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Diversity and Distribution of Vascular Epiphytic Flora in Sub-temperate Forests of Darjeeling Himalaya, India

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Authors' contributions

This work was carried out in collaboration between both authors. Author PR conducted field study, collected data and prepared initial draft including literature searches. Author SM provided taxonomic expertise with identification and data analysis. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: This communication deals with the diversity and distribution including host species distribution of vascular epiphytes also reflecting its phenological observations.
Study Design: Random field survey was carried out in the study site to identify and record the taxa. Host species was identified and vascular epiphytes were noted.
Study Site and Duration: The study was conducted in the sub-temperate forests of Darjeeling Himalaya which is a part of the eastern Himalaya hotspot. The zone extends between 1200 to 1850 m amsl representing the amalgamation of both sub-tropical and temperate vegetation. The study was conducted during the year 2018-2019.
Methodology: Process of random sampling collection was followed. Host trees with CBH >30 cm were identified and percentage of distribution of epiphytes in the host tree was analyzed and divided into two zones depending on the abundance of epiphytes. Data for the epiphytic plant specimens were collected in the field. Exsiccates were made with the collected voucher specimens and were deposited at the Calcutta University Herbarium (CUH) following the conventional methodology. Study on the taxa are based on their host tree distribution, micro-habitat and phenological status. The location and altitude of the study sites were recorded by global positioning system.

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Results: A total number of 115 species under 70 genera and 31 families have been identified with 65% other vascular angiosperms (basal angiosperms and eudicots) and 16% monocots. Orchidaceae among the monocots represented 36% with 41 species and 18 genera. Ferns and lycophytes include 25% of the diversity with 29 taxa under 6 families. Most favorable host trees were *Ficus auriculata* Lour., *Ficus neriifolia* Sm., *Saurauia nepalensis* DC., *Erythrina variegata* L., *Macaranga denticulata* (Blume) Müll. Arg., *Cryptomeria japonica* (Thunb. ex L.*f.*) D. Don and *Engelhardia spicata* Lechen ex Blume.

Conclusion: The other vascular angiosperms preferred wet monsoon for flowering whereas spring season was most favourable for Orchidaceae. Although a healthy number of vascular epiphytes have been identified, a number of threats are still prevailing in the regions which are mostly anthropogenic. Proper collaborative strategies have to be maintained for its conservation.

Keywords: Vascular angiosperm; phenology; orchidaceae; host tree; conservation.

1. INTRODUCTION

Originally, the name epiphyte is derived from two Greek words *'epi=upon* and *phyton=plants'* [1]. Epiphyte may be defined as a plant that root and perch on the surface of another plant or non living objects without driving food from its host [2-5]. They are a unique and diverse group of plants with very interesting ecology [6] comprising about 10 % of the world's total flora [7]. Epiphytes are taxonomically heterogeneous group composed of over 28,000 species under 84 families and represent an important proportion of world flora [8,9]. They may be divided into holo-epiphytes, primary hemi-epiphytes, and secondary hemi-epiphytes functional types [10]. Holoepiphytes never have root contact with the soil while hemi-epiphytes are connected to the soil during part of their life-cycle at which stage they resemble vines (i.e. herbaceous climbers). Primary hemi-epiphytes germinate on other plants, usually trees, only to become terrestrially-rooted through aerial roots while secondary hemi-epiphytes germinate in the soil to lose contact later. They contribute to the richness of local and regional floristic diversity Microhabitats on trees trunks, barks and irregular surfaces on branches are all favourable for the growth of epiphytes [11]. Epiphytes ecologically contribute to forest biodiversity in increasing species richness [12], primary productivity, biomass, water retention and also provide substrate for nitrogen fixing bacteria and serve as indicators of change in microclimate as well as global climatic change [13,14] including nutrient store [15]. They also provide food and shelter for fauna [16]. Some angiospermic epiphytes have ethnomedicinal uses and are used against several ailments [17]. Vascular epiphytes are vulnerable group and consequently represent a good indicator group of biodiversity that can be monitored to assess the effects of forest disturbance [18]. Many vascular epiphytes exhibit physiological and morphological characteristics that help them survive drought [19] and also assist in water retention, such as thickened or succulent leaves, or rhizomes and specialized water storage tissue [4,6,20,21,22]. The vascular epiphytes are sensitive to moisture which makes them a good environmental indicator for both successional stages of forest ecosystems and natural environmental variations [23,24]. The communities of vascular epiphytes have been used as bio-indicators of climate change, pollution and damage to ecosystems [25,26,27]. This sensitivity becomes important in the context of conservation, given that many of the epiphytic species have a high degree of specialization with their phorophyte, thus becoming vulnerable to extinction by habitat and climate change [28,29]. Vascular epiphytes in majority comprise of fern and monocots - especially orchids, bromeliads and aroids with relatively fewer other angiosperms [30]. Phorophyte structure, substrate availability and dispersal syndromes are main factors for distribution pattern of vascular epiphytes [31,32]. Besides, establishment of vascular epiphytes provide suitable niche through autogenic succession to other epiphytes [33]. The species of vascular epiphytes are increasingly threatened and decrease in population due to over-collecting horticulturally valuable species for commercial purposes and habitat loss due to deforestation and land use changes [30]. Works related to epiphytes have been conducted in Western Ghats [34-36], Western Himalayas [37-40], Central Himalayas [41-43] as well as towards the Eastern Himalaya [44-47].

Although, several workers have explored the flora of Darjeeling Himalaya [48-54], only few

notable works with particular reference to vascular epiphytes are known [45,46]. Therefore, there is a need to investigate and understand the rich vascular epiphytic flora from Darjeeling region of eastern Himalaya.

2. METHODOLOGY

2.1 Study Area

The present study was conducted in the Sub-temperate forests of Darjeeling Himalaya. The Darjeeling Himalaya extends between 27°13'10" N to 26°27'05" N Latitude and 88°53' E to 87°59' 30" E Longitude that is located in India's state West Bengal, in the Himalayan foothills at an altitudinal range of 130 to 3636 m amsl. It is situated at the northernmost end of the Eastern India in the form of an inverted wedge, covering about 3.68% of the total area of the state of West Bengal. The northernmost point of the district is the tri-junction near Phalut [27°13'10" N; 88°21'E] and the southern-most point is the Phansidewa block [26°27'05" N; 88°22' E]; likewise the west to east extension of the district lies between Sabarkum near Sandakphu [87°59' 30" E; 27°12' N] and Todey village along river Jaldhaka [88°53' E; 27°04' N]. Due to the altitudinal variation that range from tropical plain to sub-alpine zone, different climatic zones are available in Darjeeling Himalaya which offers favourable environment for the growth and development of all plant species including epiphytes and their migration in different habitats [52]. The Sub-temperate vegetation zone has been classified between 1200 to 1850 m amsl and represents the amalgamation of both the sub-tropical and temperate vegetation with intermediate type of forest composition. The climatic set-up of four seasons are recognized in the region: (i) Winter from December to February, (ii) Spring and summer from March to May, (iii) Monsoon or Rainy Season from June to August, and (iv) Autumn from September to November [51]. The temperature in the region varies with a minimum of 2.4°C to a maximum of 9.6°C during winter, 8.3°C to 19.1°C during spring and summer and 12°C to 18°C during autumn season with an average annual precipitation of about 337.3 mm.

