



## Diversity and distribution of herbaceous vascular epiphytes in a tropical evergreen forest at Varagalaia, Western Ghats, India

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**Abstract.** Herbaceous vascular epiphytes were screened in a total sample of 13 445 trees (in 153 species) and 348 lianas (in 30 species)  $\geq 30$  cm girth at breast height in a 30 ha plot of tropical evergreen forest at Varagalaia, Indian Western Ghats. Of these, 4.3% of trees and 3.7% of lianas were infested with epiphytes. Epiphyte diversity totaled 26 species in 19 genera and 10 families. Sixteen species were angiosperms in three families (Orchidaceae 54%; Piperaceae and Araceae 8%) and 10 species (38%) were pteridophytes in seven families. The orchid, *Pholidota pallida* was most abundant and occurred on 178 (29.6%) stems. *Asplenium nidus* occurred on the maximum of 62 host species. The species richness estimators employed for species accumulation curves after 100 times randomization of sample order have stabilized the curve at 18th and 19th hectares respectively for Incidence-based Coverage Estimator and Chao2. A total of 588 trees and 13 liana stems lodged epiphytes, 74% of which were evergreen species and 26% deciduous. Epiphyte density was greater (56%) in deciduous species (*Bischofia javanica* 30% and *Vitex altissima* 8%). A significant positive relationship was found between trunk size and epiphyte association. Larger epiphyte species occurred mostly on middle and larger stems and smaller epiphyte species occurred on smaller stems. The majority of epiphytes (92%) were of autochorous dispersal type, bearing capsule or dust diaspores, while the remaining species with berries and nutlets are dispersed by small vertebrates.

**Key words:** association, epiphytes, India, phorophyte, tropical evergreen forest, Western Ghats

### Introduction

Epiphytes are a conspicuous and characteristic life form in tropical rainforests (Richards 1996). Their diversity and distributions are greater in the neotropics when compared with paleotropics (Gentry and Dodson 1987). They constitute an important floristic, structural and functional component of tropical rainforests (Benzing 1983), and their spatial distributions generally depend on the phorophyte species, its age and microclimatic conditions (Johansson 1975; Catling et al. 1986; Freibeg 1996). Different trunk diameters of the same species usually representing different ages, are correlated with the degree of epiphyte diversity (Bennett 1986) and specific associations (Catling and Lefkovitch 1989). Epiphytes are distributed horizontally and vertically.

The crowns are much richer than the trunk in epiphytic species and individuals (ter Steege and Cornelissen 1989).

Large-scale ecological inventories on herbaceous vascular epiphytes are lacking from the Indian tropics. Hence, the present study was undertaken aiming at a large-scale detailed analysis of epiphytes in a tropical evergreen forest, screening all the phorophyte stems  $\geq 30$  cm girth at breast height (gbh) in a 30 ha ( $600 \times 500$  m<sup>2</sup>) permanent plot established in the tropical evergreen forest at Varagalaiair, Anamalais, Western Ghats. Each hectare ( $100 \times 100$  m<sup>2</sup> sub plots) was subdivided into  $10 \times 10$  m<sup>2</sup> quadrats as workable units. A total of 13 445 trees (Ayyappan and Parthasarathy, manuscript submitted) and 348 lianas ( $\geq 30$  cm gbh) (Muthuramkumar and Parthasarathy 2000) were enumerated in the 30 ha plot. Tree density per plot ranged from 272 to 669 (Ayyappan and Parthasarathy, manuscript submitted). The objectives of the present study were to investigate the species richness, abundance, distribution of vascular herbaceous epiphytes and their association with phorophytes.

### Study area

The study was conducted in the tropical evergreen forest at Varagalaiair, within the Indira Gandhi National Park and Wildlife Sanctuary, near Top slip, Anamalais, Western Ghats. It is located (latitude  $10^{\circ}25'$  and longitude  $76^{\circ}52'$  E) in Coimbatore district of Tamil Nadu, south India (Figure 1).

The elevation of our study site ranges from 600 to 660 m above msl. Mean annual rainfall is 1600 mm, recorded at Top slip, 27 km west of Varagalaiair. The study site lies between the two perennial rivers Kurampalliar and Varagalaiair. The water flow in Varagalaiair is meager during summer.

