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Lists of Species

A quantitative checklist of woody angiosperm diversity, population structure and habitat grouping in Trishna Wildlife Sanctuary of Tripura, northeast India

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Abstract: A quantitative vegetation inventory was conducted in Trishna Wildlife Sanctuary of Tripura, Northeast India. Twenty five 500×10 m belt transects were used to record diversity and population structure of woody angiosperms. Overall 289 species belonging to 158 genera and 64 families were recorded at ≥10 cm GBH (Girth at Breast Height). Moraceae (25 spp.), Phyllanthaceae (21 spp.), Leguminosae (21 spp.), Euphorbiaceae (15 spp.), and Rubiaceae (14 spp.) were the top five families with highest species diversity. Habit wise, 226 species were trees, 25 woody shrubs, 23 woody climbers, 6 bamboos, 6 rattan and 3 palm species. Shannon–Wiener diversity index values ranged between 1.42–4.25, and Simpson dominance index ranged between 0.02–0.42. Mean species richness index was 2.83 and species evenness index was 0.78. The present quantitative checklist indicates the potential plant resources of the sanctuary which can be used for future biodiversity inventories and species conservation.

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Introduction

Quantitative floristic inventories have been used in recent years to characterize vegetation in different tropical forests by documenting their structure, composition and diversity (Parthasarathy 1999; Sagar *et al.* 2003). Such forest inventories serve as an invaluable research base for diverse aspects of tropical ecology while providing crucial information for their conservation and management efforts (Ayyappan and Parthasarathy 1999). Northeast India is a global hotspot of biodiversity because of its geographical position, climatic conditions and altitudinal variations (Myers *et al.* 2000). The region has 49 protected areas (11 national parks and 38 wildlife sanctuaries) covering a land area of 13936 km^2, which comprises 5.46% of the total area of the northeast (Rodgers *et al.* 2000). Tripura is the second smallest state of northeastern India and the third smallest state in India, with 10,491 km^2 geographical area. The state comprises five hill ranges: Boromura, Atharamura, Shakhan, Jampui and Longtharai, lying parallel to each other in between plains. The highest point of the state is Betling Shib which is located in the Jampui hills at an altitude of 939 m. There are 6,292.68 km^2 area recorded as total forest area, 59.98 % of the total geographic area of the state. Out of which, Reserved Forest (RF) constitutes 66.33%, Protected Forest (PF) 0.03% and Unclassified Forests (UF) 33.64% of the total forest area. Deb (1981; 1983) recorded a total of 1,545 plant taxa for the Flora of Tripura State; with 379 species of tree, 320 shrubs, 581 herbs, 165 climbers, 16 climbing shrubs, 35 ferns, 45 epiphytes and 4 parasites. Floristically, 1573 taxa (862 genera and 193 families) represent about 12.86% of the Flora of India. According to Deb (1981), there was 86% of species widely distributed in India and adjoining countries; while very few species were restricted in adjoining areas in Shylhet, Chittangong of Bangladesh, Cachar of Assam, Mizorum and Myanmar (Majumdar *et al.* 2012a). There are four wildlife sanctuaries *viz*. Sepahijala, Trishna, Gumti and Rowa covering 604 km^2 for *in situ* conservation of forest and forest resources in Tripura. Trishna Wildlife Sanctuary (TWS) is the second largest sanctuary (194.71 km^2) of Tripura after Gumti (389.54 km^2) (SFR 2011).