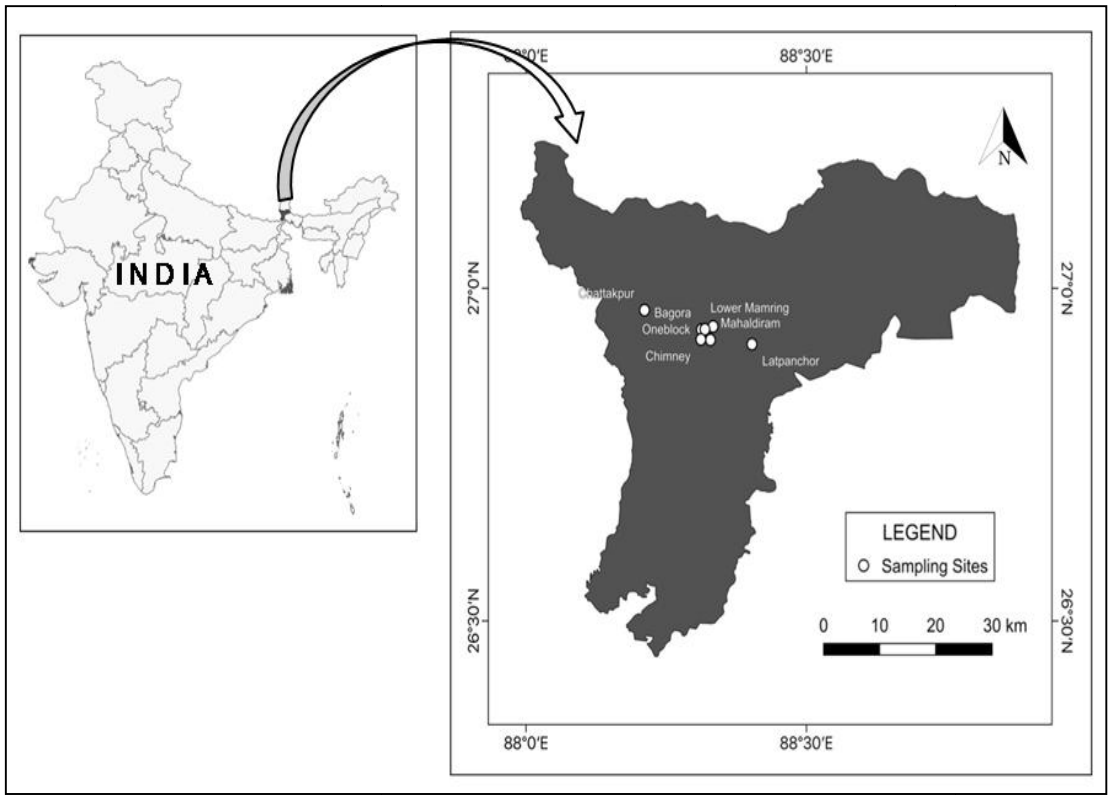

Fig. 1. Map of the study area showing sampling sites

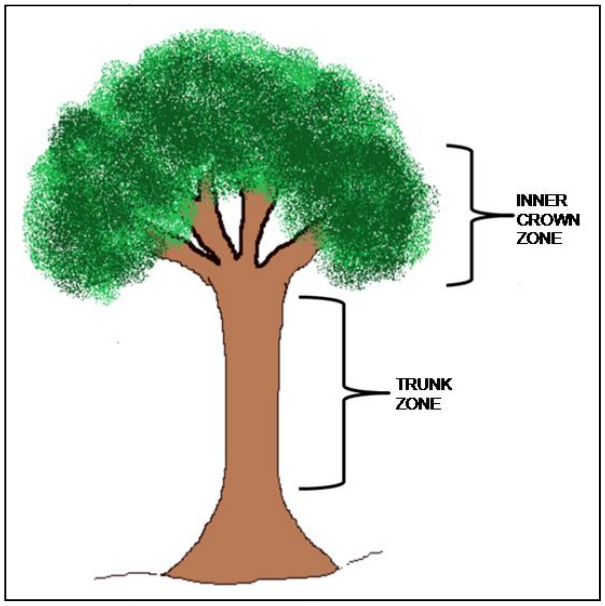

Fig. 2. Zone of host tree trunk

2.2 Data Collection

Field survey was carried out from October 2018 to October 2019 in the forest that lied within the Sub-temperate altitude. The process of random sampling collection was followed. Some of the areas under study include Bagora [26º9378' N, 88º 3127' E], Lower Mamring [26º56.557' N 88º 20.018' E], Oneblock [26º56.302' N 88º 19.134' E], Chimney [26º55.384' N 88º18.699' E], Chattakpur [26º9671' N 88º2112' E], Latpanchor [26º9159' N 88º 4028' E], Mahaldiram [26º9224' N 88º3288' E] and areas where the diversity of vascular epiphytes was rich (Fig. 1).

Data on abundance of epiphytic plant specimens were collected in the field with the assistance of local tree climber; epiphytic plants were collected both from the ground and tree. Host tree species with >30 cm CBH were identified and sampled randomly in the forest and segregated into two zones i) Trunk zone covering the area below the first branching till the base and ii) Inner crown zone covering the remaining area above the first branching (Fig. 2). The phenological status of the taxa was also noted through field visit in different seasons. The voucher specimens collected were mounted into herbarium sheets following the conventional methodology [55]. The identification of the taxa were made following suitable literatures and proper nomenclature was maintained following Plants of the World Online [56]. Properly mounted and labelled herbarium exsiccates have been preserved for future study and were deposited at the Calcutta University Herbarium (CUH). The location and altitude of the study sites were recorded by global positioning system (GPS; Garmin eTrexH).

