

# Species Composition and Distribution of Vascular Epiphytes and Parasitic Plants in the Forested Area of Lampelri

Jambay and Sonam Chopel

## Abstract

Epiphytes and parasitic plants are considered to be one of the most important components in a forest since they accumulate biomass, provide shelter, and serve as habitat for animals. Trees are felled, however, due to illegal logging and for commercial purposes, thus affecting epiphytes and parasitic plants adversely. In Asia specifically, limited studies are conducted on epiphytes and parasitic plants and Bhutan is no different. In Bhutan, this is mainly due to accessibility and seasonality of the species of interest. This study aims to make an inventory of vascular epiphytes and parasitic plants in Lampelri. Sampling method included belt transect technique along with systematic random sampling. The sampled species were identified through consultation with experts from the National Biodiversity Centre and the Flora of Bhutan book was used. Closed observation was used in counting the epiphytes and parasitic plants while those growing high on the branches of the trees were observed with the aid of binoculars. The sampled species were identified through photographs, flowers, and leaves. *Drynaria quercifolia* was found to be relatively high in abundance (RA=31.22%, n=98), followed by *Agapetes serpens* (RA=16.40%, n=45). The least abundant species found were *Daphne bhoolua* (RA=0.04%, n=1), *Rhododendron sp.* (RA=0.04%, n=1), and *Berberis asiatica* (RA=0.04%, n=1). The study area hosted many epiphytes and parasitic plants.

**Keywords:** Diversity, Epiphytes, Host plants, Parasitic plants, Species Composition

## Problem statement

Although there have been many publications on epiphytes (Watson et al. 1988), their ecological diversity and distribution still remain unknown. Epiphyte is a unique component of forest

## Introduction

Parasitic plants are plants that acquire all or part of their nutrition from another plant, called the host, without contributing to the benefit of the host species. A number of cases where parasitic plants caused tremendous damages to the host species were studied by Westwood (2020). There are around 4500 different species belonging to 280 genera under 20 families of parasitic plants (Rubiales, et al., 2011). A large number of the parasitic plants, i.e., about 4100 species are hemiparasites, attaining most or all their carbon needs through the photosynthetic ability the plants hold (Tesitel et al., 2010). Approximately, 390 species are holoparasites, where the plants lack chlorophyll. They are common among green bromeliads, orchids, and ferns thriving on the branches of the trees.

According to Bonnie (2021), epiphyte is a Greek word where 'epi' means 'upon' and 'phyton' means 'plant'. Epiphytes are one of the nature's most adaptative plants. Epiphytes are also called air plant. Epiphytes do not have attachment to any obvious nutrient source and are non-parasitic on the supporting host plants (Petruzzello & Mellisa, 2020). The neotropical realm alone is known to house over 15000 species of epiphytes and over 30,000 species worldwide, inclusive of uncatalogued species. A study done by Rhett (2012) showed that epiphytes are found throughout the rainforests, but the greater abundance of epiphytes is known in cloud forest. Dominantly, epiphytes are also found in humid and moist tropical areas. Their ability to grow above ground level aids in access to solar energy in dense shaded forests. Furthermore, epiphytes exploit the nutrients available in the tree canopy (Gradstein, 2008).

diversity vulnerable to changing environment (Xuanru et al., 2020). With industrialization and demographic increase, forest destruction is caused. When continuous destruction of forests due to anthropogenic activities occurs, it is

known to have negative effects on epiphytes (FAO, 2003; Hieta et al., 2006; Adeleye, 2017). Moreover, continuous extraction of commercially valuable vascular epiphytes will make the species extinct in the wild (Molina & Echen, 2018). Till date, only few inventories were conducted on epiphytes and parasitic plants especially in Asia, probably due to robust habitat (Hsu & Wolf, 2013; Palacio & Franco, 2001; Kuper, 2004). Epiphytes and parasitic plants are the least explored and the least studied in Bhutan. Some baseline information on epiphytes and parasitic plants are, therefore, needed and it is important that they are further studied. This research will add knowledge on the diversity and distribution range of epiphytes and parasitic plants in Bhutan.

#### Objectives:

- To assess the diversity of epiphytes and parasitic plants in Lampelri Forest at different altitudinal gradients;
- To assess the host tree preference by different epiphytes and parasitic plants; and
- To determine the growth zones of epiphytes and parasitic plants on the host tree.

#### Materials and methods

##### Sampling design

The sampling methodology included transect technique, i.e., belt transect and systematic random sampling (Pyakurel & Gurung, 2014). Sixty 10×10m sampling plots (Nepal & Dorji, 2020) were established in and around the forested area of Lampelri. An interval of 50m between each sample plots was constantly maintained along transects. A colossal data based on diversity, host preference, and zone of growth on phorophytes were recorded from 60 plots.

##### Data collection

All the epiphytes and parasitic plants occurring within the sampling quadrant (10×10m) were recorded and taken for further taxonomical

#### Study Area

The study was conducted in Lampelri Forest, located at 27.50°N and 89.74°E. The elevations range from 2650m to 3100m above sea level. Lampelri is known for its unique micro-climate and is an important tourist site.