The vegetation of our study site is a closed-canopy tropical evergreen forest with a few natural treefall gaps. Predominant trees in the typically 4-storeyed evergreen forest include *Dipterocarpus indicus*, *Vateria indica*, *Calophyllum polyanthum* and *Bombax ceiba* as emergents, *Poeciloneuron indicum*, *Palaquium ellipticum*, *Polyalthia fragrans*, *Syzygium densiflorum* in the upper storey, *Reinwardtiidendron anamallayanum*, *Fahrenheitia zeylanica*, *Dimocarpus longan*, *Myristica dactyloides*, etc. form the middle storey and *Baccaurea courtallensis*, *Cleidion spiciflorum*, *Drypetes longifolia*, *Prismatomeris tetrandra* etc. constitute the lower storey. Major lianas include *Olex scandens*, *Piper nigrum*, *Chilocarpus atrovirens*, *Kuntleria keralense*, *Gnetum ula* and the rattan *Calamus gamblei*. Dense growth of the shrub *Nilgirianthus barbatus*, the undershrub *Ecbolium viride* (both of Acanthaceae) and *Pellionia heyneana* (Urticaceae), along with a few gingers (*Amomum*, *Curcuma* and *Globba*), grasses, sedges and ferns along with treelets constitute the under storey plants. Major fauna in the study area include tiger, panther, elephant, nilgiri langur, lion-tailed macaque, malabar giant squirrel and birds such as hill myna, racket-tailed drongo, imperial pigeon, horn bills etc.

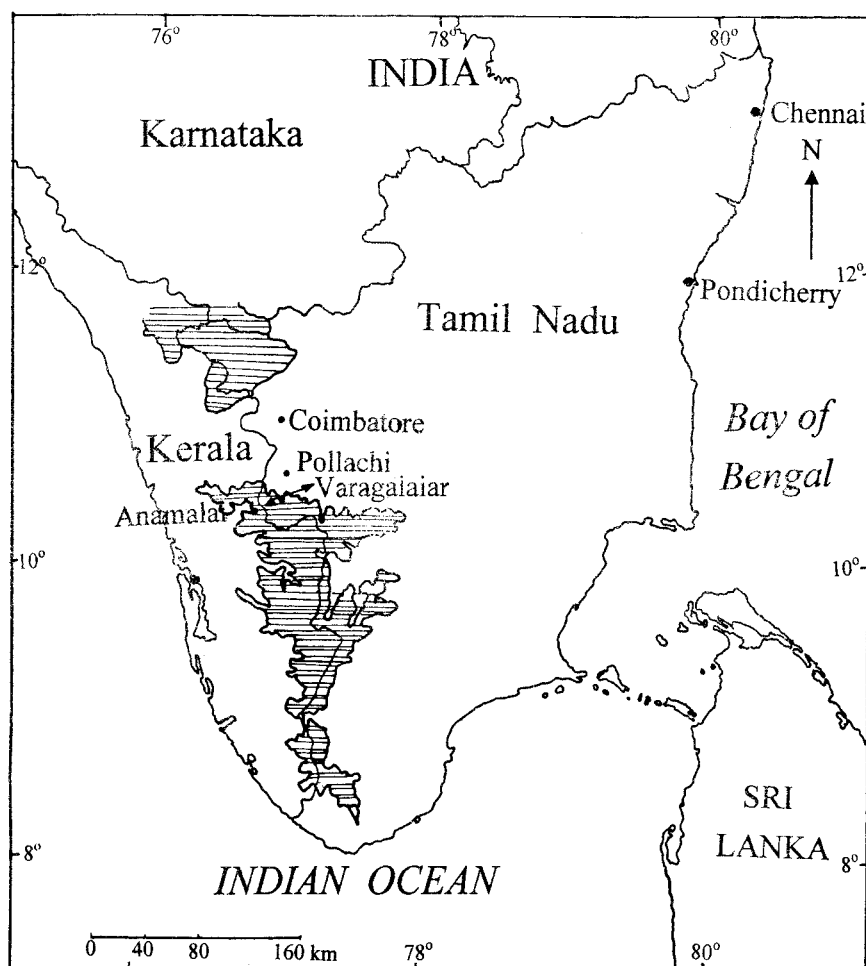


Figure 1. Map showing the location of Varagalaiair study site in the Anamalais, Western Ghats, India.

