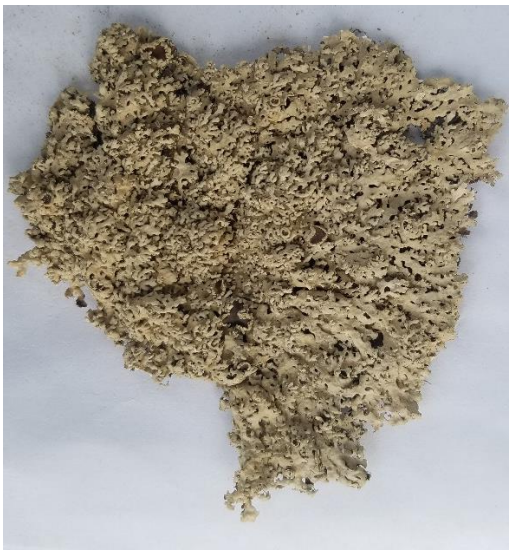


F. *Graphis* sp.3

PHOTO PLATE 3

A. *Graphis chlorotica*

B. *Graphis scripta*



C. *Heterodermia diademata*

D. *Heterodermia incana*

PHOTO PLATE 4

A. *Heterodermia speciosa*

B. *Hypotrachyna exsecta*

C. *Hypotrachyna cirrhata*

D. *Leptogium askotense*

E. *Hypotrachyna nepalensis*

F. *Ioplaca pindarensis*

PHOTO PLATE 5

A. *Lobaria pindarensis*

B. *Lobaria retigera*

C. *Lepraria eburnea*

D. *Lepraria caesioalba*

PHOTO PLATE 6

A. *Lepraria yunnaniana*

B. *Menegazzia terebrata*

C. *Nephromopsis pallescens*

D. *Nephromopsis stracheyi*

PHOTO PLATE 7

A. *Parmotrema nilgherrense*

B. *Parmelinella wallichiana*

C. *Parmelina carporrhizans*

D. *Peltigera* sp.

E. *Polyblastidium togashii*

F. *Ramalina conduplicans*

PHOTO PLATE 8

A. *Ramalina sinensis*

B. *Remototrachyna rhabdiformis*

C. *Solorina simensis*

D. *Sticta henryana*

E. *Stereocaulon* sp.

F. *Umbilicaria nepalensis*

PHOTO PLATE 9

A. *Chaenotheca* sp.

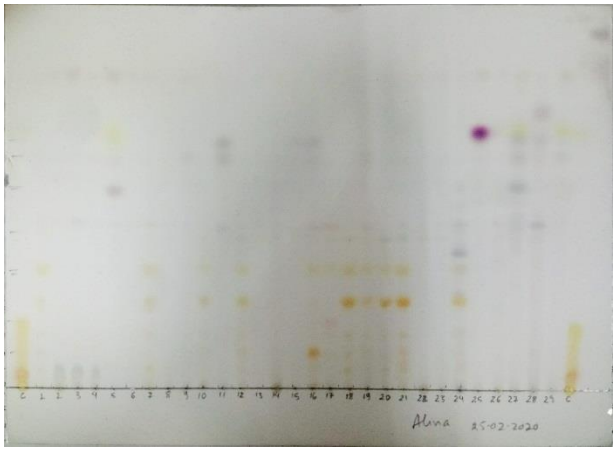
B. *Hypotrachyna adducta* with *Usnea* sp.

C. *Lecanora* sp.

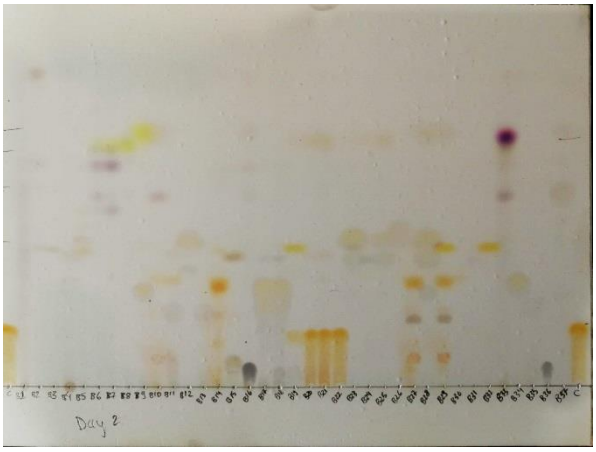
D. *Usnea orientalis*

E. *Dolichousnea longissima*

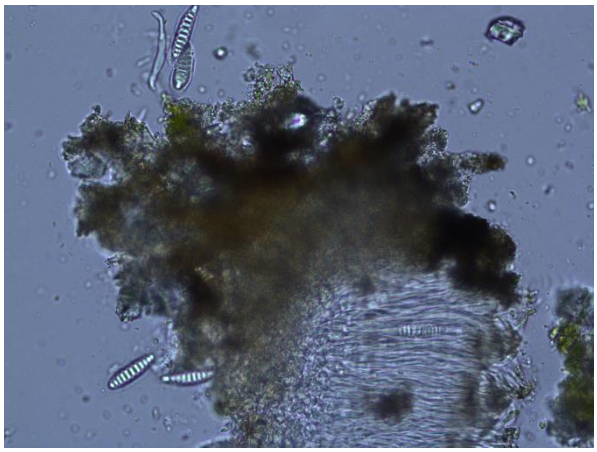
PHOTO PLATE 10



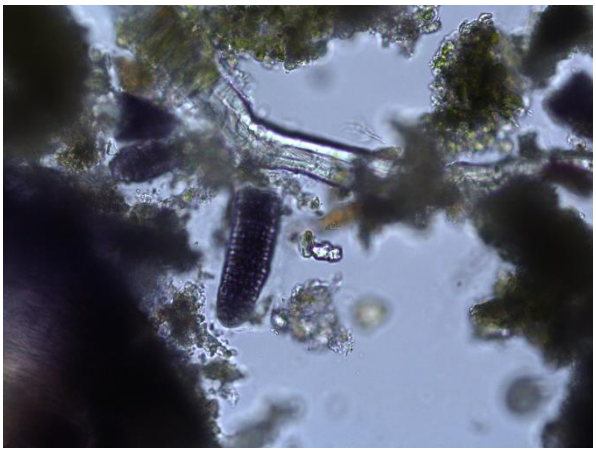
A. TLC of Lichen species- I



B. TLC of lichen species- II



C. Spores of *Graphis chlorotica*



D. Spores of *Diorygyma hieroglyphicum*