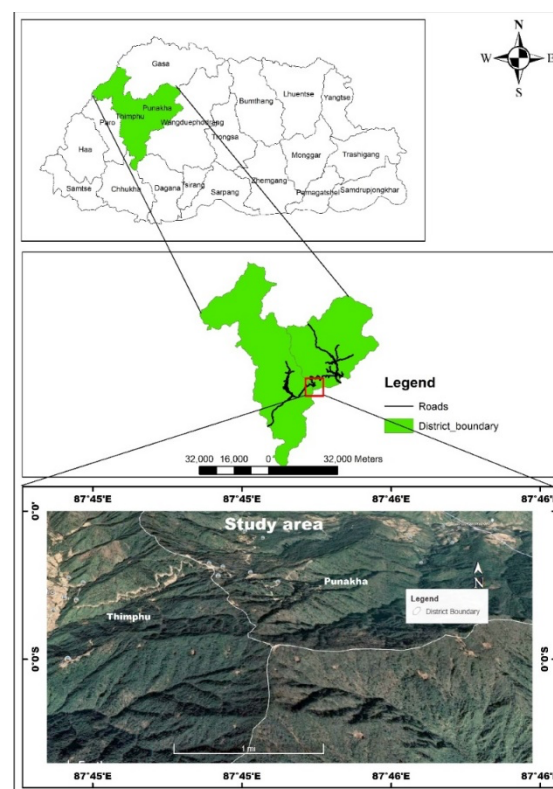
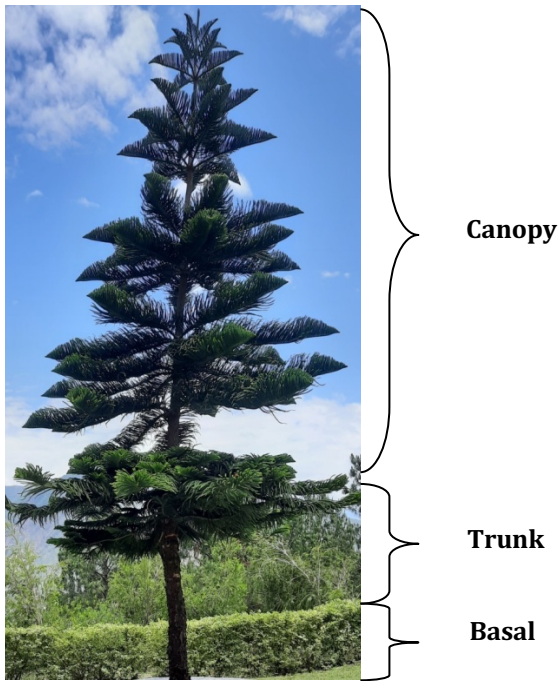


Figure 1: Study area map

identification. The species collected were taken to the National Biodiversity Centre for identification while the Flora of Bhutan (Grierson & Long, 2001; Noltie, 1994) was used for identification of a species on site.

Since phorophytes with DBH less than 10cm provided reduced surface area for vascular epiphytes, trees with DBH greater than 10cm were regarded an adequate host for sampling epiphytic and parasitic plants from each sample plot (Seifert, 1995 as cited in Jambay et al., 2021). The growth position of epiphytes and parasitic plants on a host tree was determined using the zonation method (Mojiol et al., 2009 as cited in Jambay et al., 2021). Latitude, longitude, altitude, and features of the place were also reported.



- a) **Zone 1:** Basal, from ground level to the diameter at breast height (dbh).
- b) **Zone 2:** Trunk, from dbh to the first branch.
- c) **Zone 3:** Canopy, from first branch to the tip of tree.

**Host-species preference survey method**

Figure 2: Diagram showing the zone of growth classification

Field equipment such as GPS (Garmin *etrex vista*), SUUNTO compass, SUUNTO clinometers, diameter tape, standard measuring tape, camera, binocular, Laser Range Finder, field guide book, and other relevant references were used for the survey. For epiphytes and parasitic plants thriving on big trees, inventory was carried out by climbing on the tree.

*Diversity*

Plant species diversity was studied using the Shannon-wiener and Simpson diversity indexes (Dougall & Dodd, 1997), while evenness was determined using Pielou's methodology. The following is how the check list of floristic data from the field was processed using Microsoft Excel's pivot table. Shannon-wiener index:

$$H = \sum_{i=1}^S pi \ln pi$$

Where, S = Species richness (total no. of species in a plot or an area)

Ln = natural logarithm or log

*Important Value Index (IVI)*

The Important Value Index (IVI) is a statistical variable and the most important metric for

$$pi = \frac{\text{No. of individuals of a species}}{\text{Total no. of individuals of all species}} -$$

(Relative abundance)

Simpson diversity index:

$$Ds = \frac{\sum ni(ni-1)}{N(N-1)}$$

Where, n= Number of individuals in particular species

N= Total numbers of organism of all the species

Pielou's species evenness index (Shannon's equitability):

$$J^I = \frac{H'}{H_{max}} = \frac{H}{\ln S}$$

Where, S= Total number of species in the sample/plot

H' = Shannon- wiener Index

ln = Natural logarithm

displaying an overall picture of the floristic species' ecological relevance in the vegetative community. It comprises the relative

frequencies, densities, and relative dominance of each species in a research site, with total values ranging from 0-300.

$$\text{Relative Density} = \frac{\text{Density of a species}}{\text{Total density of all species}} * 100$$

$$\text{Relative frequency} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} * 100$$

$$\text{Relative cover \%} = \frac{\text{Total \% cover of sp.A in all plots}}{\text{Total no.of plots}} * 100$$

#### *Identification of the species*

Each tree was investigated on the ground from a variety of angles to ensure that all host branches were examined. Orchids were observed using binoculars as well as with the naked eye. The orchids were captured with a long-range camera for huge trees (Canon 700D). The host species and epiphytic orchids were recognized in the field using a variety of local floras, and those that could not be identified were photographed in detail, including their flowers, leaves, and fruits, and samples were taken.

#### **Data analysis**

Microsoft Excel was used to compile, sort, filter, and clean the data. Spearman correlation will be

used to assess the link between altitude and epiphytic and parasitic plant diversity. The statistical test was performed using the software R.

#### **Results and discussion**

##### *Composition of epiphytic and parasitic species*

The data were collected from the altitudinal range of 2615-3100masl inclusive of Lampelri-Royal Botanical Park. A total of 32 species falling in 30 genera and 15 families were recorded. The most dominant family recorded was Polypodiaceae ( $n=10$ ), followed by Ericaceae family with 5 different species (Figure 4.1). The majority of the species recorded were epiphytic and only 3 species namely *Cuscuta sp.*, *Arceuthobium minutissimum*, and *Taxillus kaempferi* were known to be parasitic on the host plants.