Several studies on tree diversity, population structure and regeneration status in the tropical forest ecosystems of northeast India have been carried out by different workers (Uma Shankar 2001; Bhuyan *et al.* 2003; Upadhaya *et al.* 2003; Khumbongmoyum *et al.* 2005; Kumar *et al.* 2006; Deb and Sundriyal 2011). Several quantitative inventories of natural forest ecosystems in many Protected Areas (PAs) of northeast India were also investigated (Khan *et al.* 1987; Rao *et al.* 1990; Barik *et al.* 1996; Jamir *et al.* 2006; Deb and Sundriyal 2007). However, since the declaration of Trishna as a Sanctuary, no quantitative and qualitative floristic studies have been conducted; although, several reports (Economic review of Tripura, 2008-2009; Forest Department unpublished data) cited that there are 230 tree species, 110 species of shrub, 400 species of herbs, and 150 species of climbers in TWS. Even recent studies of butterfly diversity in different habitats of TWS also quoted some 890 taxa of plants (Majumder *et al.* 2012). If this information is correct, typically more than 50% of the flora of the state is present within only 194.71 km^2 area of this sanctuary. However, over 1,545 taxa were recorded for the whole geographical area (10,491 km^2) of the state by D. B. Deb, which probably worked out more than 40 years before (Deb 1981 & 1983); and, hence the report of 890 taxa from this small geographical area of the sanctuary is quite doubtful. Hence, existing information on floristic diversity is somewhat conflicting and further study is required to develop baseline data; with a special emphasis needed on quantitative vegetation dynamics.

An understanding of forest dynamics with relation to quantitative species composition is essential not only to maintain forest structure and productivity, but also to conserve overall biodiversity and habitat (Philips 1994; Bhat *et al.* 2000). This type of quantitative floristic inventory has thus been overlooked for all Protected Areas (PAs) in Tripura, and such studies are urgently required today to develop ground-based implications of forest management issues, conservation of diverse ecosystems and their structural elements for sustainable biodiversity and also to promote local livelihoods.

To this end, the present study aimed to survey the woody angiosperm species present in the TWS, in order to contribute a better phytogeographical and phytosociological characterization of the vegetation of PAs in Tripura, northeast India. The aim of this study was not only to provide a species list of the woody angiosperm flora, but to derive the diversity and population structure of the species to assess their present ecological status for better management of local flora, especially the plant resources which represent a rich wildlife habitat within the northeastern India. In addition, this study is also important from a wildlife and conservation point of view; because forest habitats of this sanctuary represents the remaining population of Indian Gour locally called "Bison" (along with Wild Boar, Barking Deer, Palm Civet, Wild Cat, Jackal, Indian Giant Squarrel, Wild Dog, Golden Langur, Hooklock Gibbon, Slow Loris, Capped Langur, Phayre's Langur, Stump Tailed Macaque etc.) and many species of birds and herpatofauna (Majumdar *et al.* 2012b).

Materials and Methods

Study site

Trishna Wildlife Sanctuary was previously known as Bison Reserve, as it was the only natural habitat of Indian Gour in the state, and was hence declared as a 'Wildlife Sanctuary' vide notification No. F.8 (20) For-WL/86/55165 for protection of wild population of Indian Gour including preservation of local flora and fauna. It was established in November 1987 with a total geographical area of 19,470.895 ha. with 27 revenue Mouja in south Tripura district (Figure 1A). This Sanctuary is located between 23°12′ to 23°26′ N and 91°15′ to 91°30′ E in the southwest part of the state and about 120 km from Agartala. The sanctuary is bordered on three sides by Bangladesh and geographically it looks like an elephant tongue (Figures 1B). The headquarter of this sanctuary is situated at Joychandpur, with three wildlife ranges: Abhoya, Rajnagar and Rangamura. The altitude ranges between 16.2 and 73.8 m, andaverage annual rainfall ranges from 03.58 mm to 508.20 mm, and average annual temperature ranges from 6.8°C to 37.7°C. . The topography is mainly undulation of elevated and plain lands. Soil is sandy loam to red laterite in the high-lands and whitish clay in the marshy and logged areas. Several small seasonal streams and streamlets (locally called '*Chara*') are scattered in the low-land areas (locally called *'Lunga'*) in the sanctuary, providing water for wildlife and flow down towards Bangladesh. There are more than twelve large and small artificial water reservoirs created to facilitate wildlife and water conservation within the sanctuary. Now, these lakes harbour various types of aquatic flora and fauna including several migratory birds (unpublished data).