3. RESULTS AND DISCUSSION

3.1 Results

The present study exposed the interesting composition of vascular epiphytes with a total number of 115 species under 70 genera and 31 families. 81% were spermatophytic families comprising 65% other vascular angiosperms that include basal angiosperms and eudicots and 16 % monocots. The other vascular angiosperms represented 38 species under 28 genera. The dominating family was Ericaceae, Gesneriaceae and Piperaceae with 4 species each followed by Acanthaceae, Apocynaceae and Urticaceae with 3 species (Fig. 3). The monocots were represented by 48 species under 25 genera. Orchidaceae showed biggest abundance on all phorophytes with 18 genera and 41 species representing 36% with *Dendrobium* Sw. being the most diverse followed by *Bulbophyllum* Thouars and *Cymbidium* Sw. The ferns and lycophytes include 25% of the taxa identified with 29 species and 17 genera under 6 families with Polypodiaceae being the most abundant family with species like *Pyrrosia* Mirb. *Goniophlebium*

Blume (C. Presl) *Oleandra* Cav. and *Lepisorus* (Sm.) Ching (Table 1). The study revealed that the angiospermic herb represented 40%, while the climbers and shrubs were 16 (14%) and 8 (7%) respectively. Pendulous plants like *Hoya serpens* Hook.*f.* and *H. linearis* Wall. ex D.Don also represented 2% with only 1% of parasitic plants (Fig. 4).

The vegetation of this short vertical zone between 1200 to 1850 m was found to be an amalgamation of sub-tropical and temperate type. The zone harbored dominating tree and shrub species like *Brassaiopsis hainla* (Buch.-Ham.) Seem., *Brassaiopsis hispida* Seem., *Engelhardia spicata* Lechen ex Blume, *Macaranga indica* Wight, *Alnus nepalensis* D. Don, *Luculia gratissima* (Wall.) Sweet., *Buddleja asiatica* Lour., *Camellia kissi* Wall. *Casearia glomerata* Roxb., *Cestrum aurantiacum* Lind., *Cryptomeria japonica* (Thunb. ex L.*f.*) D. Don, *Exbucklandia populnea* (R.Br. ex Griff.) R.W.Br., *Edgeworthia gardneri* (Wall.) Meisn., *Boehmeria glomerulifera* Miq., *B. macrophylla* Hornem., *Clematis semilacifolia* Wall., *Porana grandiflora* Wall., *Tetrastigma rumicispermum* (M.A. Lawson) Planch., *Osbeckia stellata* Buch.-Ham. ex D.Don, *Oxyspora paniculata* DC., *Holboellia latifolia* Wall.,, *Dichroa febrifuga* Lour., *Agapetes sikkimensis* Airy Shaw. Ground vegetation remains dominated by *Persicaria spp, Elatostema spp., Pilea glaberrima* (Blume) Blume, *Solanum erianthum* D. Don, *Viola diffusa* Ging.

3.1.1 Distribution within host tree

The distribution of vascular epiphytes within host tree species with >30 cm CBH was also investigated. The host trees like *Ficus auriculata* Lour., *Ficus neriifolia* Sm., *Saurauia nepalensis* DC., *Erythrina variegata* L., *Macaranga denticulata* (Blume) Müll.Arg., *Cryptomeria japonica* (Thunb. ex L.*f.*) D. Don, *Engelhardia spicata* Lechen ex Blume were mostly dominant in epiphytic species richness. The percentage distribution in the host tree crown was also analyzed and it was observed that the number of species significantly decreases from trunk zone to the inner crown zone. The present study showed 74% of other vascular angiosperms distributed in the trunk zone (TZ) while 26 % towards the inner crown zone (ICZ). In case of monocots, only 2% were identified from the inner crown zone and the remaining 98% from the trunk zone especially the Orchidaceae (Fig. 5). About one third of ferns and lycophytes representing 31% inhabitated the inner crown zone and the maximum taxa (69 %) were distributed on the trunk zone. Host tree species such as *Ficus auriculata* Lour., *Ficus neriifolia* Sm., *Engelhardia spicata* Lechen ex Blume with maximum branching sheltered majority of epiphytes and the distribution was contiguous. Other host trees that include *Macaranga denticulata* (Blume) Müll. Arg., *Cryptomeria japonica* (Thunb. ex L.*f.*) with thin branching sheltered comparatively lesser species.

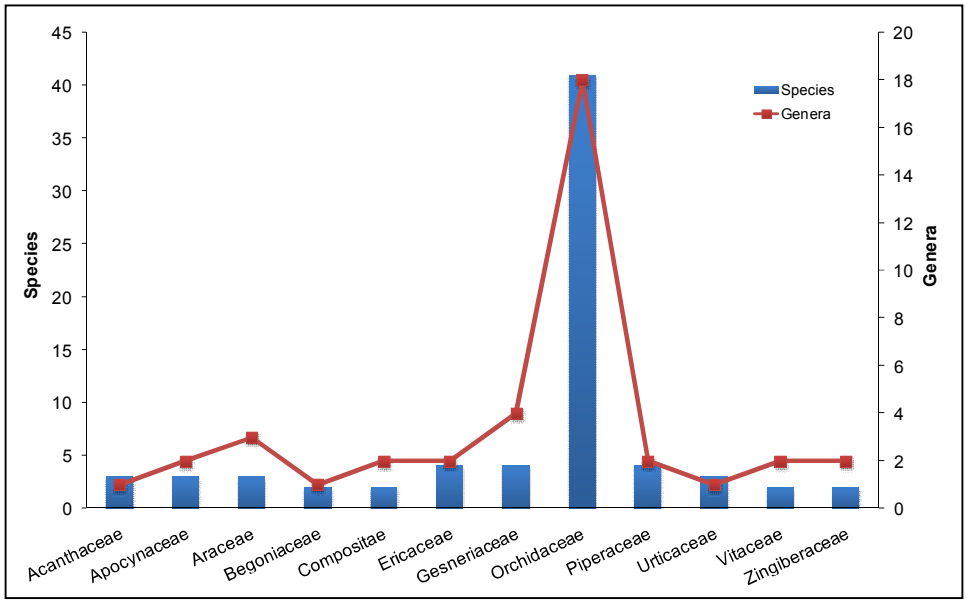

Fig. 3. Dominant families with number of species and genera

Table 1. Diversity of vascular epiphytes in sub-temperate forests of Darjeeling Himalaya