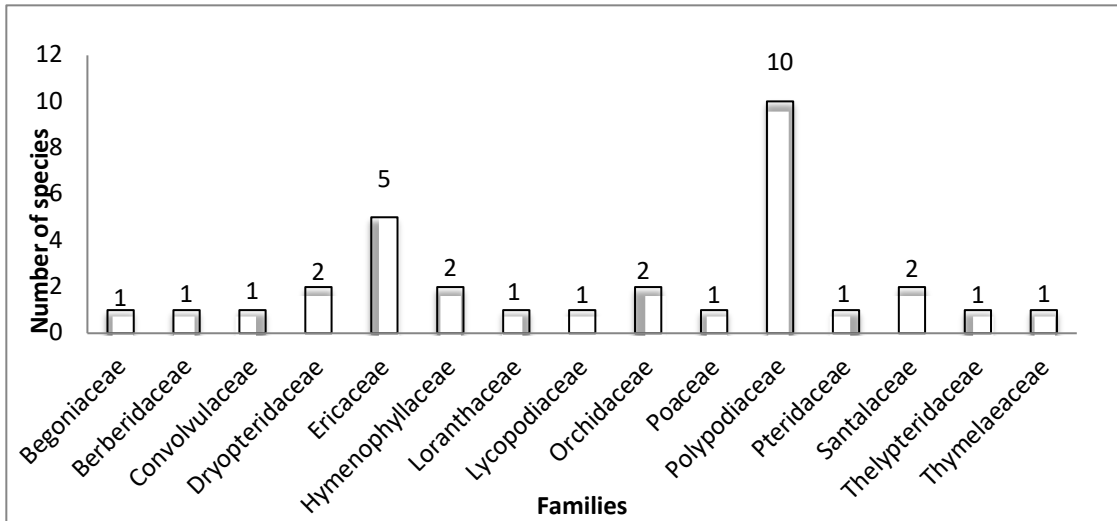


Figure 3. Family distribution of epiphytic and parasitic plant species in the study area

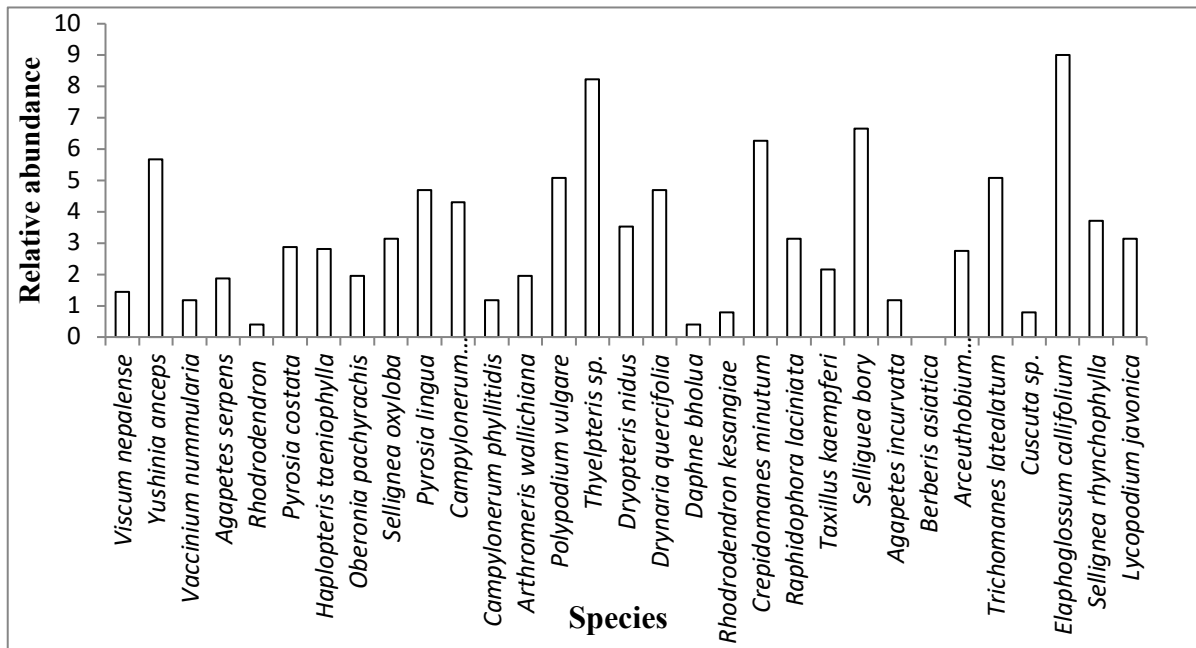


Figure 4. Epiphytic plants and parasitic plants and their relative abundance.

From a total of 32 species under 15 families, *Drynaria quercifolia* was known to be relatively high in species quantity or abundance ( $RA=31.22\%$ ,  $n=98$ ), followed by *Agapetes*

*serpens* ( $RA=16.40\%$ ,  $n=45$ ). The least abundant species found were *Daphne bholua* ( $RA=0.04\%$ ,  $n=1$ ), *Rhododendron* sp. ( $RA=0.04\%$ ,  $n=1$ ), and *Berberis asiatica* ( $RA=0.04\%$ ,  $n=1$ ) (Figure 4.2).

