INTERNATIONAL JOURNAL OF SCIENCE AND NATURE
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FLORISTIC COMPOSITION AND REPRODUCTIVE TRAITS OF LIANAS IN SHOLA FORESTS OF THE NILGIRI MOUNTAINS, WESTERN GHATS, INDIA

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ABSTRACT
The aim of the study is to describe liana diversity, floristic composition and reproductive traits among discrete patches of shola forests, Nilgiri Mountains, India. Samples were undertaken from 19 shola patches over > 2100m amsl. Sampling plots were laid 30 × 30 m randomly and subdivided into 10 × 10 m subplots. All liana individuals ≥1 cm dbh (diameter at breast height) were enumerated, identified, permanently tagged above 1.3 m from ground level with sequentially numbered aluminium tags from 127.78 plots ($30m^2$) in 11.5 ha. A total of 1290 liana individuals belonging to 14 species in 10 genera and 9 families were recorded. The stem density per hectare was 112.2, basal area 4.98 m^2 ha^{-1} and Fisher's alpha was 2.98. Based on Importance Value Index (IVI), *Elaeagnus conferta* (65.4%) ranked first dominant species followed by *Gardneria ovata* (61.3%) and *Piper trichostachyon* (30%). Common species were *Rubus ellipticus* and *Piper mullesua* (2.9%) and rare species *Rosa leschenaultiana* (0.34%) and *Passiflora leschenaultii* (0.08%). According to the Family value index (FIV), Piperaceae (31%) was first ranked dominant family followed by Rosaceae (23%), Elaeagnaceae (10%) and Loganiaceae (8.9%) were recorded. Frequency distribution of top eight diameter stem class exhibited normal distribution curve that indicates smaller stems (> 1< 10) are more in abundance. Stem twinner was higher among total species richness and tendril climber was higher among total abundance. Reproductive traits of lianas significantly associated with species diversity, however the majority of the species were hermaphrodite, no record of dioecious and monoecious. We conclude that the lianas were relatively low diversity, lower level of species and family composed for forest structure among sholas. However, lianas and their reproductive traits are structurally associated with forest communities.

KEYWORDS: Climbers, Floristic composition, lianas, montane evergreen rainforest, Nilgiri Mountains, sholas, Western Ghats

INTRODUCTION

Lianas (woody climbers) are increasing abundance across global scale forests (Schnitzer and Bongers 2011; Laurance *et al*. in press). However, liana diversity and floristic composition differ in structure depends on topography, soil nutrients climate, disturbance, and natural succession among different forest types (DeWalt *et al*., 2010; Schnitzer & Bongers, 2011, Addo-Fordjour *et al*., 2013). Several studies argued that lianas are highly responses due to disturbance and climate (Dewalt *et al*., 2010; Schnitzer and Bongers 2011; Addo-Fordjour *et al*., 2013; Laurance *et al*., 2014). In most of the tropical forests, lianas species diversity and abundance were lower than that of tree diversity (Schnizter *et al*., 2008) because lianas are naturally host-parasite with trees. Apparently, liana diversity may be increases depend on topography variation, open canopy gaps and disturbance level (Dewalt et al. 2000; Schnitzer and Bongers 2011; Addo-Fordjour *et al*., 2013). In contrast, liana diversity may be decreases through closed-canopy forest or dense forest, undisturbed forests and high-elevation montane forests. In Western Ghats of southern India, montane evergreen forests (locally 'sholas) are distributed at narrow geographic range and restricted to specific montane habitat. Generally sholas are composed with mountainous regions with an altitude above >1200 m msl. However, sholas forest are naturally discrete patches emerged with grassland and swamps in the higher elevation of the Nilgiri Mountains, Westerns Ghats, India. There were several floristic study were examined on tree diversity and vegetation pattern related with shola size and palaeoecological constraints (Caner *et al*., 2007; Mohandass and Davidar, 2009; Mohandass and Davidar, 2010). Several studies were conducted on liana diversity and distribution through large-scale and small-scale plots in the mid and low elevation evergreen of the Western Ghats (Muthuramkumar and Parthasarathy 2000; Padaki and Parthasarathy, 2000; Parthasarathy *et al*., 2004; Muthuramkumar *et al*., 2006). Studies on liana diversity and floristic composition through large-scale and small-scale survey were still given much less attention. Thus the study primarily focused on to describe the liana diversity and floristic composition through liana floristic inventory survey (Mohandass, 2007). Although lianas have a similar in growth form and are generally tend to be light demanding (Schnitzer and Bongers, 2011) that changes species differentiation and climbing mechanisms (Putz, 1984). Climbing mechanism could be another important structural mechanism to assess the light intensity in the closed and open-canopy forests (Gianoli *et al*., 2010).