Data collection

This research work was permitted by Department of Biotechnology (DBT), Govt. of India received through DBT Network Project sanction order no. BT/PR7928/NDB/52/9/2006, for a five year period. An extensive floristic survey was performed to cover different wildlife habitats in Trishna Wildlife Sanctuary from 2010 to 2011 by 25 belt transects of 500 × 10 m (0.5 ha.) following stratified random sampling methods (Figures 1B). In each transect, all plants which attained ≥10 cm girth at breast height (GBH) were enumerated, measured and counted in five contiguous 100 ×10 m subplots to provide a quantitative documentation. Plant specimens were processed following standard methodology (Jain and Rao 1977) and subsequently deposited into the herbarium of Department of Botany, Tripura University. Species identification was carried out with the help of Flora of Tripura State (Deb 1981; 1983) and Flora of Assam (Kanjilal *et al.* 1930-1940). The identities of the plants were confirmed by comparison with authentic specimens deposited in the herbarium of Botanical Survey of India, Eastern Circle, Shillong (ASSAM). The nomenclature of plants was updated as per The Plant List project page (The Plant List 2013) (http:// www.theplantlist.org/) and The International Plant Names Index (IPNI 2013). Voucher number of collected species was cited as per the unique herbarium code (*e.g.,* TR0190T31; where TR### represents the belt transects number and T## represents an individual plant species of that transects), which was developed for each individual species following representative belt transects laid randomly throughout TWS. Codes of each unidentified species were used directly for easy data analysis.

Data analysis

Species stand structure (frequency, density, abundance and basal area) were analyzed from the transect data following Misra (1968). Importance value index (IVI) was calculated by summing up relative frequency, relative density and relative dominance values for each transect (Muller–Dombois and Ellenberg 1974). Species diversity index was determined by Shannon–Wiener's index (Shannon and Wiener 1963). Dominance index was calculated by Simpson index (Simpson, 1949). Evenness index was calculated according to Pielou (1966) and species richness index was determined using the formula of Menhinick's richness index (1964). All the species were grouped among ten GBH classes (≥10, > 30, > 60, > 90 , > 120, > 150, > 180, > 210, > 240, >270 cm) and height classes (>1, >3, > 6, > 9, > 12, > 15, > 18, > 21, > 24, >27 m) to observe the overall distribution of populations among different girth and height classes. Population grouping of each species was analysed by the number of individuals of each species which was grouped into different population groups viz. Predominant (>50), Dominant (25 to <50), Common (10 to <25), Rare (2 to <10) and Very Rare (<2) (Kadavul and Parthasarathy 1999; Majumdar *et al.* 2012c).

Results

Six forests types were evaluated based on the predominant tree composition and maximum IVI contribution among the 25 studied transects of TWS