## Methods

Fieldwork was carried out from January to March 1999. Herbaceous vascular epiphytes that occurred on all trees and lianas  $\geq 30$  cm gbh were recorded. Each tree was divided into four zones: main stem and primary, secondary and tertiary branches. The epiphyte observations were made using a single-legged ladder and binocular. Non-vascular cryptogams (bryophytes etc.) and woody vascular epiphytes (lianas) are not included in this study. All individuals of herbaceous epiphytes were identified using the regional flora (Gamble and Fischer 1915–1935) and were confirmed at Botanical Survey of India, southern circle, Coimbatore (MH). Voucher specimens are deposited at the herbarium of the School of Ecology, Pondicherry University.

### *Data analysis*

For species diversity, Shannon and Simpson indices (Magurran 1988) were calculated. Frequency of a species was taken as the number of phorophytes on which the epiphyte species were recorded. The importance value index (IVI) was calculated for all species by summing up the values of relative density and relative frequency, i.e. for a total of 200 only.

Species-area curves were raised using the program EstimateS (version 5 R.K. Colwell <http://viceroy.eeb.uconn.edu/estimates>), based on mean species accumulation curve after 100 times randomization of sample order. This was carried out by Estimators program (Colwell l.c.) by defining the patchiness parameter 'A' as 0, 0.5 and 0.75 for random, moderately patchy and highly patchy respectively. The relationship of epiphytes with trunk girth class was determined only for species with frequencies exceeding 1%. For this analysis, trees were divided into six trunk girth classes: <60 cm gbh (132 trees); 60.1–120 cm (141 trees); 120.1–210 cm (217 trees); 210.1–300 cm (73); 300.1–390 cm (26) and >390 cm gbh (12). A contingency table (Hietz and Hietz-Seifert 1995a) was formed with categories defined by the species associations and the six trunk girth classes to determine if there is a relationship between trunk size and species groups.

## **Results**

### *Species diversity*

A total of 26 species of herbaceous vascular epiphytes that belonged to 19 genera and 10 families were recorded on 601 individuals of phorophytes in a total sample of 13 445 trees and 348 lianas of  $\geq 30$  gbh, in the 30 ha permanent plot of tropical evergreen forest at Varagalaiar, Indian Western Ghats (Table 1). Based on Sorensen index, the similarity in epiphyte species composition of the thirty 1-ha subplots was 70–96% and that of host species was 67–73%. This reflects the homogeneity of epiphyte and phorophyte diversity in the study plot. The Shannon and Simpson diversity indices were 2.15 and 0.17 respectively for the 30 ha study area (Table 1).

### *Species-area curve*

Species accumulation curves, both the observed and the estimated, attained an asymptote at various scales. The species accumulation curves of the best satisfied estimators (incidence-based coverage estimators (ICE) and Chao 2) were plotted against the area sampled (Figure 2). The ICE and Chao 2 estimators reached a stable value of 29.19 and 30.81 respectively, after the 18th hectare, and the observed curve stabilized at the 28th hectare. After analysing the patchiness parameter (random, moderately patchy

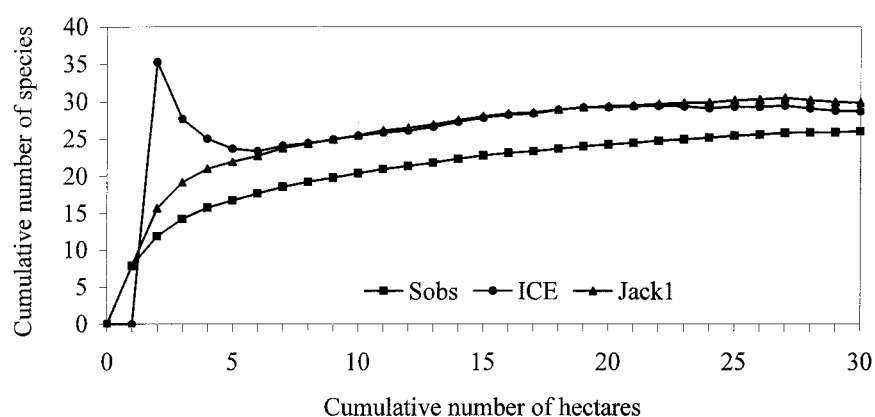
*Table 1.* Results of diversity inventory of herbaceous vascular epiphytes in the 30-ha permanent plot of tropical evergreen forest at Varagalaia, Anamalais, Western Ghats, India.