Interestingly, lianas reproductive characteristics are well reported in several studies (Putz, 1984; Muthuperumal and Parthasarathy, 2013). In Neotropical forests, wind seed dispersal is common among lianas (Gentry, 1982; Howe & Smallwood, 1982). In tropical rainforests, lianas produced delicious fruits for animals (Putz, 1984). In tropical rainforests, pollinators are highly visiting the liana flowers to pollinate the flowers at canopy level (Kato *et al*., 2008). Thus, lianas provide many natural resources for animals and humans in several ways. However, information on liana diversity relationship with reproductive traits were given much less attention in the shola forest of the Western Ghats. Thus, this study primary objective is concerned to describe the liana diversity; floristic composition and association with reproductive traits were examined.

STUDY AREA

The study was carried out in the tropical montane evergreen forests (sholas) of Korakundah and Upper Bhavani Reserve Forest in upper mountainous regions of southern Western Ghats, India. The study area is located about 60-km southwest of Ootacamund, Nilgiri Headquarters. The study sites Korakundah (11° 13. 840' latitude N and 76° 35.115' longitude E) and Upper Bhavani lies in between 11° 14' latitude N and 76° 33' longitudes E. The elevation ranges from 2200 to 2400 m above msl. The slope was mostly steep and varies in degrees. The bedrock is composed of gneisses, charnockites, schists (von Lengerke, 1977). The soil texture varies from clay to clay-loam. Acidic in nature (pH: 4.5 to 6), these soils contain a high percentage of iron and alumina (Meher-Homji, 1967) and the soil are classified as Andisols (Caner *et al*., 2000).

The mean annual rainfall was recorded from Korakundah Tea Estate and Upper Bhavani Electricity department, during the periods for ten years (1994 -2003) was 1887 and 2637 mm (Mohandass & Davidar 2009). The area receives Southwest monsoon, June-September and later October-November is Northeast monsoon. The mean annual temperature ranges from 12 to 29°C in summer and 5 to 24°C in winter. Dry season lasts from December to March and frost can occur in December to January. The seasonality as measured by a series of continuous months where rainfall is <100mm was 5 months (Mohandass, 2007).

Sholas are discrete patchy in nature although large extensive sholas do occur. It is an evergreen stunted forest with short-boled trees seldom higher than 10m forming a dense and crown (Mohandass and Davidar, 2010). The emergent trees reach >25m in height, *e.g. Syzygium tamilnadensis* and *Michelia nilagirica* and canopy trees were about 15-25 *e.g. Daphniphyllum neilgherrense*, *Symplocos foliosa* , *Ilex denticulata* and *Ilex wightiana*, sub-canopy trees were about 10 –15 *e.g. Litsea wightiana*, *Syzygium densiflorum* and *Saprosma fragrans* and understorey species, *e.g. Psychotria nilgiriensis* var. *nilgiriensis* and *Lasianthus venulosus* were <7 m height. Some of the important habitat existed under the shola such as streamside, slopes, plateau and edges (Mohandass, 2007). Dominant trees and shrubs species belong to families such as Lauraceae, Rubiaceae and Symplocaceae. Piperaceae were diverse group of liana assemblage. Parasites, Epiphytes, mosses and lichens are common. Forbs and grasses are also common under the shola vegetation. Lianas are important structural component for Toda tribe using various cultural activities for their livelihood plants, tribes using their own language word '*kwehdry*. Some patches of sholas were disturbed since last 5 decades by local private people, in the aspects of tea cultivation, exotic tree plantation such as *Acacia dealbata*, *Eucalyptus globulus* and *Pinus patula* and dam construction for hydroelectric reservoirs in and around Korakundah and Upper Bhavani Reserve forest of Nilgiri Mountains.