**Epiphytic and Parasitic Plant Species Dominance in the study area**

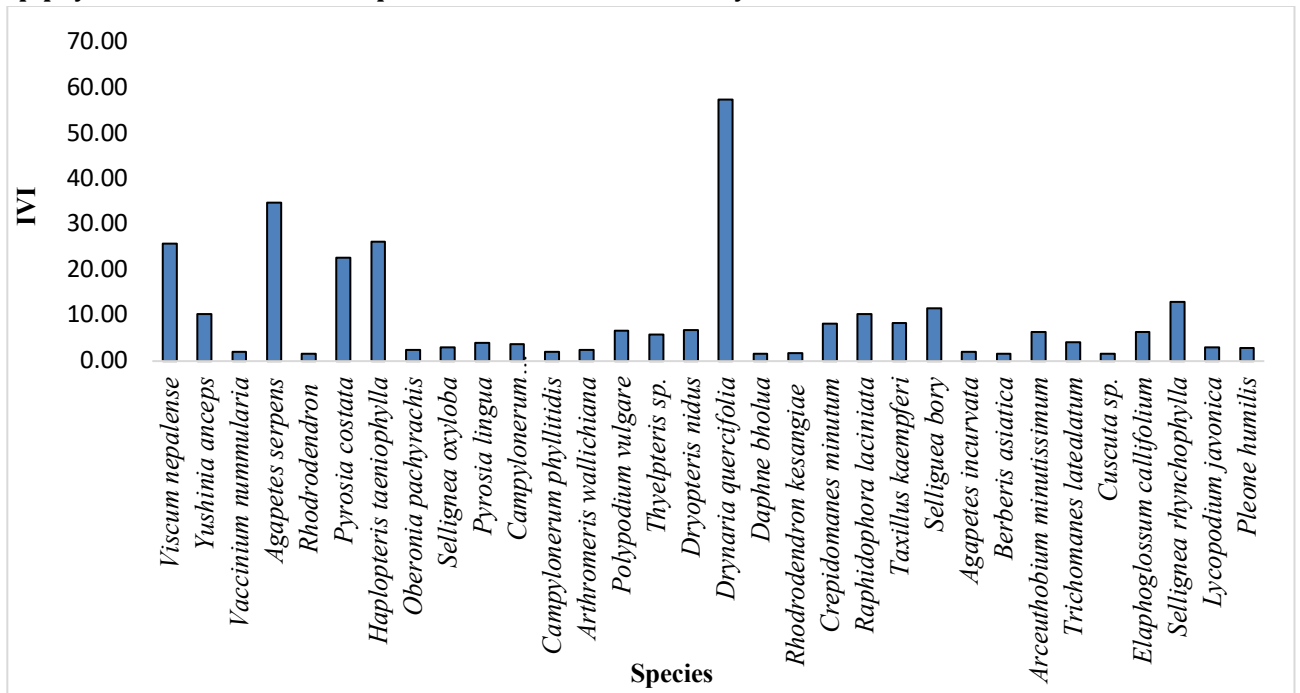


Figure 5: IVI of individual species recorded from the study area

Important Value Index (IVI) was calculated for individual species that were recorded from the study area. *Drynaria quercifolia* was found to be the most dominant species (IVI=57.37), followed

by *Agapetes serpens* with IVI of 34.77. *Daphne bholua*, *Rhododendron sp.* and *Cuscuta sp.* were known to be the least dominant species (IVI=1.55 each) (Figure 4.3).

**Species diversity, richness, and evenness of epiphytic and parasitic plants**

Table 1: Epiphytic and parasitic plant diversity, evenness, and richness

Shannon diversity index (H')	Simpson's diversity index (D)	Pielou's evenness (J)	Margalef's richness (Dmg)
2.93	0.07	0.85	4.87

The Lampelri region was known to harbour a diverse epiphytes and parasitic plants. Species diversity, evenness, and richness corresponded to 2.93, 0.07, 0.85 and 4.87 for the Shannon diversity index, Simpson's diversity index, Pielou's evenness and Margalef's richness, respectively (Table 4.1). The Lampelri region was found to be highly diverse with Shannon diversity index greater than 2.5 and Simpson's diversity index close to zero.

*Relationship between altitude and species diversity in the study area*

Spearman's rho correlation conducted between altitude and species diversity in the study area showed no significant association ( $p>0.173$ ). However, there was a weak and negative correlation between altitude and species diversity ( $r=-0.180$ ). According to Tenzin & Yonten (2021), the number of orchid species recorded from different altitudinal classes showed variations in species diversity (H') and richness (Dmg), with the highest being recorded from 1150 -1350 m (H' = 2.45, Dmg = 3.45)

followed by 1551 - 1750 ( $H' = 2.44$ ,  $Dmg = 3.16$ ), and finally 1751 -1950 ( $H' = 2.40$ ,  $Dmg = 2.99$ ).

When the number of epiphytic orchids reached a particular level of abundance, the number of species decreased with increase in height. This is also in line with the findings of Bose et al. (1999), who found that epiphytic orchids are plentiful up to 1800masl and that their frequency of occurrence diminishes as altitude rises.

The epiphytic species richness peaks at roughly 1500masl (Kromer et al., 2005). Wolf et al.

(2009) discovered that the epiphytic orchids had a noticeable mid-elevation bulge in species richness at the altitudinal level of 1500m. According to Acharya et al. (2011), the largest epiphyte species richness is seen at lower elevations around 1500masl (*masl*).

*Environmental variables and the species diversity*

	Slope	Elevation	Temperature (°C)	Precipitation (mm)	Evapotranspiration (mm)	Water Balance (mm)	H
N	51	51	51	51	51	51	51
Min	15	2660	9.53548	521.492	794.4	-447.89	0
Max	70	3098	11.9479	1146.5	849.15	798.652	0.691
Sum	2030	146546	549.1111	42986.2	41946.03	11876.83	8.454
Mean	39.8039	2873.451	10.76688	842.8667	822.4711	232.8791	0.16576
Std. error	2.13266	18.72646	0.102362	24.62434	2.341072	47.92705	0.03918
Variance	231.960	17884.69	0.534374	30924.27	279.5114	117147.1	0.07829
Stand. dev	15.2302	133.7337	0.731009	175.853	16.71859	342.2676	0.27980
Median	35	2910	10.55456	888.7792	817.9	340.772	0
25 prcntil	30	2745	10.14071	667.5092	808.9	-106.216	0
75 prcntil	55	2982	11.47195	950.8712	838.525	457.93	0.393
Skewness	0.04314	-0.08576	0.093488	0.124569	0.085536	-0.03633	1.18496
Kurtosis	-	-1.25886	-1.25265	-0.91453	-1.2595	-0.91018	-
Geom. mean	36.5690	2870.388	10.74259	824.5802	822.3046	0	0
Coeff. var	38.2632	4.654113	6.789418	20.86368	2.032727	146.9722	168.798