Taxa	Habit type	Life form	Distribution	Phenology
Acanthaceae Jussieu				
Thunbergia coccinea Wall ex D.Don	CL	P	ICZ	Dec-March
Thunbergia indica Alatta	CL	P	ICZ	June
Thunbergia lutea T. Anderson	CL	P	ICZ	Aug-Dec
Apocynaceae Jussieu				
Ceropegia pubescens Wall.	CL	P	TZ	July-Sept
Hoya linearis Wall. ex D. Don	Pe	P	TZ	Sept
Hoya serpents Hook.*f.*	Pe	P	TZ	July-Oct
Araceae Jussieu				
Colocasia affinis Schott	H	A	TZ	June-Aug
Pothos scandens L.	CL	P	TZ	Dec-April
Rhaphidophora glauca (Wall.) Schott	CL	P	TZ	Sept-May
Asparagaceae Jussieu				
Polygonatum oppositifolium (Wall.)Royle	H	P	TZ	May
Asteraceae Berchtold & J. Presl				
Mikania micrantha Kunth	CL	P	TZ	June
Senecio scandens var. *crataegifolius* (Hayata)Kitam	CL	P	TZ	Sept-Oct
Begoniaceae C. Agardh				
Begonia flaviflora H.Hara	H	P	TZ	June-July
Begonia hatacoa var. *hatacoa* Buch-Ham. ex D.Don	H	P	TZ	Oct-Nov
Berberidaceae Jussieu				
Holboellia angustifolia Wall.	CL	A	TZ	April-June
Cucurbitaceae Jussieu				
Herpetospermum tonglense (C.B Clarke) H.Schaef. & S.S Renner	CL	P	TZ	June
Dioscoreaceae R. Brown				
Dioscorea bulbifera L.	CL	A	TZ	July-Sept
Ericaceae Durande				
Agapetes incurvata (Griff.)	S	P	ICZ	May-June
Agapetes serpens (Wight) Sleumer	S	P	ICZ	May-June
Vaccinium retusum (Griff.)Hook.*f.* ex C.B.Clarke	H	P	TZ	June
Vaccinium vacciniaceum (Roxb.) Sleumer	H	P	TZ	April

Taxa	Habit type	Life form	Distribution	Phenology
Gentianaceae Jussieu				
Tripterospermum volubile (D.Don) H.Hara	CL	P	TZ	June-Oct
Gesneriaceae Dumortier				
Aeschynanthus hookeri C.B.Clarke	S	P	ICZ	July-Nov
Didymocarpus aromaticus D.Don	H	P	TZ	July-Sept
Henckelia pumila (D.Don) A.Dietr.	H	A	TZ	Aug
Lysionotus serratus D.Don	S	P	TZ	July-Sept
Melastomataceae Jussieu				
Oxyspora paniculata DC.	S	P	TZ	July-Sept
Moraceae Gaudich				
Ficus sarmentosa Buch.Ham. ex Sm.	CL	P	TZ	May-July
Papaveraceae Jussieu				
Dactylicapnos scandens (D.Don) Hutch.	CL	P	TZ	July-Nov
Piperaceae Giseke				
Peperomia heyneana Miq.	H	P	TZ	May-Aug
Peperomia pellucida (L.) Kunth	H	P	ICZ	April-July
Peperomia tetraphylla (G.Forst.) Hook. & Arn.	H	P	TZ	Feb-April
Piper pedicillatum C.DC.	S	P	TZ	June
Primulaceae Batsch ex Borkhausen				
Lysimachia japonica Thunb.	H	P	TZ	March-April
Rubiaceae Jussieu				
Neohymenopogon parasiticus (Wall.) Bennet	S	P	ICZ	June-Aug
Santalaceae R. Brown				
Dendrotrophe granulata (Hook.*f.* & Thomson ex A.DC) A.N. Henry & B.Roy	Pa	P	ICZ	May-Aug
Saxifragaceae Jussieu				
Astilbe rivularis Buch.Ham ex D.Don	S	P	TZ	June-Nov
Urticaceae Jussieu				
Pilea pumila A.Gray	H	P	TZ	June-Aug
Pilea scripta (Buch.Ham. ex D.Don) Wedd.	H	P	TZ	June-Aug
Pilea ternifolia Wedd.	H	P	TZ	June-Aug
Violaceae Batsch				
Viola pumila Chaix	H	A	TZ	April-June

Taxa	Habit type	Life form	Distribution	Phenology
Vitaceae Jussieu				
Cayratia pedata (Lam.) Gagnep.	CL	P	TZ	June-Nov
Cissus javana DC.	CL	P	ICZ	June-Oct
Zingiberaceae Martinov				
Cautleya spicata (Sm.) Baker	H	P	TZ	July-Nov
Hedychium griffithianum Wall.	H	P	TZ	June-Nov
Orchidaceae Jussieu				
Acampe praemorsa var. *praemorsa* (Roxb.) Blatt. & McCann	H	P	ICZ	March-April
Acampe rigida (Buch.-Ham. ex Sm.) P.F.Hunt	H	P	TZ	Aug-Sept
Aerides multiflora Roxb.	H	P	TZ	May-July
Agrostophyllum myrianthum King & Pantl.	H	P	TZ	July-Aug
Agrostophyllum planicaule (Wall. ex Lindl.) Rchb.*f*.	H	P	TZ	July-Aug
Bulbophyllum careyanum (Hook.) Spreng.	H	P	TZ	Nov
Bulbophyllum crassipes Hook.*f*.	H	P	TZ	April
Bulbophyllum odoratissimum (Sm.) Lindl.ex Wall.	H	P	TZ	April-Aug
Bulbophyllum reptans (Lindl.) Lindl. ex Wall.	H	P	TZ	March
Bulbophyllum roseopictum J.J.Verm., Schuit. & de Vogel	H	P	TZ	Sept-Oct
Coelogyne cristata Lindl.	H	P	TZ	May
Coelogyne flaccida Lindl.	H	P	TZ	March
Cymbidium aloifolium (L.) Sw.	H	P	TZ	Oct-Jan
Cymbidium eburneum Lindl.	H	P	TZ	August
Cymbidium elegans var. *elegans* Lindl.	H	P	TZ	August
Cymbidium erythraeum Lindl.	H	P	TZ	May
Dendrobium amoenum Wall. ex Lindl.	H	P	TZ	May-June
Dendrobium aphyllum (Roxb.) C.E.C.Fisch.	H	P	TZ	Feb-July
Dendrobium bicameratum Lindl.	H	P	TZ	April
Dendrobium chrysanthum Wall. ex Lindl.	H	P	TZ	Sept
Dendrobium comatum (Blumee) Lindl.	H	P	TZ	Sept
Dendrobium denudans D.Don	H	P	TZ	Sept
Dendrobium erythraeum Schuit. & de Vogel	H	P	TZ	Sept
Dendrobium humilicolle Schltr.	H	P	TZ	June
Dendrobium longicornu Lindl.	H	P	TZ	June
Dendrobium moschatum (Banks) Sw.	H	P	TZ	June
Dendrobium pachyphyllum (Kuntze) Bakh.*f*.	H	P	TZ	March