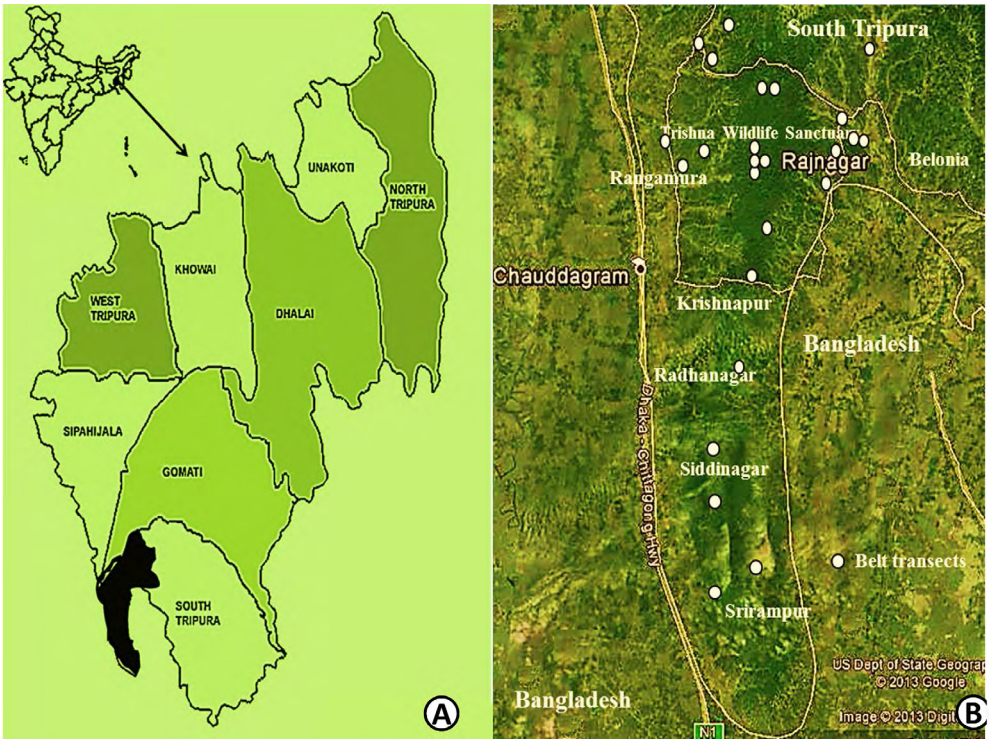

Figure 1. (A) Location of Trishna Wildlife Sanctuary, Tripura, Northeast India; (B) Location of belt transects within the sanctuary.

(Figure 2). Transect wise, the three most predominant tree compositions and their IVI contribution to each sampling plots were calculated (Table 1). Overall 10,949 individuals were counted at ≥10 cm GBH from 12.5 ha. sampling area of the sanctuary. A total of 289 species (range 11–109) were recorded belonging to 158 genera (range 11–68) and 64 families (range 9–47). Out of 289 species, 285 species were identified up to family level, 282 species up to genus level, 271 up to species level and 7 species (4 tree + 3 woody climber) remain unidentified due to unavailability of reproductive parts. Taxonomically, 287 species were angiosperm; one climbing gymnosperm (*Gnetum montanum*) and one pteridophyte (*Cyathea gigantean*) was also recorded as these species attained >10 cm GBH within the transects. However, *Bhesa robusta* (Centroplacaceae), *Sterculia lanceifolia* (Malvaceae), *Castanopsis lanceifolia* (Fagaceae), *Ficus auriculata* (Moraceae) and *Drimycarpus racemosus* (Anacardiaceae), newly recorded tree species of Tripura state (Majumdar *et al.* 2012a), also extended their geographical distribution in this sanctuary.

Mean Shannon's diversity index was 3.23, which ranged from 1.42 to 4.25. Mean Simpson's dominance index was 0.12, ranging between 0.02 and 0.42. Pielou's evenness index ranged between 0.2 and 0.94 with a mean value of 0.78. Menhinick's species richness index was 2.83 ranging between 0.61 and 5.10. Out of 64 plant families, 4 remained unidentified. Moraceae presented 25 species followed by Phyllanthaceae (21), Leguminosae (21), Euphorbiaceae (15), Rubiaceae (14), Malvaceae (12), Lauraceae (11), Arecaceae (10) and Anacardiaceae (10). The five most diversified families (Moraceae, Phyllanthaceae, Leguminosae, Euphorbiaceae, Rubiaceae) were contributed 169.04 ha^{-1} density and 2.67 m^2 ha^{-1} basal area. Again, out of 64 families, 24 families represented only one species each and contributed 109.04 ha^{-1} density and 2.14 m^2 ha^{-1} basal area for these forests. Dipterocarpaceae was the most predominant family with a population density of 193.68 ha^{-1}, 4.72 m^2 ha^{-1} basal area and IVI of 57.79. Five top predominant families (Dipterocarpaceae, Poaceae, Moraceae, Theaceae and Phyllanthaceae) were calculated for 462.16 ha^{-1} density, 8.07 m^2 ha^{-1} basal area and 132.06 IVI. Population density of the members belonging to Moraceae family were 25.92 ha^{-1} with 1.11 m^2 ha^{-1} basal area and contributed IVI of 18.47 (Table 4).