Figure 6. Meteorological and Hydrological data analysis

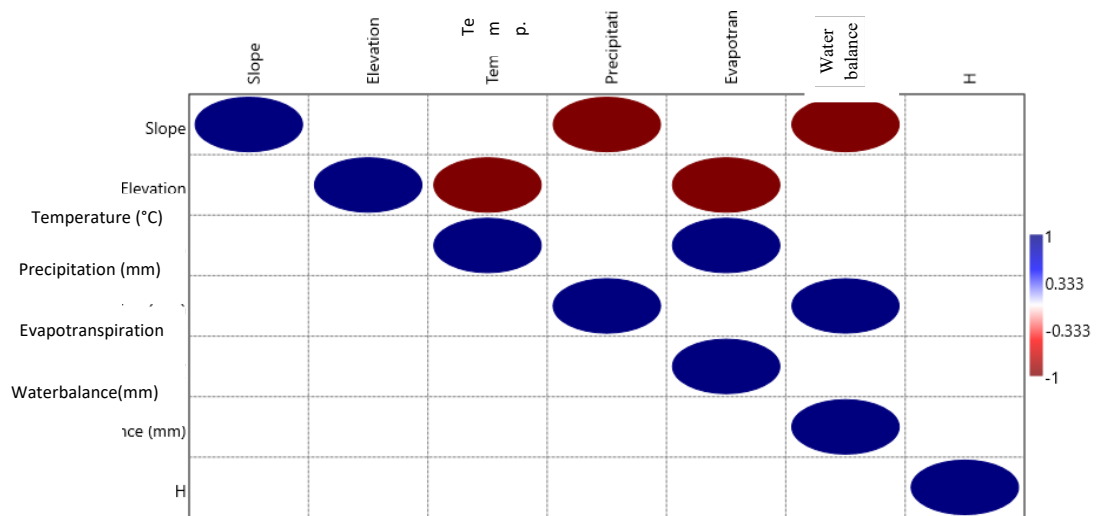
*Relationship between different environmental factors and species diversity*

Figure 7. Correlation between different environmental factors and species diversity.

Mountainous terrains and topography create fine-scale environmental mosaic that varies in precipitation, moisture, water balance, temperature, and slope (Gazol & Ibanez, 2010). This in turn influences the species diversity i.e., species richness and species abundance. Spearman's rho correlation shows that there was significantly strong negative correlation between slope and precipitation, and also between slope and water balance. Significantly, strong negative correlation was also observed between elevation and temperature and elevation and evapotranspiration. Figure 4.4 also shows that there was strong positive correlation between temperature and evapo-transpiration and between precipitation and water balance.

Likewise, Gazol and Ibanez (2010) investigated vascular plant diversity patterns in an unmanaged temperate forest in northern Spain. Environmental and spatial characteristics were used to measure diversity. On south facing slopes, diversity values were higher than on north facing slopes. Furthermore, Song et al., (2021) discovered that soil moisture at lower elevations and temperature at higher elevations had a substantial impact on tree species distribution. Plant distribution along an elevational gradient typically represents

differences in water availability at different elevational gradient.

Precipitation has been shown to be the limiting factor for plant dynamics across broad scale altitudinal gradients (Ali et al., 2019), particularly for understory tree seedlings, which are more susceptible to water availability in the dry season than in the rainy season (Ali et al., 2019). (Comita & Engelbrecht, 2009). Species diversity dropped in tropical regions during the dry season, which coincided with a decrease in soil moisture along elevational gradients. Previous research has suggested that tree species at higher elevations prefer cool, wet environments because they are heavily influenced by environmental factors such as temperature (Wu et al., 1987).

Elevation and valley depth have long been considered to be the most important indicators of tree species distribution in central European mountain ecosystems. Geomorphometric variability has been discovered to alter species occurrence and biomass patterns, contributing to increased species diversity (Dyderski & Pawlok, 2020).

## Correlation between species diversity with different environmental variables

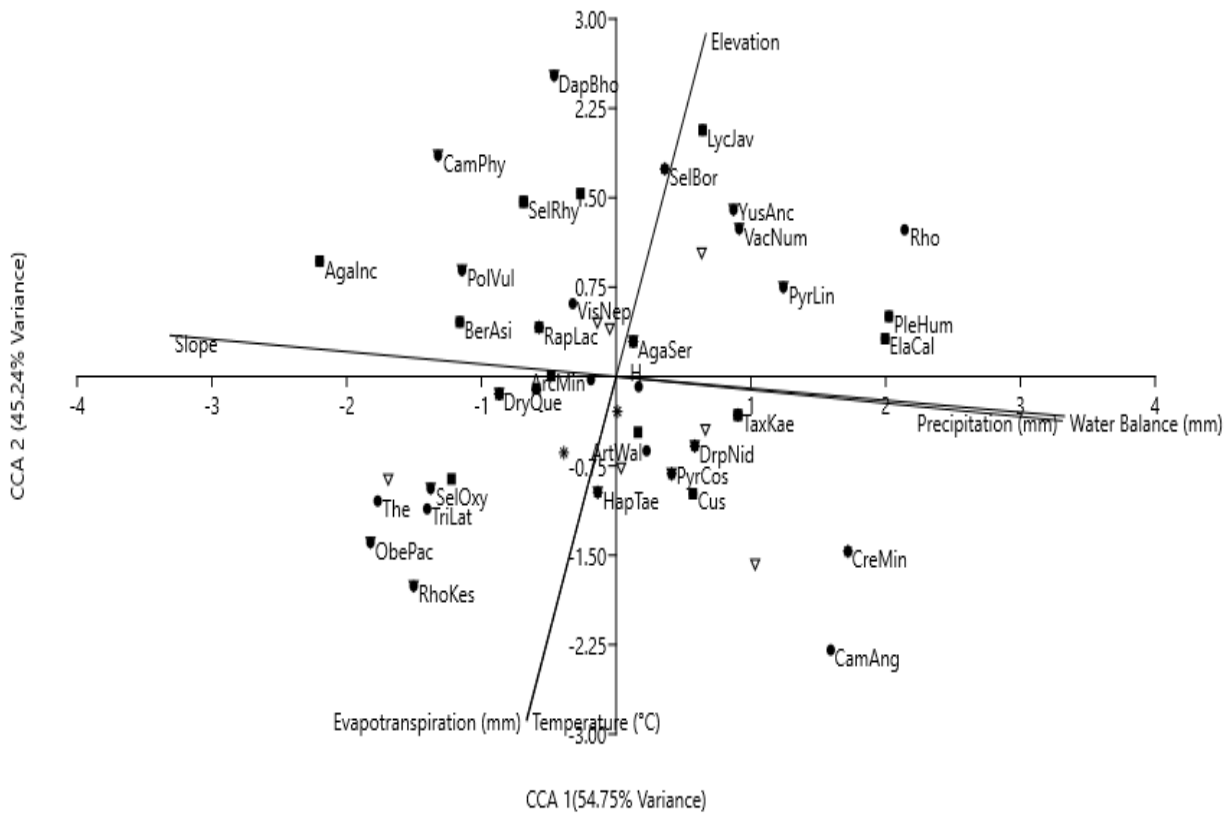


Figure 8. Canonical correspondence analysis.