Variable	
Species richness	26
Range of species per hectare	2–13
Number of genera	19
Number of families	10
Number of host tree species	96
Number of host liana species	9
Diversity indices	
Shannon	2.15
Simpson	0.17
Sorensen's similarity index of epiphyte species in thirty 1-ha subplots (%)	70–96

and high patchy) for the observed species, 75% of the species accumulated in the 4th hectare (Figure 3). The number of singletons (species with only one individual in the pooled sample) would be indistinguishable from the number of uniques (species that occur in only one sample) in this data set and the number of doubletons (species with only two individuals in the pooled sample) is indistinguishable from the number of duplicates (species that occur in only two samples). This indicates that the epiphyte species are randomly distributed.

*Population density of species, dominance and rarity*

A total of 3392 individuals of herbaceous vascular epiphytes were enumerated in the 30 ha plot. Angiosperms formed 62% and pteridophytes 38%. The population



*Figure 2.* Species–area curve for epiphytes in the 30-ha plot of tropical evergreen forest at Varagalaia, Anamalais, Western Ghats, India, showing the observed, and the estimated incidence-based coverage estimator (ICE) and Chao 2 curves.

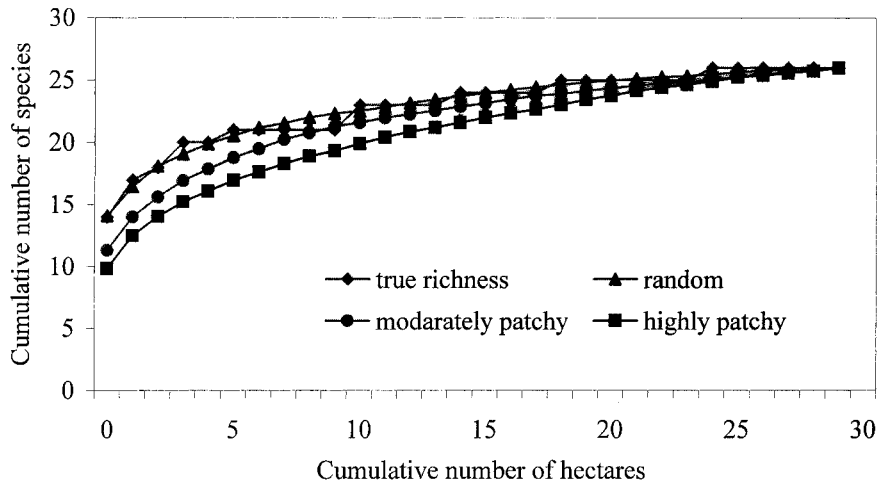


Figure 3. Effect of random (▲), moderately patchy (●) and highly patchy (■) spatial distributions on the rate of species accumulation of epiphytes. Relative and absolute abundance of epiphytes were unchanged from the observed field data (♦).

density of the 26 epiphyte species varied considerably (Table 2). Of the total 26 species, the orchid *Oberonia iridifolia* (1155 individuals, IVI 4.93) was predominant and four other species *Pholidota pallida* (457; IVI 35.5), *Cottonia peduncularis* (411; IVI 23.41), *Dendrobium ovatum* (326; IVI 15.12) of Orchidaceae and *Asplenium nidus* (300; IVI 28.5) of Aspleniaceae were dominants ( $f = 300$  to  $<1000$ ); 4 species (15%) were common ( $f = >100$  to  $<300$ ); 6 species (23%) were rare ( $f = >10$  to  $<100$ ) and 11 species (42%) were very rare. Notable common species include *Peperomia portulacoides* (146; IVI 4.67) of Piperaceae and the fern *Drynaria quercifolia* (142; IVI 8.75) of Polypodiaceae.

#### Distribution of epiphytes

Of the total of 26 species, only one species *Asplenium nidus* was distributed widely and occurred in all 30 ha. Six species occurred in 15–29 ha, 15 species in 2–14 ha and 4 species, the ferns *Pteris pellucida*, *Christella dentata* and *Phlegmariurus phlegmariaria* and the aroid *Remusatia vivipara* occurred in only one hectare in the whole study area.

The frequency distribution of epiphytes on trees  $\geq 30$  cm gbh (Figure 4) shows that the epiphyte density per phorophyte ranged from 1 to 257, with most phorophytes supporting only a single epiphyte. The mean number of epiphytes per tree was six. The orchid *Pholidota pallida* occurred on 30% of phorophytes, *Asplenium nidus* on 27%, *Cottonia peduncularis* 15%, *Oberonia iridifolia* 15% and the remaining species on less than 10% of the phorophytes (Table 2).