Population density of 95 species was recorded in less than 0.25 ha^{-1} (ranging from 0.08 to 0.24 ha^{-1}) and 26 species was found whose density was less than 5 ha^{-1} (ranging from 5.20 to 142.32 ha^{-1}). Again, 144 species were recorded with a basal area of less than 0.01 m^2 ha^{-1} (i.e. 0.26 m^2 ha^{-1} basal area for 144 species) and only 5 species were found where basal area ranged between 0.50 and 3.28 m^2 ha^{-1}. The distribution of the populations of the different groups suggested that the predominant group (PD) contributed to the highest density 659.68 ha^{-1} followed by the common group (C) 91.52 ha^{-1} and density of dominant group (D) was 78.34 ha^{-1}, which was less than the common group. The basal area of the predominant group (PD) was 10.84 m^2 ha^{-1} followed by rare group (R) 1.15 m^2 ha^{-1}, common group (C) 1.02 m^2 ha^{-1}, dominant (D) 0.83 m^2 ha^{-1} and very rare (VR) 0.04 m^2 ha^{-1}. Grouping of individuals within five different population classes are calculated in Table 2. Distribution of stems in different age / girth classes suggested that more than 60 % of the populations were in sapling stage (≥10–30 cm GBH) with density 527.84 ha^{-1}; which also includes mature bamboo, mature woody shrubs and climbers. Adult population (30-120 cm GBH) were 38.55 % with 337.68 ha^{-1} density and only 1.19% population were in mature state (>120 cm GBH) with density 10.40 ha^{-1}. Canopy class distribution of forest strata revealed that 51.32 % stems were in understory (< 6 m height) with density 449.60 ha^{-1}, 43.10% stems with density of 377.60 $ha.^{-1}$ were in mid stories (<15 m height) and 48.72 $ha.^{-1}$ stems density (5.56%) were in the upper

Table 1. Classification of forest ecosystem in Trishna Wildlife Sanctuary (TWS) based on top three predominant species composition and their contribution of IVI in 25 belt transects.