Figure 8 shows canonical correspondence analysis (CCA) displaying the relationship of species diversity and their environmental variables inclusive of elevation, temperature, precipitation, evapo-transpiration, water-balance and slope. Species such as *Daphne bholua*, *Yushinia anceps*, *Vaccinium numularia*, *Agapetes serpens*, and *Lycopodium javonica* were highly influenced by environmental variable like elevation. *Taxillus kaempferi*, *Dryopteris nidus*, and *Pyrosia costata* were found to be influenced by water balance and precipitation while species such as *Selliugaea bory*, *Thelypteris*, *Trichomanes latealatum*, and *Rhododendron kesangiae* were dominantly influenced by evapo-transpiration. *Agapetes incurvata*, *Selliugaea rhynchophylla*, *Campylonerum phyllitidis*, *Berberis asiatica*, *Polypodium vulgure*, *Viscum nepalense*, and *Raphidophora laciniata* were known to be

influenced dominantly by slope variable which is obvious in a mountainous place.

*Host tree composition*

Epiphytes and parasitic plants were found on diverse group of phorophytes. A total of 15 different species of host plants belonging to 12 genera and 9 families were recorded from the study area. Fagaceae family was the most common and dominant host species with five different species, namely *Quercus oxyodon*, *Quercus glauca*, *Quercus griffithii*, *Quercus sp.*, and *Castanopsis tribuloides*. Pinaceae was the second dominant host family with three species under the family. Three species hosted by pinaceae family were *Abies densa*, *Tsuga Dumosa*, and *Picea spinulosa* (Figure 4.4). *Schima wallichii*, *Quercus griffithii*, and *Schima khasiana* are the most prevalent and dominating host species in Nepal, according to Adhikari et al. (2015).

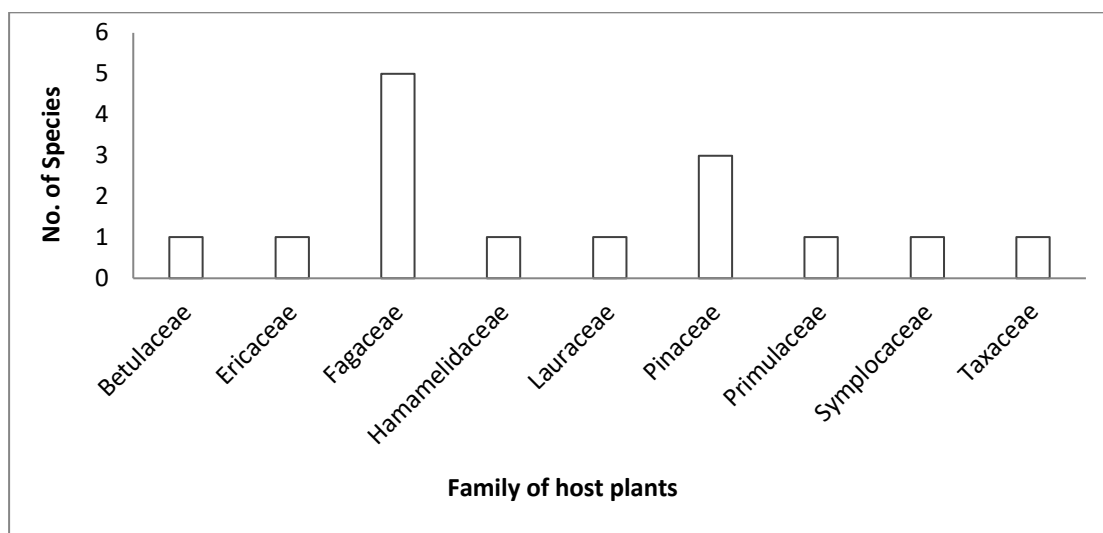


Figure 9. Family distribution of host plants

Table 2: Epiphytes and their preferred phorophyte

Host plant	Epiphytes and parasitic plants found
<i>Abies densa</i>	<i>Taxillus kaempferi</i> , <i>Agapetes serpens</i> , <i>Rhododendron sp.</i> , <i>Daphne bholua</i> , <i>Viscum nepalense</i> , <i>Rhododendron kesangiae</i>
<i>Quercus sp.</i>	<i>Raphidophora laciniata</i> , <i>Selliguea rhynchophylla</i> , <i>Elaphoglossum califolium</i> , <i>Agapetes serpens</i> , <i>Pyrosia costata</i> , <i>Pyrosia lingua</i>
<i>Quercus oxyodon</i>	<i>Drynaria quercifolia</i> , <i>Crepidomanes minutum</i> , <i>Trichomanes latealatum</i> , <i>Dryopteris nidus</i> , <i>Yushinia anceps</i> , <i>Campylonerum phyllitidis</i>
<i>Picea spinulosa</i>	<i>Vaccinium nummularia</i>
<i>Symplocus glomerata</i>	<i>Haplopteris taeniophylla</i> , <i>Oberonia pachyrachis</i>
<i>Tsuga dumosa</i>	<i>Pyrosia costata</i> , <i>Selliguea bory</i> , <i>Agapetes serpens</i> , <i>Selliguea rhynchophylla</i> , <i>Lycopodium javonica</i> , <i>Yushinia anceps</i> , <i>Thelypteris sp.</i> , <i>Selliguea oxyloba</i> , <i>Campylonerum angustifolia</i>
<i>Quercus glauca</i>	<i>Viscum nepalense</i> , <i>Pleone humilis</i> , <i>Arthromeriswallichiana</i>
<i>Quercus griffithii</i>	<i>Agapetes serpens</i> , <i>Drynaria quercifolia</i> , <i>Agapetes incurvata</i> , <i>Taxillus kaempferi</i> , <i>Pyrosia costata</i> , <i>Polypodium vulgure</i>
<i>Castanopsis tribuloides</i>	<i>Haplopteris taeniophylla</i> , <i>Viscum nepalense</i>
<i>Taxus bacatta</i>	<i>Arceuthobium minutissimum</i>
<i>Lyonia ovalifolia</i>	<i>Cuscuta sp.</i>