Taxa	Habit type	Life form	Distribution	Phenology
Dendrobium transparens Wall. ex Lindl.	H	P	TZ	March
Eria coronaria (Lindl.) Rchb.*f.*	H	P	TZ	May-June
Gastrochilus calceolaris (Buch.-Ham. ex Sm.) D.Don	H	P	TZ	April-July
Oberonia pachyrachis Rchb.*f.* ex Hook.*f.*	H	P	TZ	March-April
Otochilus fuscus Lindl.	H	P	TZ	March
Otochilus lancilabius Seidenf.	H	P	TZ	Oct-Nov
Pleione praecox (Sm.) D.Don	H	P	TZ	Sept-Oct
Porpax elwesii (Rchb.*f.*) Rolfe	H	P	TZ	June
Porpax filiformis (Wight) Schuit., Y.P.Ng & H.A.Pedersen	H	P	TZ	Dec
Rhynchostylis retusa (L.) Blume	H	P	TZ	Nov
Thunia alba (Lindl.) Rchb.	H	P	TZ	June
Uncifera obtusifolia Lindl.	H	P	TZ	June
Vanda cristata Wall.ex Lindl.	H	P	TZ	May-June
Vandopsis undulata (Lindl.) J.J.Sm.	H	P	TZ	May-June
Aspleniaceae Newman				
Asplenium ensiforme Wall. ex Hook. & Grev	H	P	TZ	June-Sept
Asplenium phyllitidis D.Don	H	P	TZ	June-Sept
Asplenium yoshinagae subsp. *indicum* (Sledge) Fraser-Jenk.	H	P	TZ	March-April
Lindsaeaceae M. R. Schomb				
Lindsaea orbiculata (Lam.) Mett. ex Kuhn	H	P	TZ	July-Oct
Lycopodiaceae P. Beauvois ex Mirbel				
Huperzia pulcherrima (Wall. ex Hook. & Grev.) Pic.Serm	H	P	ICZ	July-Oct
Huperzia squarrosa (G.Forst.)Trevis	H	P	ICZ	July-Oct
Nephrolepidaceae Pichi Sermolli				
Nephrolepis cordifolia (L.) C.Presl	H	P	TZ	Aug-Nov
Polypodiaceae J. Presl & C. Presl				
Drynaria mollis Bedd.	H	P	TZ	June-Aug
Drynaria propinqua(Wall. ex Mett.) J.Sm. ex Bedd.	H	P	TZ	June-Aug
Elaphoglossum callifolium (Blume) J.Sm.	H	P	TZ	May-July
Goniophlebium amoenum (Wall. ex Mett.) Bedd.	H	P	TZ	Aug-Sept
Goniophlebium argutum J.Sm	H	P	TZ	Aug-Sept
Goniophlebium lachnopus (Wall. ex Hook.) J.Sm	H	P	TZ	Aug-Sept
Lepisorus scolopendrium (Buch-Ham ex D.Don) Mehra & Bir	H	P	TZ	July-Sept
Leucostegia truncata (D.Don) Fraser-Jenk.	H	P	TZ	July-Sept

Taxa	Habit type	Life form	Distribution	Phenology
Loxogramme cuspidata (Zenker) M.G.Price	H	P	TZ	June-Sept
Loxogramme involuta (D.Don) C.Presl	H	P	TZ	Aug-Oct
Microsorum membranaceum (D.Don) Ching	H	P	TZ	Aug-Oct
Oleandra pistillaris (Sw.) C.Chr.	H	P	TZ	Aug-Oct
Oleandra wallichii (Hook.) C.Presl	H	P	TZ	Aug-Oct
Phymatosorus cuspidatus (D.Don) Pic.Serm	H	P	ICZ	Aug-Oct
Pyrrosia costata (Wall. ex C.Cresl) Tagawa & K.Iwats.	H	P	ICZ	June-Sept
Pyrrosia lanceolata (Wall.) Farw.	H	P	ICZ	June-Sept
Pyrrosia lingua (Thunb.) Farw.	H	P	ICZ	June-Sept
Pyrrosia manni (Giesenh.) Ching	H	P	ICZ	June-Sept
Pyrrosia nuda (Giesenh.) Ching	H	P	ICZ	June-Sept
Selliguea oxyloba (Wall. ex Kunze) Fraser-Jenk.	H	P	TZ	Aug-Oct
Pteridaceae E.D.M. Kirchner				
Haplopteris elongata (Sw.) E.H. Crane	H	P	ICZ	July-Oct
Vittaria sp.	H	P	TZ	July-Sept

Key: H: Herb; S : Shrub: Cl: Climber; Pa : Parasitic; Pe : Pendulous; A: Annual; P: Perennial; ICZ : Inner crown zone; TZ: Trunk zone