METHODOLOGY

We sampled nineteen sholas of different sizes in both study sites of Korakundah and Upper Bhavani Reserve Forest. Liana inventories were done from November 2002 to September 2004 and total area sampled in 11.5 ha. Sholas were selected according to sizes randomly; each shola was selected between the distances not less than 100m. Sholas sizes were categorized into two size classes large > 1.5 ha, and small sholas were <1.5 ha. Small plots of dimensions laid 30×30 m were used to survey the large sholas randomly. In terms of small sholas, we made entire area of sampling using the same size of quadrat and then each plot was divided into 10 × 10 m subplot. The slope correction was made by slope meter in degrees. Each subplot habitat niche was recorded as follows: edges, gradual slopes, steep slopes, hill top and valley. The geographical coordinates of each plot were determined by using a Geographical Positioning System (GPS). In the study, lianas (woody climbers) of ≥ 1 cm dbh were enumerated, identified, tagged, and mapped to the nearest meter. Each liana individual's diameter at breast height (dbh) were measured 1.3 m above ground level where the stem was cylindrical and sequentially numbered using aluminium tags (Parthasarathy *et al*., 2004, Gerwing *et al*., 2006). All liana stem individuals were inventoried in small sholas whereas in large sholas, the sampling effort was terminated where the species area curves reaches a plateau (see Mohandass & Davidar, 2009). Liana specimens were identified to species level using various floras (Fyson, 1932; Gamble 1915-1935; Matthew, 1999). Nomenclature was followed the Flora of Palni hills (Matthew, 1999) and APG III plant Classification (Bremer *et al*., 2009). The voucher specimen was deposited in the Herbarium of Department of Ecology and Environmental Sciences, Pondicherry University. Identification of sample specimens was confirmed at Botanical Survey of India, Coimbatore and Herbarium French Institute of Pondicherry (HIFPS).

Data analyses

All the plots of data were pooled and number of species and number of liana individuals were tallied. Therefore lianas analyses were conducted from pooled data of total species richness, stem number and basal area of different shola sizes. Basal area was calculated using the formula: $Dbh^2 / (4*\pi)$. The various diversity indics were used to compare the liana diversity from overall sholas. (i) Fisher's alpha measure of diversity was used to assess species diversity (Fisher *et al*., 1943; Condit *et al*., 1998;

Cai ZQ *et al*., 2009). Shannon, Simpson index and eveness index were also calculated to assess species diversity (Anbarasan and Parthasarathy, 2013). To understand floristic structure, the importance value index (IVI) was also calculated by summing up relative frequency, relative density and relative basal area of every species (Curtis and McIntosh, 1950). Taxonomic composition was quantified based on Family importance value (FIV) and was calculated by summing the relative diversity, relative density and relative basal area of each family, according to the formula of Mori *et al*. (1983). The frequency to stem diameter was calculated for top eight species to find whether the mean and median value of dbh class are different (to test normal distribution). We categorized liana species into various climbing types as follows: Stem twinner, tendril, Root climbers and Scramblers (Dewalt *et al*., 2000; Muthuperumal and Parthasarathy 2010). The proportion of each climbing mechanism was calculated from species richness and stem density. Flower size, fruit size, fruit types, sexual system, pollination mode and dispersal mode was observed for each species through direct field investigation. Flower diameter size was classified into small flower (>1<10 mm), medium flower (>10<20mm), large flower (>20mm) and same size categorization was followed for estimating fruit size. Fruit types was classified into fleshy and dry (Chen and Li 2008). Pollination mode was recorded from 8 hr observation for each species. Dispersal mode was classified into Vertebrate (animal and bird dispersed fruits with soft and fleshy outer layer) and Mechanical (wind-dispersal fruits, explosive and passive dispersal). Proportion of each traits and liana diversity was tested by G-test in order to find significant association.

RESULTS

Species diversity and density

A total of 1290 stem individuals (≥1 cm dbh) of lianas belonging to 14 species, 10 genera and 9 families were enumerated in 11.5 ha of the montane evergreen forest *(shola)* in the Korakundah and Upper Bhavani Reserved forest of the Nilgiris (Table 1). Five species and 117 individuals were recorded above ≥ 10 cm dbh in 11.5 ha. Stem density per hectare 112.2 ha-1 was recorded. Fisher's alpha was low 2.98 (> 1 cm dbh) and 1.06 above 10 cm dbh. Shannon index was 1.8 and Simpson index was 0.77 were represented among sholas (Table 1). The dominant lianas contain 494 individuals for *Gardneria ovata (*Loganiaceae) and rarest individual was *Passiflora leschenaultii* (Passifloraceae) (Table 2). First three species of liana density accumulates 76% of stems to compare with remaining species density (Table 2). Based on abundance, 29% of species were dominant, 50% were common and 21% were rare species. The basal area value (≥ 1 cm dbh) was 4. 98 m^2 ha^{-1} and (≥ 10 cm dbh) 2.2 m^2 ha^{-1} were recorded from 11. 5 ha, however lianas are more frequent in abundance less than <10 cm dbh (91%).

TABLE 1. Summary of liana plants ≥1 cm dbh recorded in 19 sholas of total area 11.5 ha were recorded from shola forests of the Nilgiri Mountains.