<i>Dodecadenia grandiflora</i>	<i>Berberis asiatica</i>
<i>Corylus ferox</i>	<i>Haplopteris taeniophylla</i>
<i>Maesa chisia</i>	<i>Haplopteris taeniophylla</i>
<i>Exbucklandia populnea</i>	<i>Raphidophora laciniata</i>

As shown in Table 4.3, host species such as *Tsuga dumosa* was found to be the most common host plant preferred by epiphytes and parasitic plants (n=9), followed by *Abies densa*, *Quercus griffithii*, and *Quercus oxyodon* (n=6). The host species least preferred by the plants were *Lyonia*, *Dodecadenia*, *Taxus bacatta*, and *Corylus ferox* with only one type of species found supported by them. Out of 32 species, *Agapetes serpens* and *Haplopteris taeniophylla* were the two most common epiphytes found on different types of host plants.

Tenzin and Yonten (2021) found out that Families containing many species had the highest occupancy rate at the family level (e.g., Fagaceae).

The Fagaceae family had the highest total number of orchids, with 603 individuals, followed by Theaceae with 457 individuals, and Ericaceae with 314 individuals, while most other families had a tiny number of orchid individuals reported. This contradicts Sayago et al. (2013)'s result that showed epiphytes are more likely to be found in frequent host species. The species composition of epiphytic orchids is also linked to the host species and the families to which they belong. In similar geographic or climatic conditions, the same host plant hosts similar types of epiphytic orchids (Callaway et al., 2002).

Table 3. Epiphytes and parasitic plants and their zone of growth.

Species	Family	Zone of Growth
<i>Viscum nepalense</i>	Santalaceae	Canopy
<i>Yushinia anceps</i>	Poaceae	Basal
<i>Vaccinium nummularia</i>	Ericaceae	Trunk
<i>Agapetes serpens</i>	Ericaceae	Canopy
<i>Rhodrodendron</i>	Ericaceae	Trunk
<i>Pyrosia costata</i>	Polypodiaceae	Canopy
<i>Haplopteris taeniophylla</i>	Pteridaceae	Trunk
<i>Oberonia pachyrachis</i>	Orchidaceae	Trunk
<i>Sellignea oxyloba</i>	Polypodiaceae	Basal
<i>Pyrosia lingua</i>	Polypodiaceae	Trunk
<i>Campylonerum angustifolium</i>	Polypodiaceae	Basal
<i>Campylonerum phyllitidis</i>	Polypodiaceae	Trunk
<i>Arthromeris wallichiana</i>	Polypodiaceae	Trunk
<i>Polypodium vulgare</i>	Polypodiaceae	Trunk
<i>Thelypteris sp.</i>	Thelypteridaceae	Basal
<i>Dryopteris nidus</i>	Dryopteridaceae	Basal
<i>Drynaria quercifolia</i>	Polypodiaceae	Canopy

<i>Daphne bholua</i>	Thymeleaceae	Basal
<i>Rhododendron kesangiae</i>	Ericaceae	Trunk
<i>Crepidomanes minutum</i>	Hymenophyllaceae	Trunk
<i>Raphidophora laciniata</i>	Begoniaceae	Trunk
<i>Taxillus kaempferi</i>	Loranthaceae	Canopy
<i>Selliguea bory</i>	Polypodiaceae	Trunk
<i>Agapetes incurvata</i>	Ericaceae	Canopy
<i>Berberis asiatica</i>	Berberidaceae	Basal
<i>Arceuthobium minutissimum</i>	Santalaceae	Canopy
<i>Trichomanes latealatum</i>	Hymenophyllaceae	Trunk
<i>Cuscuta sp.</i>	Convolvulaceae	Trunk
<i>Elaphoglossum callifolium</i>	Dryopteridaceae	Basal
<i>Selliguea rhynchophylla</i>	Polypodiaceae	Basal
<i>Lycopodium javonica</i>	Lycopodiaceae	Basal

### Conclusion

Though the study was conducted in a small forested area at Lampelri, the diversity of epiphytes and parasitic plants was significant, with 31 species identified, three of which were parasitic and 28 of which were epiphytic. A total of 56 host species were identified, with 15 species belonging to 9 groups and 12 genera. This research suggests that Lampelri is home to many more species than were discovered during the survey.

In epiphytes and parasitic communities at various altitudes, there were differences in species richness, abundance, and species composition. On trees at higher layers and on evergreen hosts, species richness and abundance were higher. Epiphytic abundance was higher on evergreen hosts. Families with several species have the highest occupancy (e.g., Fagaceae). There were also several connections between host characteristics, host species, and host family. Despite the fact that the current study highlights several elements of epiphytic and parasitic plants in the Lampelri area, the epiphyte rich areas still require more extensive

analysis in terms of their interactions with various organisms.

Since epiphytes respond to different seasons for flowering, research should be carried out over several years, or at least two seasons, to produce a more representative data collection. In addition, numerous additional variables, such as bark texture, pH, and rainfall, should be examined in future investigations. It would be an interesting to see if pH levels and rainfall affect or differ from associations that lead to epiphyte variety. Since, epiphytes can be used as house decor pieces and ornamental plants; it can be a source of income for rural livelihood through ecotourism in the Lampelri Botanical Park. Local people in that locality should be aware of their importance. Habitat destruction and habitat fragmentation have been major issues causing adversities on biodiversity conservation in the past decades. Meticulous study of endangered epiphytes and control of effects from parasitic plants are highly recommended for better conservation practices.