Table 2. Percentage frequency of all herbaceous vascular epiphytes on 601 phorophytes, number of host species on which they occurred, their population density and importance value index (IVI) in the tropical evergreen forest at Varagalaia, Western Ghats.

Species	Frequency (%)	No. of host species on which occurred	Density	IVI
1. <i>Asplenium falcatum</i> Lam. (Aspleniaceae)	1.5	8	11	1.44
2. <i>Asplenium nidus</i> L. (Aspleniaceae)	26.5	62	300	28.47
3. <i>Bulbophyllum tremulum</i> Wight (Orchidaceae)	1	5	8	0.98
4. <i>Christella dentata</i> (Forsk) Brownsey & Jermy (Thelypteridaceae)	0.2	1	1	0.15
5. <i>Cottonia peduncularis</i> (Lindl.) Reichb. (Orchidaceae)	15.1	41	411	23.35
6. <i>Cymbidium aloifolium</i> (L.) Sw. (Orchidaceae)	1.8	8	12	1.71
7. <i>Dendrobium aqueum</i> Lindl. (Orchidaceae)	0.3	2	2	0.31
8. <i>Dendrobium heterocarpum</i> Wall. (Orchidaceae)	0.5	3	7	0.58
9. <i>Dendrobium macrostachyum</i> Lindl. (Orchidaceae)	3.3	12	28	3.29
10. <i>Dendrobium ovatum</i> (Willd.) Kranz. (Orchidaceae)	7.5	22	326	15.17
11. <i>Drymoglossum piloselloides</i> (L.) Presl (Polypodiaceae)	1.3	8	103	4.02
12. <i>Drynaria quercifolia</i> (L.) J.Sm. (Polypodiaceae)	6.2	21	142	8.75
13. <i>Liparis viridiflora</i> (Blume) Lindl. (Orchidaceae)	3.5	11	31	3.51
14. <i>Oberonia iridifolia</i> Lindl. (Orchidaceae)	15.5	27	1155	45.53
15. <i>Oberonia sebastiana</i> Shetty & Vivek. (Orchidaceae)	4.5	15	54	4.93
16. <i>Papilionanthe subulata</i> (Koen.) Gray (Orchidaceae)	1.2	6	7	1.07
17. <i>Peperomia portulacoides</i> (Lam.) Dietr. (Piperaceae)	0.5	2	146	4.67
18. <i>Phlegmariurus phlegmaria</i> (L.) Sen et Sen (Lycopodiaceae)	0.2	1	2	0.18
19. <i>Pholidota pallida</i> Lindl. (Orchidaceae)	29.6	35	457	35.45
20. <i>Psilotum nudum</i> (L.) Beauv. (Psilotaceae)	0.3	1	3	0.34
21. <i>Pteris multiaurita</i> Agardh (Pteridaceae)	0.3	2	2	0.31
22. <i>Pteris pellucida</i> Presl (Pteridaceae)	0.2	1	1	0.15
23. <i>Remusatia vivipara</i> (Lodd.) Schott (Araceae)	0.2	1	1	0.15
24. <i>Smithsonia maculata</i> (Daltz.) Saldanha (Orchidaceae)	4.3	20	38	4.33
25. <i>Smithsonia straminea</i> Saldanha (Orchidaceae)	8.5	28	136	10.31
26. <i>Vittaria elongata</i> Sw. (Vittariaceae)	0.8	4	8	0.85
Total			3392	200

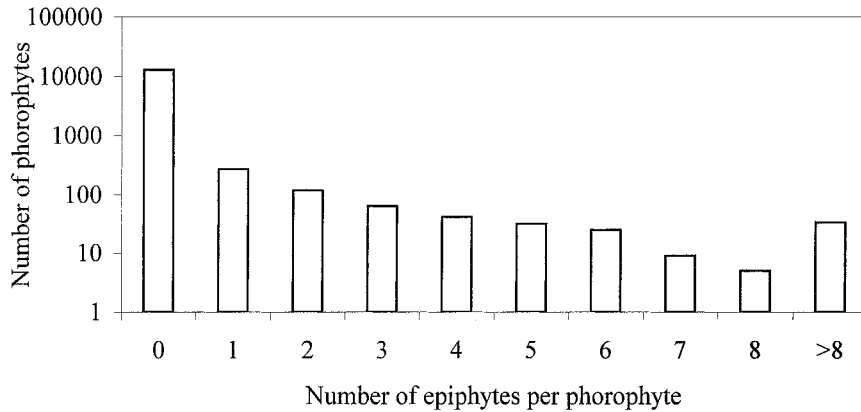


Figure 4. Frequency distribution of epiphytes on phorophytes  $\geq 30$  cm gbh in tropical evergreen forest at Varagalaiair, Western Ghats.