Variables	≥ 1 cm dbh	≥10 cm dbh
Species richness	14	5
Number of genera	10	5
Number of family	9	5
Number of Individuals	1290	117
Stem density per hectare	112.2	10
Basal area m^2 ha^{-1}	4.98	2.2
Fisher's alpha	2.19	1.06
Shannon index	1.8	0.78
Simpson index	0.77	0.40
Evenness	0.43	0.44

Species and family composition

According to Importance value index (IVI), *Elaeagnus conferta* (65.4%), ranked first dominant species followed by *Gardneria ovata* (61.3%), *Piper trichostachyon* (30%), *Toddalia asiatica* (20.5%) and *Cissampelopsis walkeri* (6%) were recorded. These species are highly contributed for liana community composition and distributed at wide habitat range among sholas. The common lianas were *Piper schmidtii* (4.84%), *Rubus ellipticus* (3.7%), *Rubus rugosus* (3%), *Piper mullesua* (2.9%) and *Parsonsia alboflavescens* (1.4%) Rarest species were *Jasminum brevilobum* (0.16%), *Rosa leschenaultiana* (0.34%) and *Passiflora leschenaultiana* (1.4%) distributed at narrow habitat range. Rarest lianas *Rubus racemosus* (0.66%), *Rosa leschenaultiana* (0.34%), *Jasminum brevilobum* (0.16%), and *Passiflora leschenaultii* (0.08%) were distributed at specific habitat (edges) (Table 2). According to the Family value index (FIV), Piperaceae (31.24%), followed by Rosaceae (23.2%), Elaeagnaceae (10.1%), Loganiaceae (8.9%) were dominant family and highly contributed shola forest structure. However, common family Rutaceae (8.37%), Compositae (7.81%), Apocynanceae (7.71%) and rarest family Oleaceae (7.7%) and Passifloraceae (7.7%) were recorded (Table 3).

Distribution of liana dbh class

A frequency distribution of liana dbh class is said to be skewed and indicated normal distribution when its mean and median are different among seven top species (Fig. 1) except *R. ellipticus*. The frequency distribution of all smaller dbh (>1 < 5 cm) class of stem density was higher among sholas. For instance, closely related species of Piperaceae are mostly smaller dbh class accumulated 23% (>1 < 5 cm dbh). However stem density decreased with increasing dbh class indicates larger lianas were fewer. Species-wise *E. conferta* leads larger lianas and higher in stem density (Fig. 1).

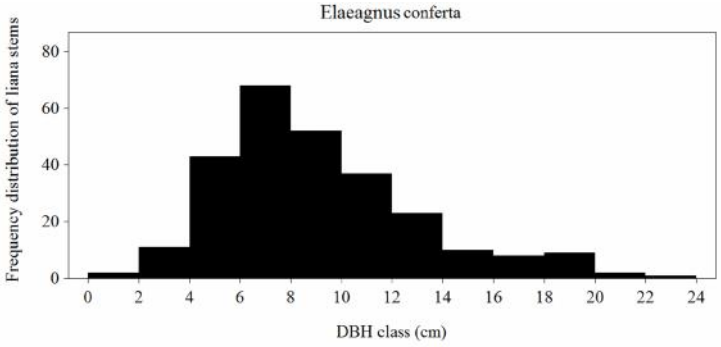
TABLE 2. List of liana species names, number of individuals, basal area m^2 ha^{-1} and importance value Index (IVI) in the upper Nilgiris