SL. NO.	FOREST ECOSYSTEM	TOP 3 PREDOMINANT TREE ASSOCIATION BASED ON MAXIMUM CONTRIBUTION OF IVI	SUM OF IVI (%)	BELT TRANSECT NO.
A	PRIMARY FOREST			
1	Moist Bamboo Brakes	*Bambusa tulda, Schima wallichii, Terminalia bellirica*	129.6	TR0167
2	Moist Bamboo Brakes	*Bambusa tulda, Schima wallichii, Crypteronia paniculata*	102.8	TR0168
3	Moist Bamboo Brakes	*Bambusa tulda, Dipterocarpus turbinatus, Macaranga denticulata*	152.1	TR0169
4	Moist Bamboo Brakes	*Bambusa tulda, Wrightia antidysenterica, Terminalia bellirica*	112.1	TR0170
5	Moist Bamboo Brakes	*Bambusa tulda, Lannea coromandelica, Schima wallichii*	99.27	TR0171
6	Moist Deciduous Sal	*Shorea robusta, Wrightia antidysenterica, Ziziphus rugosa*	97.28	TR0172
7	Moist Deciduous Sal	*Shorea robusta, Schima wallichii, Terminalia bellirica*	174.3	TR0173
8	Moist Deciduous Sal	*Shorea robusta, Microcos paniculata, Chaetocarpus castanicarpus*	137.4	TR0174
9	Moist Deciduous Sal	*Shorea robusta, Terminalia bellirica, Schima wallichii*	73.8	TR0175
10	Moist Deciduous Sal	*Shorea robusta, Dipterocarpus turbinatus, Terminalia bellirica*	172.5	TR0176
11	Moist Deciduous Sal	*Shorea robusta, Terminalia bellirica, Mitragyna rotundifolia*	183.6	TR0177
12	Moist Deciduous Sal	*Shorea robusta, Dipterocarpus turbinatus, Wrightia antidysenterica*	130.2	TR0178
13	Moist Mixed Deciduous	*Ficus benghalensis , Bombax ceiba, Terminalia bellirica,*	47.37	TR0179
14	Moist Mixed Deciduous	*Wrightia antidysenterica, Terminalia bellirica, Careya arborea*	48.39	TR0181
15	Moist Mixed Deciduous	*Schima wallichii , Castanopsis indica, Microcos paniculata*	36.59	TR0182
16	Moist Mixed Deciduous	*Maesa ramentacea , Terminalia bellirica, Bambusa tulda*	54.4	TR0183
17	Moist Mixed Deciduous	*Schima wallichii, Mitragyna rotundifolia, Syzygium cerasoides*	137.6	TR0184
18	Moist Mixed Deciduous	*Schima wallichii , Bambusa tulda, Careya arborea*	64.29	TR0185
19	Moist Mixed Deciduous	*Schima wallichii, Terminalia bellirica, Wrightia antidysenterica*	124.1	TR0186
20	Semi Evergreen Patch	*Dipterocarpus turbinatus, Castanopsis indica, Schima wallichii*	96.8	TR0188
21	Semi Evergreen Patch	*Dipterocarpus turbinatus, Schima wallichii, Bombax ceiba*	84.92	TR0189
22	Semi Evergreen Patch	*Dipterocarpus turbinatus, Schima wallichii, Microcos paniculata*	153.8	TR0190
23	Semi Evergreen Patch	*Dipterocarpus turbinatus, Schima wallichii, Microcos paniculata*	150.7	TR0191
B	SECONDARY FORESTS			
24	Rubber Plantation	*Havea brassilensis, Artocarpus heterophyllus, Anacardium occidentalis*	244.5	TR0187
25	Teak Plantation	*Tectona grandis, Wrightia antidysenterica, Bambusa tulda*	115.8	TR0192

stories (>15 m). Density distribution in different age and height classes are given in Table 3.

Overall forest population density ranged between 328 -and 1330 ha.$^{-1}$ and mean density was 875.92 ha.$^{-1}$. Mean basal area was calculated as 13.87 m^2 ha.$^{-1}$ ranging between 3.71 and 52.82 m^2 ha.$^{-1}$. *Shorea robusta* was recorded with maximum density (142.32 ha.$^{-1}$) followed by *Bambusa tulda* (120.88 ha.$^{-1}$), *Schima wallichii* (55.92 ha.$^{-1}$), *Dipterocarpus turbinatus* (48.64 ha.$^{-1}$) and *Microcos paniculata* (31.92 ha.$^{-1}$), which possessed the top five most dense occurrences in the TWS. However, *Dipterocarpus turbinatus* was recorded with highest basal area (3.28 m^2 ha.$^{-1}$) followed by *Schima wallichii* (1.44 m^2 ha.$^{-1}$), *Shorea robusta* (1.42 m^2 ha^{-1}), *Terminalia bellirica* (0.73 m^2 ha^{-1}) and *Bambusa tulda* (0.45 m^2 ha.$^{-1}$) as the top five species recorded with highest basal area. Based on the IVI, *Dipterocarpus turbinatus* was most ecologically important species (29.72) followed by *Shorea robusta* (27.19), Schima *wallichii* (18.31), *Bambusa tulda* (17.69) and *Terminalia bellirica* (9.32). Out of 289 species, 226 species

Table 2. Diversity and population structure of woody angiosperm plants along five different population groups in Trishna Wildlife Sanctuary (TWS).