#### Family composition

Of the total of 10 plant families of herbaceous vascular epiphytes in the study area, 3 families (Orchidaceae, Piperaceae and Araceae) were angiosperms (16 species) and 7 were pteridophytes (10 species). Family contribution to genera, species and population density and family importance value (FIV) varied among the 10 families (Table 3). The most species-rich family was Orchidaceae (14 species, FIV 132.6), followed by Aspleniaceae (FIV 16.9), Polypodiaceae (14.9) and Pteridaceae (2 species each). The other six families (60%) were each represented by a single species (Table 3).

Table 3. Family-wise contribution to species, genera, population density and family importance value index (FIV) of all herbaceous vascular epiphytes in the 30-ha plot of tropical evergreen forest at Varagalaiair, Western Ghats. Families are given in decreasing FIV.

Sl. no.	Family	Species richness	Genera	Density	FIV <sup>a</sup>
1	Orchidaceae	14	9	2672	132.62
2	Aspleniaceae	2	1	311	16.86
3	Polypodiaceae	2	2	245	14.92
4	Piperaceae	1	1	146	8.15
5	Pteridaceae	2	1	3	7.78
6	Vittariaceae	1	1	8	4.08
7	Psilotaceae	1	1	3	3.93
8	Lycopodiaceae	1	1	2	3.91
9	Araceae	1	1	1	3.88
10	Thelypteridaceae	1	1	1	3.88
Total		26	19	3392	200.00

<sup>a</sup> FIV = Family importance value (the sum of family relative diversity and density only); (a) Family relative diversity = the number of species in a family present in the sample/the total number of species in the sample, (b) family relative density = the number of individuals in a family/total number of vascular epiphytes in the sample.

### *Diaspore types*

Among the 26 epiphytes, 24 species (92%) produce capsule and dust diaspores (Orchidaceae and pteridophytes) and 8% produce berries and nutlets (Piperaceae and Araceae). The majority of species are autochorous (wind) dispersal type, and a few with berries and nutlets dispersed by small vertebrates.

### *Host species composition*

Of the total number of 13 445 trees enumerated in the 30 ha plot (Ayyappan and Parthasarathy, manuscript submitted) and 348 lianas ( $\geq 30$  cm gbh) (Muthuramkumar and Parthasarathy 2000), 588 trees and 13 lianas lodged epiphytes. *Vitex altissima* (65 individuals), *Bischofia javanica* (56), *Dimocarpus longan* (31), *Chionanthus malaelengi* (20) and *Fahrenheitia zeylanica* (15) were the predominant host trees. A maximum of 13 species of epiphytes occurred on *Vitex altissima*, 11 species on *Bischofia javanica*, *Aporosa lindleyana*, *Flacourtia montana* and *Schleichera oleosa*.

Of the total 96 host species, 74% were evergreen and 26% were deciduous species. Epiphyte density was notably greater (56%) on the deciduous species, e.g. *Bischofia javanica* (1035) and *Vitex altissima* (284).

### *Epiphyte and phorophyte association*

Of the 26 epiphytic species only 15 had a frequency exceeding 1% (Table 2). Clustering of the 15 species based on Euclidean distance with complete linkage revealed seven groups (Table 4). A significant positive relationship existed between trunk size

Table 4. Composition of seven groups of herbaceous vascular epiphytes on hosts in the tropical evergreen forest at Varagalaia, based on clustering, using euclidean distance. Plant size classes are: 1 = <25 cm long, 2 = 25–40 cm and 3 = >40 cm.

Group	Species	Plant size class	Average
1	<i>Asplenium nidus</i>	3	
	<i>Pholidota pallida</i>	3	3
2	<i>Asplenium falcatum</i>	3	
	<i>Cymbidium aloifolium</i>	3	3
3	<i>Drymoglossum piloselloides</i>	1	
	<i>Papilionanthe subulata</i>	1	1
4	<i>Liparis viridiflora</i>	2	
	<i>Dendrobium macrostachyum</i>	2	2
5	<i>Oberonia sebastiana</i>	1	
	<i>Smithsonia maculata</i>	1	1
6	<i>Oberonia iridifolia</i>	2	
	<i>Cottonia peduncularis</i>	1	
	<i>Smithsonia straminea</i>	1	1.3
7	<i>Dendrobium ovatum</i>	3	
	<i>Drynaria quercifolia</i>	3	3