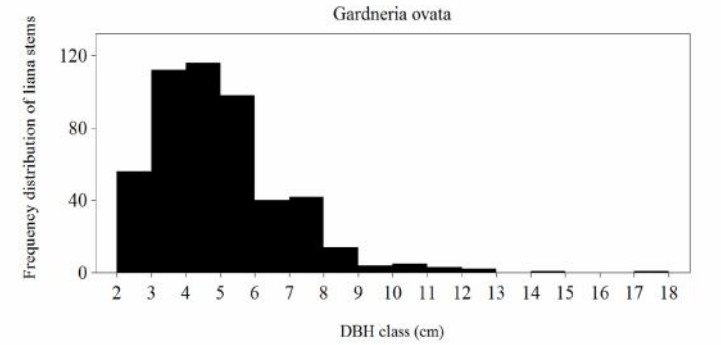
Species Names	Family	D/ha	BA m^2 ha^{-1}	RD (%)	RF (%)	RBA (%)	IVI
Elaeagnus conferta Roxb.	Elaeagnaceae	23.13	2.37	20.62	0.23	44.55	65.40
Gardneria ovata Wall.	Loganiaceae	42.96	1.2	38.29	0.43	22.56	61.28
Piper trichostachyon (Miq.) C. DC.	Piperaceae	19.22	0.68	17.13	0.19	12.78	30.11
Toddalia asiatica (L.) Lam.	Rutaceae	8.78	0.67	7.83	0.09	12.59	20.51
Cissampelopsis walkeri (Arn.) C. Jeffrey & Y.L. Chen	Compositae	4.52	0.12	4.03	0.05	2.26	6.33
Piper schmidtii Hook. f.	Piperaceae	3.91	0.07	3.49	0.04	1.32	4.84
Rubus ellipticus Sm.	Rosaceae	3.04	0.05	2.71	0.03	0.94	3.68
Rubus rugosus Smith in Rees var. *rugosus*	Rosaceae	1.91	0.08	1.71	0.02	1.50	3.23
Piper mullesua Buch.-Ham. Ex D. Don	Piperaceae	2.61	0.03	2.33	0.03	0.56	2.92
Parsonsia alboflavescens (Dennst.) Mabb.	Apocynaceae	1.13	0.02	1.01	0.01	0.38	1.39
Rubus racemosus Roxb.	Rosaceae	0.52	0.01	0.47	0.01	0.19	0.66
Rosa leschenaultiana Red. & Thory ex Wight & Arn.	Rosaceae	0.17	0.01	0.16	0.00	0.19	0.34
Jasminum brevilobum DC.	Oleaceae	0.17	0	0.16	0.00	0.00	0.16
Passiflora leschenaultii DC.	Passifloraceae	0.09	0	0.08	0.00	0.00	0.08

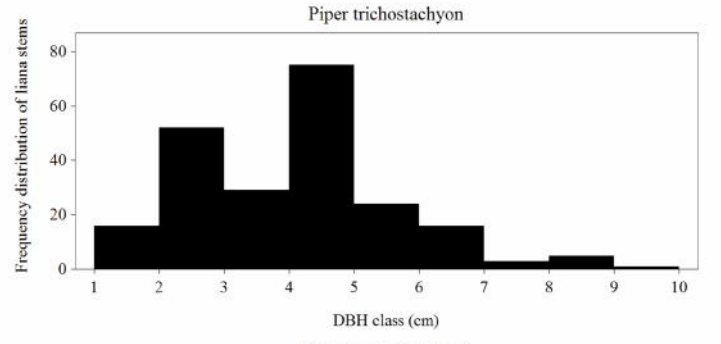
D/ha = Density per hectare, BA= Basal area DRD = relative density, RF= relative frequency, RBA = relative basal area, IVI = importance value index

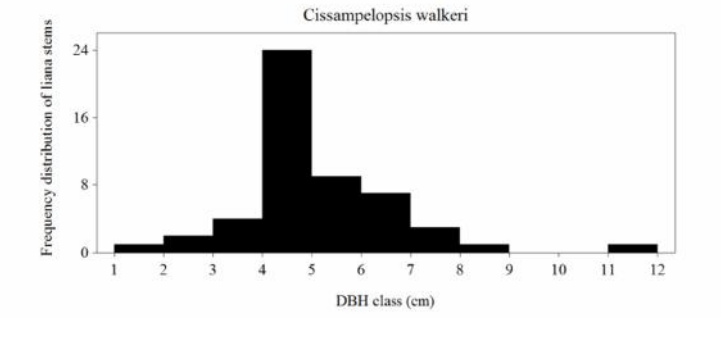
TABLE 3. Family-level composition shows based on family-value index in the shola forests of Nilgiri Mountains.

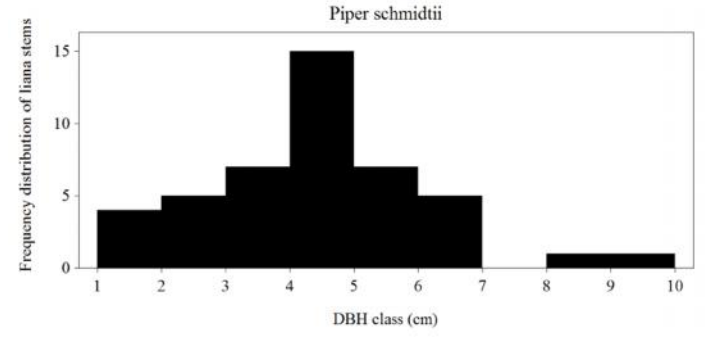
Family	Relative Density	Relative Diversity	Relative Basal area	FIV
Piperaceae	2.21	28.57	0.46	31.24
Rosaceae	1.66	21.43	0.14	23.23
Elaeagnaceae	0.55	7.14	2.37	10.07
Loganiaceae	0.55	7.14	1.20	8.90
Rutaceae	0.55	7.14	0.67	8.37
Compositae	0.55	7.14	0.12	7.81
Apocynaceae	0.55	7.14	0.02	7.71
Oleaceae	0.55	7.14	0.00	7.70
Passifloraceae	0.55	7.14	0.00	7.70