POPULATION GROUP	INDIVIDUAL RANGE	NUMBER OF SPECIES	DENSITY ha^{-1}	BASAL AREA m^2 ha^{-1}	IMPORTANT VALUE INDEX (IVI)
Predominant (PD)	>50	35	659.68	10.84	188.72
Dominant (D)	>25	27	78.56	0.83	33.8
Common (C)	>10	70	91.52	1.02	45.11
Rare (R)	>2	124	43.52	1.15	29.65
Very Rare (VR)	<2	33	2.64	0.04	2.72
Total		**289**	**875.92**	**13.88**	**300**

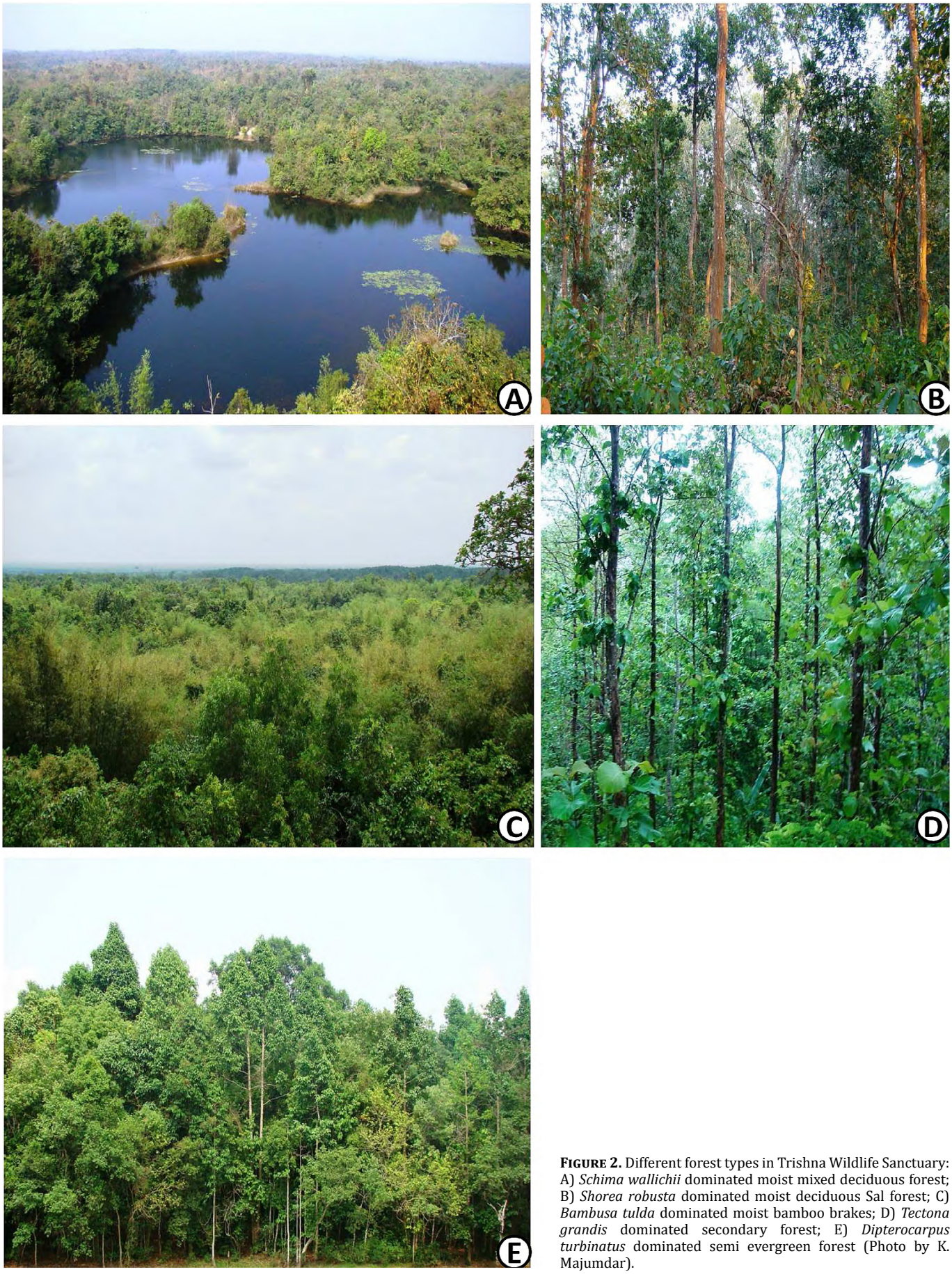

Figure 2. Different forest types in Trishna Wildlife Sanctuary: A) *Schima wallichii* dominated moist mixed deciduous forest; B) *Shorea robusta* dominated moist deciduous Sal forest; C) *Bambusa tulda* dominated moist bamboo brakes; D) *Tectona grandis* dominated secondary forest; E) *Dipterocarpus turbinatus* dominated semi evergreen forest (Photo by K. Majumdar).

were tree, 25 woody shrubs, 23 woody climbers, 6 rattan, 6 bamboo and 3 palm species were recorded across TWS. Quantitative population structure (density and basal area), importance value index with distinct habit types of all species are given in Table 4. Some important plant species of TWS are also featured in Figures 3–8 for easy identification.

Discussion

Forest characteristics

Most forest areas in the central part of the sanctuary were bamboo dominated. Based on the composition and character drawn by Champion and Seth (1968), this bamboo dominated forest community was grouped as Moist Bamboo Brakes (2B/E3); where *B. tulda* was found dominated by the IVI over *S. wallichii, T. bellirica*, *M. paniculata*, *M. baccifera* and *W. antidysenterica*. Forest stands, where Sal were predominantly recorded over other tree species were classified as East Himalayan Lower Bhabar Sal Forest (3C/C1b (ii), as they showed similar characteristics of Moist deciduous Sal forest proposed in Champion and Seth (1968) forest classification system. However, these