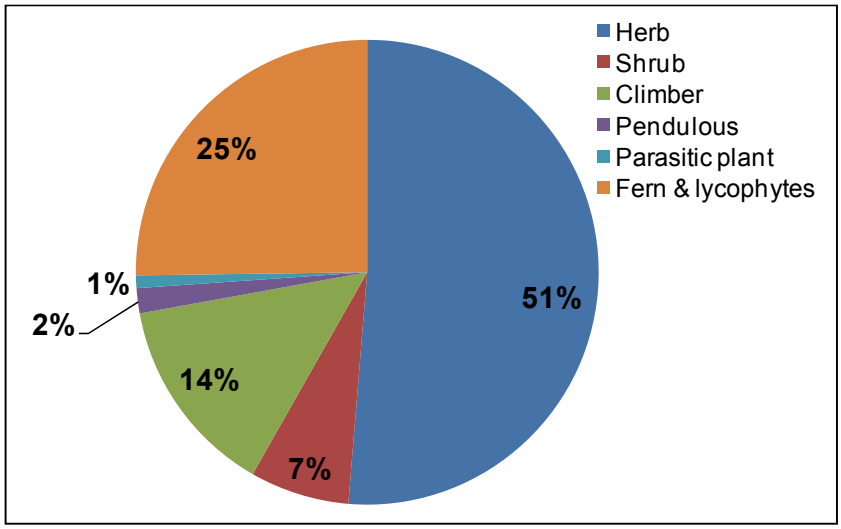

Fig. 4. Different habit groups of vascular epiphytes

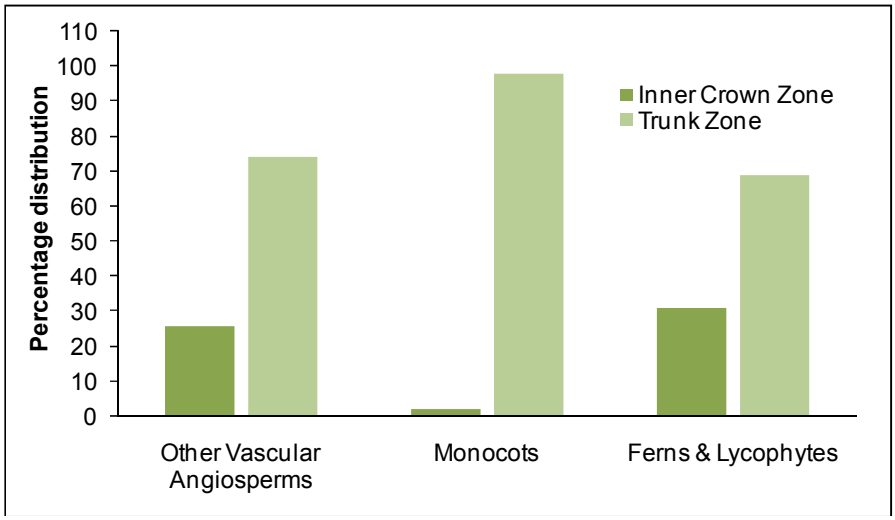

Fig. 5. Percentage distribution in host tree trunk

3.1.2 Microhabitat and phenology

The entire ferns and lycophytes including Orchidaceae recorded from the study area were found to be perennial, while among the other vascular angiosperms, 89% were perennial while only 11% of species were found to be annual. All the epiphytic angiosperms were found to be facultative that grew either on the host tree trunk or as terrestrial, except species of *Aeschynanthus* which is truly epiphytic. Ferns and lycophytes are divided into three categories a) Epiphyte/Terrestrial fern that grew both on tree trunk and forest floor representing 59% b) Epiphyte/Epilithic that grew on tree trunk and as lithophytes represented 31% and c) True epiphyte that grew only on host tree trunk was 10%. Similarly, Orchidaceae were also categorized into a) True epiphyte, growing only on the host tree trunk representing 41% and b) Epiphyte/Epilithic with 59% that grew both on the tree trunk as well as on the rock surface.

In the present study, the phenology of the taxa that was observed, highlighted 24 % of other vascular angiosperms bloomed in spring and summer season whereas 60%, 9% and 7% flowered in monsoon, autumn and winter season respectively. Similarly, 46% (19 taxa) of Orchidaceae bloom in spring while 27%, 22%

and 5% flowered in summer, autumn and winter season respectively (Fig. 6). It can be concluded that maximum number of other vascular angiosperms flower in wet monsoon season whereas spring season was observed to be most preferable flowering period for Orchidaceae.

3.2 Discussion

The present study recorded a number of vascular epiphytic taxa that were distributed within a short range between sub-temperate to temperate forests of Darjeeling Himalaya. Similar type of works from different regions includes sampling vascular epiphyte diversity, species richness, community structure tree line-composition and population biology have also been conducted [57,58,59].

Association of epiphytes excluding orchids to host and environmental variables were highlighted [44] whereas in the present study, all the epiphytes including Orchidaceae were related to host and environmental variables. Previous study in Darjeeling Himalaya [46] recorded 88 epiphytic species in upper montane tropical forest which was lesser than the present study that identified 115 vascular epiphytic species. The study strongly supports the biggest abundance of Orchidaceae in the area and the distribution of different epiphytic species closer to the first branching. Some of the recorded epiphytic angiosperms in the present study such as *Neohymenopogon parasiticus, Vaccinium retusum, Lysionotus serratus, Hoya linearis, Peperomia heyneana, Polygonatum oppositifolium* were recorded more than 50 years ago in the region [45]. Though India's epiphytic orchid is to be found primarily in the Eastern Himalayas and Western Ghats, 99 epiphytic orchids in Western Himalayas have also been recorded [40] which was however less than the present documentation. Earlier study on fern and fern allies from Western Ghats [39] identified many epiphytes common to the fern and fern allies of Darjeeling Himalayas and some of them have also been identified in this communication too. Epiphytic species richness increases with increasing rainfall [60] while [61] found a decrease of epiphytic richness in the most humid habitats. [62] documented the massive decline of epiphyte diversity at high elevation upto 4000m and the actual mechanism of limited epiphytic growth at low temperature are still unknown. Ferns are the most common vascular epiphytes in humid temperate regions [63] while in the present study Orchidaceae was the most abundant vascular epiphytes.