Elaeagnus conferta
Frequency distribution of liana stems
0
20
40
60
80
0 2 4 6 8 10 12 14 16 18 20 22 24
DBH class (cm)


Gardneria ovata
Frequency distribution of liana stems
0
40
80
120
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
DBH class (cm)


Piper trichostachyon
Frequency distribution of liana stems
0
20
40
60
80
1 2 3 4 5 6 7 8 9 10
DBH class (cm)


Cissampelopsis walkeri
Frequency distribution of liana stems
0
8
16
24
1 2 3 4 5 6 7 8 9 10 11 12
DBH class (cm)


Piper schmidtii
Frequency distribution of liana stems
0
5
10
15
1 2 3 4 5 6 7 8 9 10
DBH class (cm)

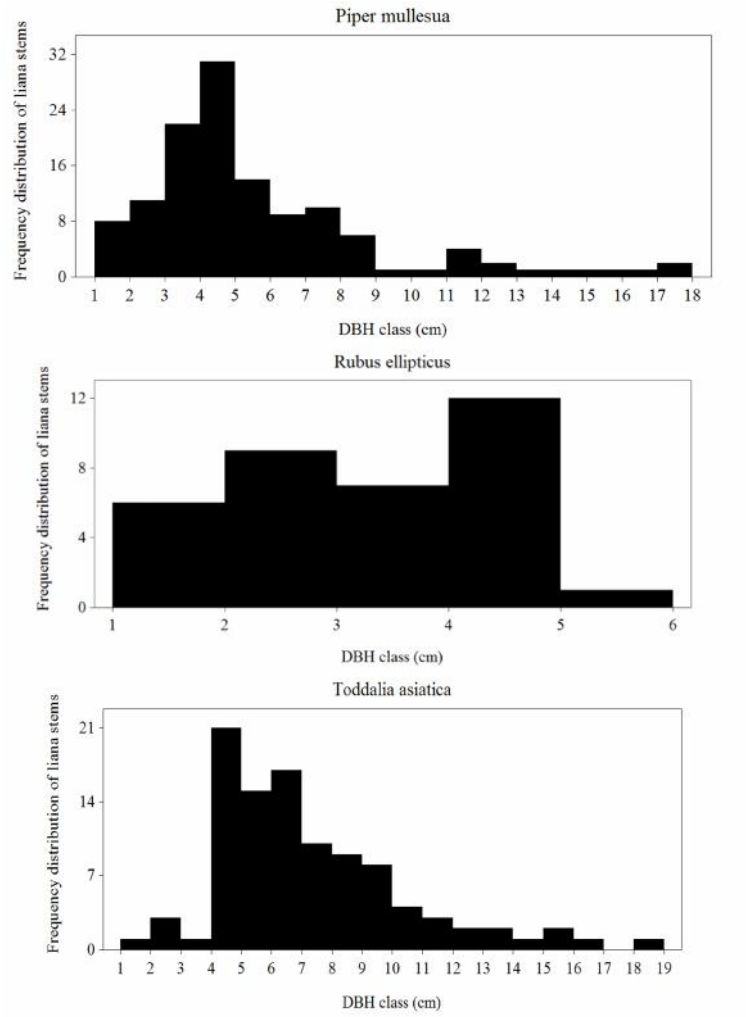


FIGURE1. Diameter and abundance-distribution pattern of most common species in shola forests, Nilgiri Mountains, India

Climbing and dispersal mechanism

Most of lianas are stem twiners 50% of species richness which accounted for 17.1 % of stem abundance. However, tendril are dominated stem individuals (39%) includes *G. ovata*, *P. alboflavescens*, and *P. leschenaultii*. Thus, percentage of species richness and stem density differed significantly among climbing types. One scrambler species *E. conferta* (21%) predominantly present among stem individuals (Fig. 2). Dispersal mode shows that the percentage of vertebrate liana species richness (79%) and density (97%) and mechanical dispersal in species richness (21%) and density (3%) respectively (Fig. 3).