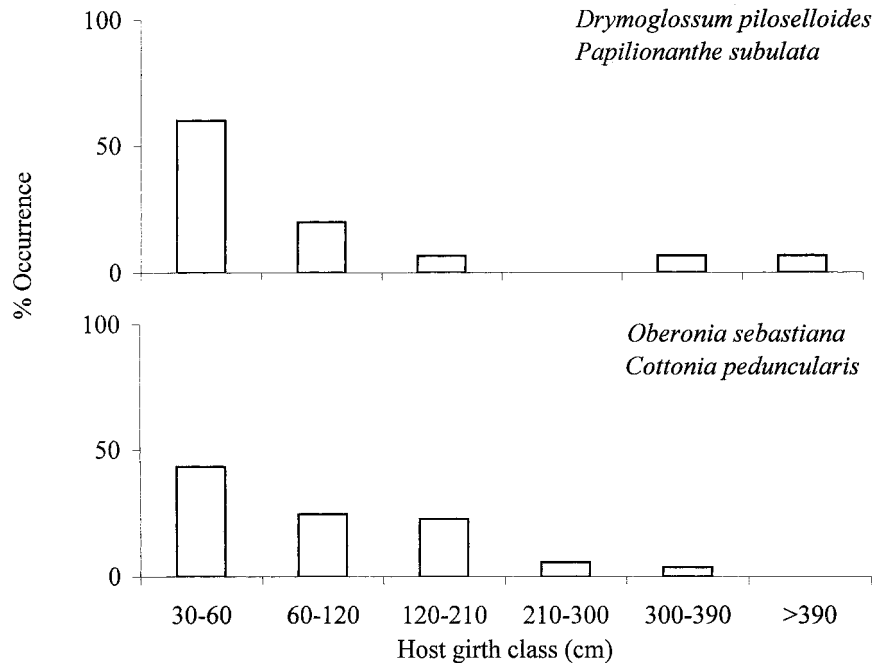


Figure 5. Percentage occurrence of two associations of small epiphytes on six trunk diameter classes in the tropical evergreen forest at Varagalaiar, Western Ghats.

and epiphyte association. The percentage occurrence of selected groups with respect to trunk girth class and species association (Figures 5 and 6) for the four associations from clustering (Table 4) indicated that the larger species mostly occurred on middle- and larger ( $\geq 60$  cm gbh) trunks and smaller epiphytes mostly occurred on smaller trunks (30–60 cm gbh). Most of the epiphytes (65%) were found on main trunks. The primary branch lodged 17.4%, secondary branch 8.3% and tertiary branch 7%.

## Discussion

Epiphyte species richness of our site is lower than in other studies, notably of Gentry and Dodson (1987) – 127 species on 1000 m<sup>2</sup> in Costa Rica and Ingram and Nadkarni (1993) – 65 species on a single tree in Costa Rica. Our herbaceous vascular epiphyte species numbers are well within the range found in other lowland and montane forests of Central and South America (Sugden and Robins 1979; Kelly 1985; ter Steege and Cornelissen 1989; Hietz and Hietz-Seifert 1995b). Since our study area receives only moderate rainfall with a dry period of 4–5 months, epiphyte diversity is less. Epiphytes mostly occurred on trees located along the humid riverbanks, and moisture seems to be the most important ecoclimatic variable (Benzing 1983). Epiphytes