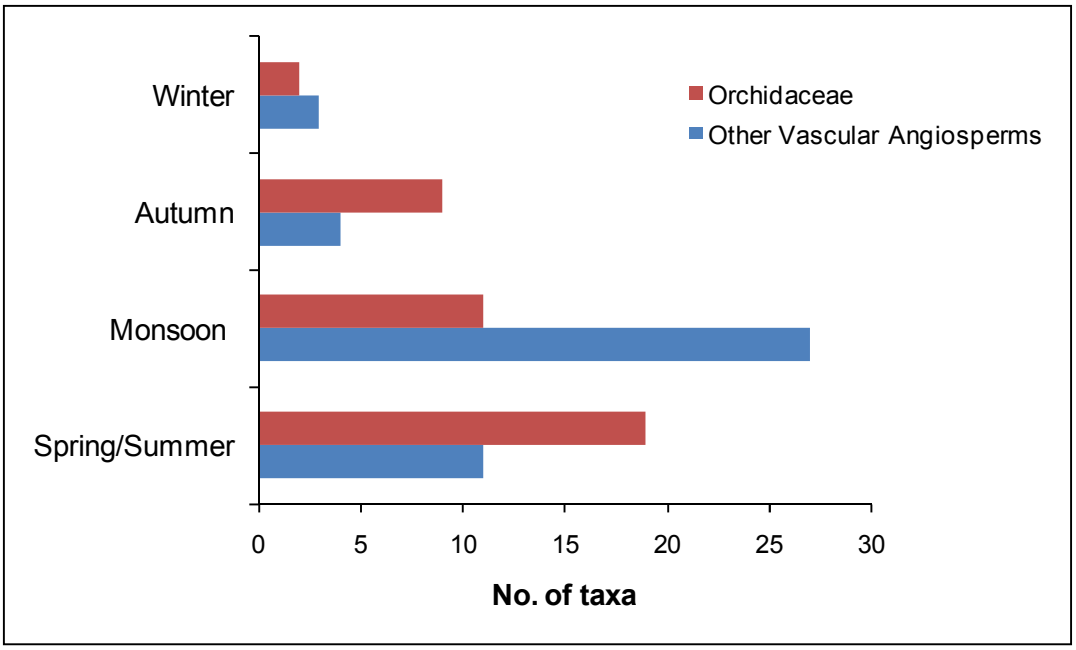

Fig. 6. Phenological status for the epiphytic taxa

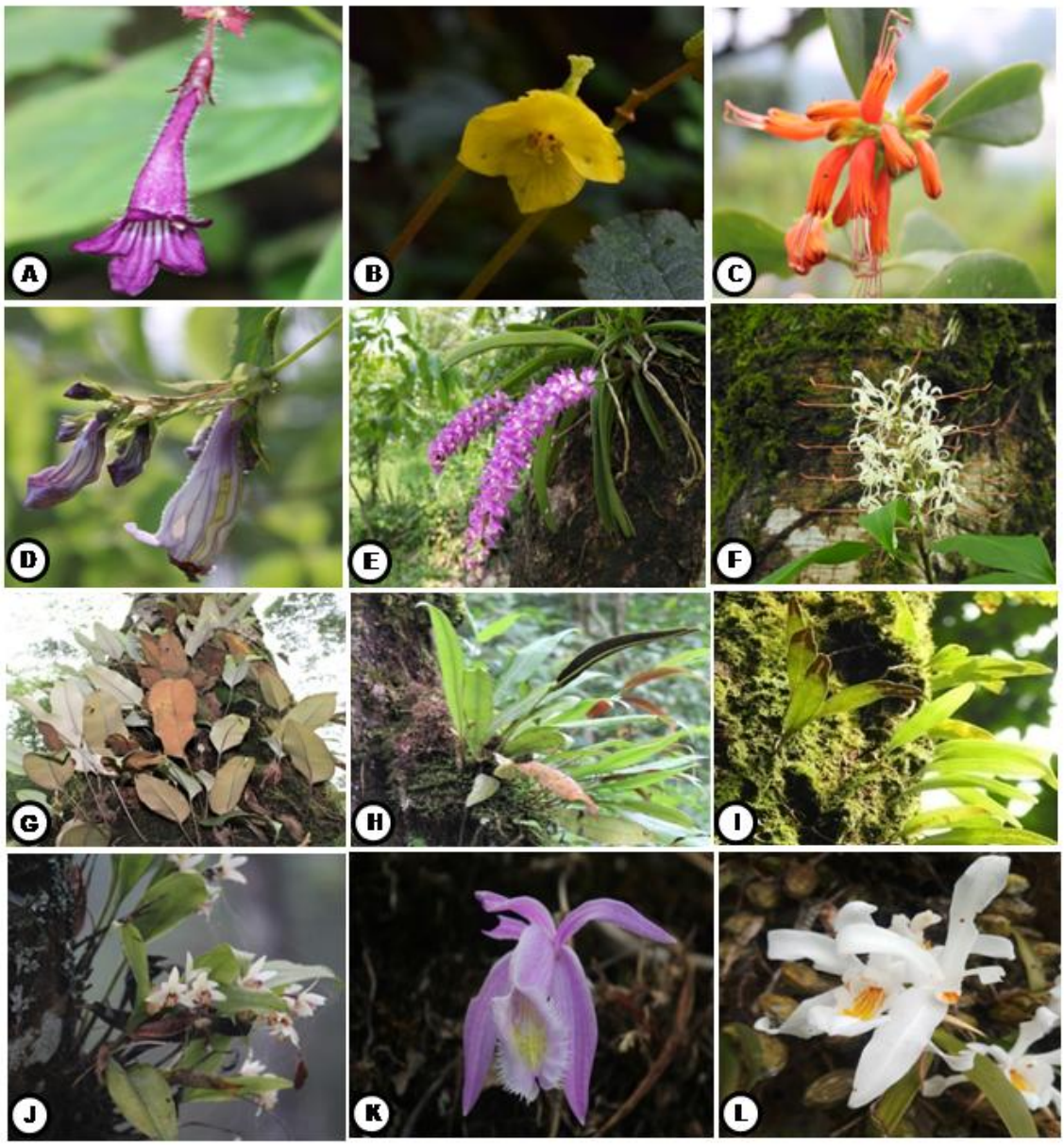

Plate 1. A. *Didymocarpus aromaticus* B. *Begonia flaviflora* C. *Aeschynanthus hookeri* D. *Lysionotus serratus* E. *Rhynchostylis retusa* F. *Hedychium griffithianum* G. *Pyrrosia lingua* H. *Elaphoglossum callifolium* I. *Pyrrosia lanceolata* J. *Eria coronaria* K. *Pleione praecox* L. *Coelogyne cristata*

Host tree interaction in nine species harboring eleven epiphytic taxa have been recorded from agro forestry system [64]. Our study reflects the decrease in the number of vascular epiphytes from trunk zone to crown zone. This decrease in epiphytic richness may be due to increase in ultraviolet radiation, decrease in humidity and increase in photon flux density along the increasing canopy height of the hosts [65], lack of adaptation for high water stress in vertical canopy branches [66,67,68].

Parasitic plant like *Dendrotrophe granulata* (Hook. f. & Thomson ex A.DC.) Henry & Roy and some critically threatened (CR) orchid *Gastrochilus calceolaris* (Buch.-Ham. ex Sm.) D.Don [69] species were also recorded from study area including *Cymbidium eburneum* Lindl.

which is endemic to Eastern Himalaya and Northeastern India [70]. Species like *Agapetes incurvata* (Griff.) Sleumer was found to be endemic to eastern Himalaya while *Thunbergia lutea* T.Anderson is endemic to Darjeeling region. Many orchid taxa *Agrostophyllum myrianthum* King & Pantl., *Bulbophyllum reptans* (Lindl.) Lindl. ex Wall., *B. odoratissimum* (Sm.) Lindl., *Pleione praecox* (Sm.) D.Don, *Vandopsis undulate* (Lindl.) J.J.Sm. are sparsely populated and *Aerides multiflora* Roxb., *Cymbidium erythraeum* Lindl., *Dendrobium bicameratum* Lindl., *Gastrochilus calceolaris* (Buch.-Ham. ex Sm.) D.Don, *Porpax elwesi* (Rchb.*f.*) Rolfe, *Unifera obtusifolia* Lindl., are rarely found while *Agrostophyllum planicaule* (Wall. ex Lindl.) Rchb.*f.* (NT), *Bulbophyllum tortuosum* (Blume) Lindl. (NT), *Cymbidium eburneum* Lindl., (NT), are categorized as near threatened [71]. Species like *Holboellia angustifolia* Wall., *Elaphoglossum callifolium* (Blume) J.Sm., *Hoya serpens* (Hook.*f.*), *Polygonatum oppositifolium* (Wall.) Royle, *Begonia flaviflora* H. Hara, *Herpetospermum tonglense* (C.B.Clarke) H.Schaef. & S.S.Renner, were found to be less in population number.