## References

- Acharya, K. P., Vetaas, O. R., Birks, H. J. B. (2011). Orchid species richness along Himalayan elevational gradients, *Journal of Biogeography*. 38: 1821-1833.
- Adhikari, Y.P, Fischer, A, &Pauleit, S. (2015). Sustainable conservation perspectives for epiphytic orchids in the central Himalayas, Nepal, *Applied Ecological Environment Research*. 13: 753-767.
- Bose, T.K., Bhattacharjee S.K., Das P. &Basak U.C. (1999). *Orchids of India*. Naya Prakash Bidhan Sarani, Calcutta, India.
- Callaway, R. M, Reinhart, K. O, & Moore, G. W. (2002). Epiphyte host preferences and host traits: mechanisms for species-specific interactions, *Orchid Ecology*. 132: 221-230.
- Bose, T.K., Bhattacharjee S.K., Das P. &Basak U.C. (1999). *Orchids of India*. Naya Prakash Bidhan Sarani, Calcutta, India.
- Benzing, D. H. (2004). Vascular epiphytes. *In: Forest canopies*, 175-211.
- Benzing, D. H. (1990). *Vascular Epiphytes General Biology and Related Biota*. Cambridge University Press. Cambridge, UK.
- Bouwmeester, H., Sinha, N. & Scholes, J. (2021). Parasitic plants: physiology, development, signalling and ecosystem interactions. *Plant Physiology*. 185: 1267-1269. DOI:10.1093/plphys/kiab055.
- Callaway, R. M, Reinhart, K. O, & Moore, G. W. (2002). *Epiphyte host preferences and host traits: mechanisms for species-specific interactions*, *Orchid Ecology*. 132: 221-230.
- Cummings, J., Martin, M., & Rogers, A. (2006). Quantifying the abundance of four large epiphytic fern species in remnant complex notophyll vine forest on the Atherto Tableland. North Queensland, Australia. *Cunninghamia*. 9(4), 521-527.
- Didham, R.K., Tylianakis, J.M., Hutchison, M.A., Ewers, R.M., and Gemmell, N.J. (2005). Are invasive species the drivers of ecological change? *Trends in ecology and evolution*, 20(9), 470-474.
- Grierson, A. J., & Long, D. G. (2001). *Flora of Bhutan, including a record of plants from Sikkim*. (Vol. 2): Royal Botanical Garden.
- Gentry, A. H. & Dodson, C. (1987b). Diversity and biogeography of neotropical vascular epiphytes. *Annals of Missouri Botanical Gardens*. 74:204-233.
- Hsu, C., Horng, F., & Kuo, C. (2002). Epiphyte biomass and nutrient capital of a moist sub tropical forest in north-eastern Taiwan. *J. Trop. Ecol.* 18: 659-670.
- Hietz, P. (1999). *Diversity and conservation of epiphytes in changing environment*. Proceedings of the International Conference on Biodiversity and Bioresources: Conservation and Utilization, pp. 23-27. Phuket, Thailand.
- Hietz, P., & Seifert, H. U. (1995). Composition and ecology of vascular epiphytes along an altitudinal gradient in central Veracruz, Mexico. *Journal of Vegetation Science*, 6(4), 487-498.
- Ingram, S. & Nadkarni, N. (1993). Composition and distribution of epiphytic organic matter in a neotropical cloud forest, Costa Rica. *Biotropica*. 25:309-321.
- Kress, W. J. (1986). The systematic distribution of vascular epiphytes: An update. *Selbyana*. 9:2-22.
- Kohler, L., Tobon, C., Frumau, K. & Brujinzeel, L. (2007). Biomass and water storage dynamics of epiphytes in old growth and secondary montane cloud forest stands in Costa Rica. *Plant Ecology*. 193:171-184.

- Mojiol, A. R., Jitinu, A. A., Adella, A., Ganang, G. M., and Nasley, N. (2009). Vascular epiphytes diversity at Pusatsejadi, Kawang Forest Reserve. *Journal of Ecology*, 2(1), 121-127.
- Molina, A. R. & Echem, T. R. (2018). Survey of Vascular Epiphytes in Selected Areas in Zamboanga City. *World Journal of Pharmaceutical and Life Sciences*, 4(7), 34-38.
- Press, M. C. & Phoenix, G. K. (2005). Impact of Parasitic Plants on Natural Communities. *New Phytology*. 166: 737-751. DOI: 10.1111/j.1469-8137.2005.01358.x.
- Rubiales, Diego. & Heide. (2011). *Parasitic Plants*. In: Encyclopedia of Life Sciences. DOI:10.1002/9780470015902.a0021271.
- Sillet, S.C. (1999). Tree crown structures and vascular epiphytes distribution in Sequoia sempervirens rainforest canopies. *Selbyana*, 20(1), 76-79.
- Tesitel, J., Watson, D. M., McLellan, R. & Bandaranayake, P. C. G. (2021). The Bright Side of Parasitic Plants: What are they good for? *Plant Physiology*. 185:1309-1324.
- Werner, F. A., Homeier, J., Oesker, M. & Boy, J. (2012). Epiphytic biomass of tropical montane forest varies with topography. *Journal of Tropical Ecology*. 28:23-31.
- Wolf, J. H. D. & Flamenco, S. A. (2003). Patterns in species richness and distribution of vascular epiphytes in Chiapas, Mexico. *Journal of Biogeography*. 30, 1689-1707.
- Zotz, G. & Bader, M. (2011). Sampling Vascular Epiphyte Diversity-Species richness and community structure. *Ecotropica*. 17: 103-112.
- Zotz, G. (2007). Johansson revisited: the spatial structure of epiphyte assemblages. *Journal of Vegetation Science*. 18: 123-130.
- Zotz, G. (2016). *The Role of Vascular Epiphytes in the Ecosystem*. In: Plants on Plants- The Biology of Vascular Epiphytes. Fascinating Life Sciences. Springer, Cham. Retrieved from [https://doi.org/10.1007/978-3-319-39237-0\\_9](https://doi.org/10.1007/978-3-319-39237-0_9).
- Zotz, G. (2007). The spatial structure of epiphyte assemblages, *Journal of Vegetation Science*. 18: 123-130