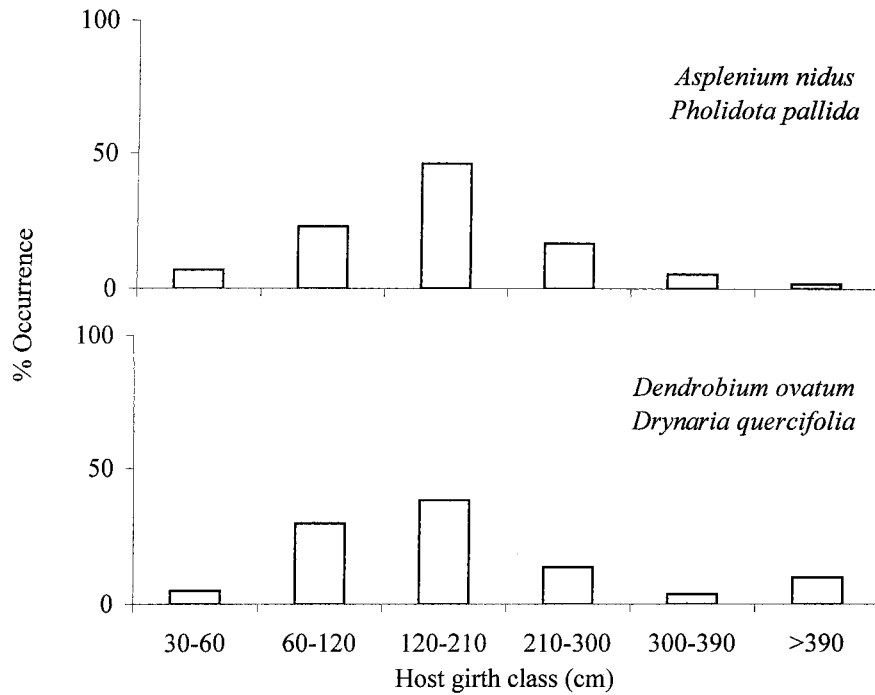


Figure 6. Percentage occurrence of two associations of large epiphytes on six trunk diameter classes in the tropical evergreen forest at Varagalaia, Western Ghats.

therefore need to be able to absorb water quickly when it is available and to conserve it when it is hot (Richards 1996).

Chazdon et al. (1998) suggested that incidence-based estimators, ICE and Chao 2, best satisfied the requirement of ideal estimators. These were well suited for our data set.

For IVI of epiphytes, their abundance plays a major role rather than the frequency as in the case of *Oberonia iridifolia*, which ranked first due to greater density, although its frequency was lower (Table 2) when compared to the other dominants, *Pholidota pallida* and *Asplenium nidus*. Orchids and ferns are the most species-rich groups of herbaceous vascular epiphytes in our study site. This is coincident with the reports of neotropical cloud forests (Atwood 1984; Gentry and Dodson 1987; Richards 1996; Catling and Lefkovitch 1989).

Most epiphytes produce small, wind-dispersed diaspores (Kelly 1985; Kelly et al. 1994) and 92% of epiphyte species in our site belong to this category. The dominance of 54% of capsule and 38% of dust diaspores among the epiphytes of Varagalaia is due to the remarkable diversity of the orchids and pteridophytes.

The occurrence of larger number of species on bigger trees can partly be explained by the larger area offered with a greater variety of branch diameters, crotches and knot holes, with different micro-habitats for epiphytes. Mostly thick branches are often densely covered with vascular epiphytes, accumulating substantial amounts of

humus, nutrients and moisture. These are suitable for epiphytes with higher substrate requirements as reported in cloud forest of Veracruz, Mexico (Hietz and Hietz-Seifert 1995a) and West African rainforest (Johansson 1974, 1975). The larger epiphytes in Varagalaia forest such as *Asplenium nidus*, *Drynaria quercifolia* and *Pholidota pallida* colonize bigger deciduous trees such as *Bischofia javanica* and *Vitex altissima*.

The significant relationship found between epiphyte species association and trunk girth classes in our study and the occurrence of larger epiphyte species on middle and larger stems and smaller epiphyte on smaller trunks, conforms with the report of Catling and Lefkovitch (1989) in Guatemalan cloud forest.

A complex array of factors particularly the combination of humid, riverine location and greater light availability are mostly colonized by epiphytes. *Bischofia javanica* with moderately soft, thin barks, with greater moisture capacitance and *Vitex altissima* with a fissured and relatively thick bark offer a suitable microsite for epiphytes to colonise. The under storey tree *Chionanthus mala-elangi*, because of its occurrence in riverine areas also harbours many epiphytes.

The rainforest epiphytes are mainly small plants, although few grow to several meters high (Richards 1996). This is also the case in our Varagalaia study site. In our site, 85% of the epiphytic species occurred on main trunks and primary branches of the phorophytes. ter Steege and Cornelissen (1989) also reported highest epiphytic diversity in the lower canopy of the lowland rainforest of Guyana.

## Conclusion

This study on herbaceous vascular epiphyte in the 30 ha permanent plot yielded data on the extent of species diversity, distribution and patterns of species association in a tropical evergreen forest in the Western Ghats. Much research still needs to be done on the canopy biology of rainforest trees. This type of baseline inventory is a much needed area of research in order to understand better the role of these dependent life forms in forest function and to provide data for their conservation.

## Acknowledgements

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