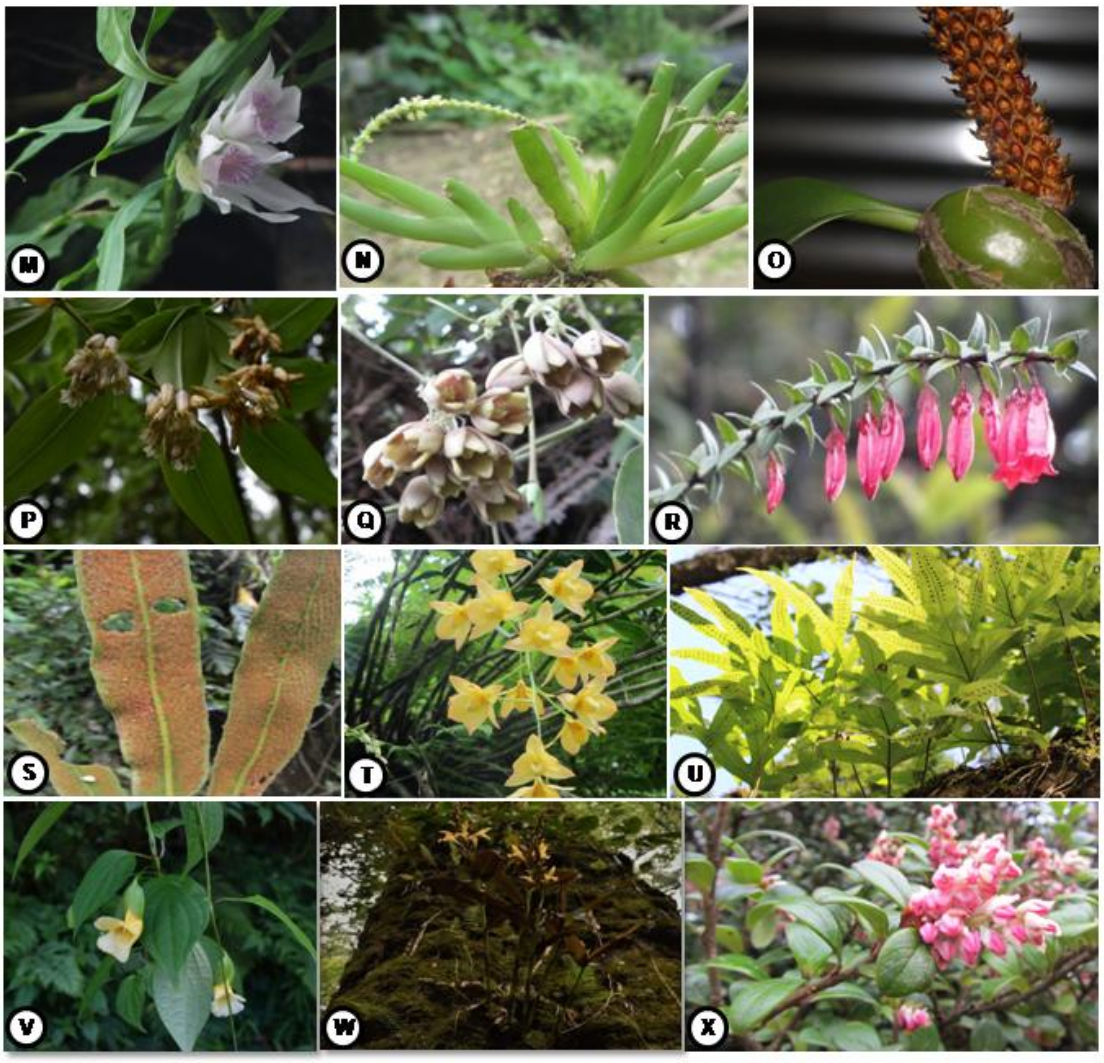

Plate 2. M. *Thunia alba* N. *Oberonia pachyrachis* O. *Bulbophyllum crassipes* P. *Polygonatum oppositifolium* Q. *Holboellia angustifolia* R. *Agapetes serpens* S. *Pyrrosia costata* T. *Dendrobium moschatum* U. *Selliguea oxyloba* V. *Thunbergia lutea* W. *Cautleya spicata* X. *Vaccinium retusum*

The availability of enough time and space for colonization and higher diversity of microhabitats are the main reason for more epiphytic species on large trees rather than smaller trees [72,73, 74]. In the present investigation, maximum individual count of taxa was recorded from the old trees with larger trunk >100 cm CBH whereas only few individuals were recorded from trees having smaller trunk with <40 cm CBH. Hence there is positive relationship between phorophyte size and abundance of vascular epiphytes which supports the findings of other studies [33,75,76]. Similarly host bark traits are found to affect the distribution and development of vascular epiphytes, rough or coarse bark of host tree support many epiphytes whereas host with smooth bark supported few epiphytes [77] because they retain moisture for longer and seedling recruitment is better in rough bark than on smooth bark [42].

Although a good number of taxa have been observed in the study, the plants are still under serious threat. Being an extension of Himalaya hotspot it is not difficult to imagine the extent of anthropogenic pressure exerted on natural vegetation almost in all corners of the area. Habitat loss, forest destruction and degradation, loss of suitable host tree and human impact such as settlement and agriculture are the greatest threat for epiphytes [41]. Human population and the rate of habitat modification is too much in the hill region and almost all forests are affected. The collections of plants for ethnobotanical practices by the inhabitants living in the vicinity of sub-temperate forests are also one of the reasons for decline in the species. Some ethno-medicinal plants have also been identified that are widely used. Taxa like *Astilbe rivularis* was commonly used against ulcer, bleeding during child birth, asthma and brain diseases [78]. Similarly, rhizome juice of *Cautleya spicata* was used in the treatment of stomach disorders [79]. Among the orchids that were recorded, species that attributed to medicinal properties against various ailments include *Acampe praemorsa* (Anti-rheumatism) [80], *Aerides multiflora* (Antibacterial), *Dendrobium chrysanthum* (anti-inflamatory activity) and *Coelogyne cristata* (Phytoalexin) [81]. Beside these, indiscriminate use of natural resources including forest fuels, collection of medicinal plants and ornamental orchids for house nursery and commercial marketing are inevitable reasons for the decline in the diversity of epiphytes as well as other taxa. It has also come to notice that the frond of *Nephrolepis cordifolia* is being extensively collected by the local people leading to the decrease in species abundance at some sites under study.

4. CONCLUSION

The vascular epiphytic flora of sub-temperate region of Darjeeling Himalaya is valuable natural resources. The present investigation resulted in documenting a total of 115 other vascular angiosperms, ferns and Orchidaceae where the other vascular angiosperms preferred wet monsoon for flowering as compared to spring season mostly favoured by Orchidaceae. The host tree reflected dominance of trunk zone over inner crown zone with respect to epiphytic species distribution. This work would definitely provide significant information for regional flora as well as flora of eastern Himalaya hotspot. However, it has been observed that deforestation, collection of plants for commercial purposes, construction and agriculture practices prevailing in the study area have been causing frequent change in species diversity and composition of vascular epiphytes and other taxa as well. Many of the taxa are already under low population count. Therefore there lies role of conservationist, taxonomist, ecologist, in collaboration with forest departments and concerned participation of the locals for proper conservation of the rich and valuable epiphytic taxa in the region.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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