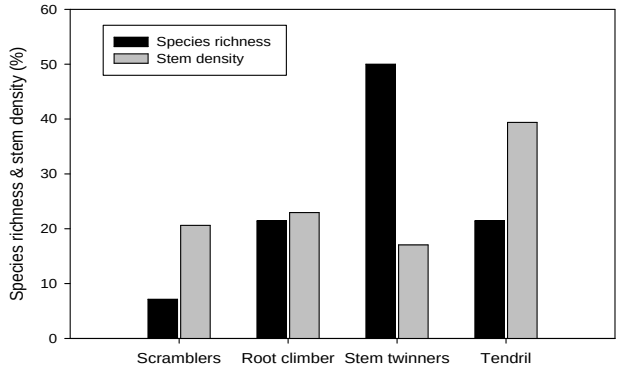


FIGURE 2. Number of liana species and their percentage of individuals in each climbing mechanism of Nilgiri Mountains, India

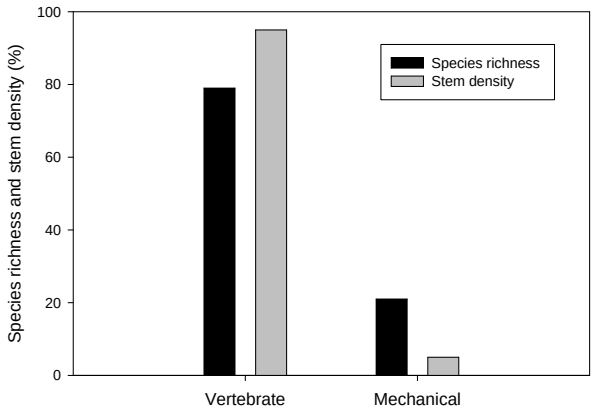


FIGURE 3. Percentage of dispersal mechanism on liana species richness and liana density in the Nilgiri Mountains, India.

Reproductive traits

Reproductive traits of lianas are significantly associated with species diversity (G-test = 79.68, df = 14, P < 0.0001). All lianas are belongs to hermaphrodite, there was no record of dioecious and monoecious sexual system. Smaller size flowers had proportionately more species diversity than expected. Species richness of medium size fruits had proportionately higher than expected but smaller fruits are higher among stem density. Species diversity were significantly associated with fruit types (G-test = 4.71, P < 0.03; Table 4). Species diversity of animal dispersal agents was significantly higher than expected (G-test = 11.31, df =1, P < 0.001) between sholas. Pollination mode was significantly associated with species diversity (G-test = 18.36, df=4, P = 0.001). However bee pollination had proportionately more in species diversity than expected among sholas (mean = 50.5%).

TABLE 4. The association between liana species richness and stem density with reproductive traits in shola forest of the Nilgiri Mountains, Western Ghats, India.

Reproductive traits	Species richness	Stem density	G-test	DF	P-value
Flower size	(%)	(%)			
Small	50	86	32.53	2	0.0001
Medium	36	14			
Large	14	0.23			
Fruit size					
Small	43	62	11.84	2	0.003
Medium	50	38			
Large	7	0.08			
Fruit types					
Fleshy	86	95	4.71	1	0.03
Dry	14	5			
Dispersal mode					
Vertebrate	79	95	11.31	1	0.001
Mechanical	21	5			
Pollination mode					
Bees	50	51	18.36	4	0.001
Bird	7	21			
Butterfly	7	0.16			
Wind	14	5			
Wind and small insects	21	23			

DISCUSSION

The present study resulted that high elevation montane forests (sholas) of Upper Nilgiris in Western Ghats exhibits liana species diversity and abundance were relatively low to compare other mid (~500 -1500) and low (<500m) elevation tropical wet and low montane evergreen forests (Muthuramkumar & Parthasarathy 2000; Padaki & Parthasarathy 2000; Chitibabu & Parthasarathy 2001). Liana diversity are considerably high in mid and low elevation evergreen forests of the Western Ghats (Padaki and Parthasarathy 2000; Mohandass *et al*., unpublished data). The present study contributed 16% of species richness and 4% of liana abundance to compare overall woody species floristic composition (Mohandass & Davidar 2009). But liana-poor forests, such as Semengoh, Sarawak can comprise <10% of the overall woody species diversity (Appanah *et al*., 1992). In Amazon basin, liana diversity comprised 44% of the woody species, averaging

51 liana species ha^{-1} (Perez-Salicrup *et al*., 2001). Despite lianas may be more abundant in seasonally dry forests than in wet forests (Gentry, 1991). The abundance, diversity and taxonomic composition of lianas among shola forests were not similar to compare other tropical lower montane and wet forest evergreen of the Western Ghats (Ganesh *et al*., 1996; Parthasarathy *et al*., 2004). Thus lianas exhibit significant forest resource components among shola forests. Many studies demonstrate that liana diversity varies with several abiotic factors such as total rainfall, length of dry season, soil fertility and disturbance (Dewalt *et al*., 2010; Schnizter & Bongers 2011). Among the shola forests, liana species diversity might be influenced by three possible factors such as length of dry season, total rainfall and disturbance; however detailed investigation should be required. The present study exhibits species composition is similar to compare with other shola forests (> 1800 m amsl) of the Western Ghats. For instance, *Piper* species are dominant among total species richness at Kukkal shola forests and Amaggal shola forests (Davidar *et al*., 2007; Mohandass *et al*., unpublished). However, common and rare species are varied to compare at Kukkal and Amaggal sholas with other shola forest and low-elevation rainforest (Davidar *et al*., 2007; Muthuramkumar *et al*., 2006). It indicates high number of liana species varied depends on topography variation, climate and soil fertility. However, liana abundance was not similar among dominant and common species within the shola forests. It varies depends on local elevational gradients and light intensity. For instance, in this study exhibits *E. conferta* and *G. ovata* were dominant liana abundance. In Kukkal shola forests, *Ventilago maderaspatana* Gaertn. comprises 42 stems per hectare (Davidar *et al*., 2007) and *Tetrastigma leucostaphylum* (Dennst.) Alston were recorded 51 individuals per hectare (Mohandass et al. unpublished). Similarly, family-wise Piperaceae was dominant species and Loganiaceae was dominant abundance family. Vitaceae and Rhamnaceae was dominant family in mid-elevation shola forests (Davidar *et al*., 2007; Mohandass *et al*., unpublished). Therefore, species composition among species richness and stem density are considerably varied among shola forests in the Western Ghats. Liana diameter distribution > 1 cm dbh class comprised 4% and 1% (> 10 cm dbh) of stems the stems exhibited lower (> 1 cm dbh; 287-481 stems in Valparai) than that of value reported in the mid-elevation rainforests of the Western Ghats (Muthuramkumar & Parthasarathy 2000). Our results suggested that stem twiners found 50% among total species richness, it exhibits similar to compare with other studies in Western Ghats (Muthuramkumar & Parthasarathy 2000) whereas tendril 39% were dominant among total abundance. It indicates climbing mechanism was differed among number of species and abundance. Therefore climbing mechanism was differed to compare with mid-elevation evergreen forests of the Western Ghats (Muthuramkumar & Parthasarathy 2000). The percentage of small flowers was higher in total species richness (50%) and total stem density (68%). Dioecy was common among tree species (Mohandass unpublished data), however it was not occurring among liana community. Fruits are mostly fleshy that influences by vertebrate dispersal mechanism. Sholas are prevalently influences by insect pollinators among liana community. Thus, midst liana species and individuals, animal dispersal, hermaphroditic flowers and insect pollination predominate across shola forests. However similar pattern was existed between tree community across all forest types and size classes among worldwide tropical forests (Frankie *et al*., 1974, Gentry 1982, Bawa, 1990, Ibarra-Manrı´quez and Oyama, 1992, Kress and Beach 1994; Chazdon *et al*., 2003). Our results also supported that succession stage of shola forest influence the relative abundance of liana species with different sexual systems and pollination modes, but have relatively little or no effect on the frequency of these traits among liana species (Chazdon *et al*., 2003) due to lianas were low diversity in the studied regions.

CONCLUSION

The results of the study revealed that shola forest of lianas were low species richness and density that contribute less to overall plant diversity of montane evergreen shola forests and wet evergreen forest of the Western Ghats (Parthasarathy *et al*., 2004; Mohandass & Davidar 2009). Our study also supported that liana diversity and density might be decrease with increasing elevation or altitude (Gentry 1991; Parthasarathy *et al*., 2004). However, detailed investigation is necessary to confirm these predictions from low elevation (> 1200 m) to high elevation (> 2100 m) among shola forests. Our results also demonstrates that low diverse pattern of reproductive traits within shola liana communities. Thus, knowledge of liana floristic composition particularly at the genus and family level, offers critical insight into the likely frequency of sexual systems, pollination modes and dispersal syndromes (Chazdon *et al*., 2003). Though the additional information would be required to understand the geographic similarities of reproductive traits among shola plant communities.

ACKNOWLEDGEMENTS

This publication was supported by National Natural Science Foundation of China (NSFC) through Young Scientist Grant. No. 31200173. P.R. China. We thankful to Prof. Qing-Jun Li for their kind support for facilitate to writing this paper. This study was partially supported by a small grant from the Center for Tropical Forest Science and assistance from Dr Egbert G Leigh Jr. We thank Mr Hegde and staff of UNITEA Pvt. Ltd., Chamraj group. Nilgiris. We thank Tamilnadu Forest Department for given permission to entry into the Korakundah and Upper Bhavani Reserve Forest, and Tamilnadu Electricity Board, provided accommodation during the research work.

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