Sal forests varied in association with different community and locality levels. Mostly, several sites were found where *S. wallichii* dominated even over Sal and Dipterocarpus. This type of community association represented similar traits of the Moist Mixed Deciduous Forest (3C/C3) type of Champion and Seth (1968); where *S. wallichii* mainly associated with *T. bellirica, C. arborea, B. ceiba, M. rotundifolia.* Mature strata of *D. turbinatus* typically found in Cachar Tropical Semi Evergreen Forest (2B/2s2/c2) type of Champion and Seth (1968); mostly *Castanopsis sps, E. spicata, C. arborea, T. bellirica*, *C. castanicarpus, M. paniculata* were the main co-dominant composition in this community. Earlier, pure *D. turbinatus* dominated semi evergreen forests or sometime mixed with *S. robusta* were distributed predominantly throughout this sanctuary (Kashari RF and Trishna PRF).

Due to extensive anthropogenic pressure, especially after immigration from Bangladesh, most of these forest areas were subsequently destroyed and restricted within the Trishna PRF; now only limited pure patches could be found in the localities of Joychandpur and Durgapur. Several villages are located along the boundary of the sanctuary, where large areas of natural forest were destroyed for habitation and road constructions. Some portion of the adjoining forest areas in the sanctuary were modified into rubber, bamboo and teak plantations. Continuous habitat disturbances might result shortly degradation of natural forest and development of several community association and successional stages (Table 1). The predominant composition (top three species on the basis of IVI contribution) varied within the sanctuary (Table 1), following local edaphic factors and degree of

Table 3. Distribution of woody angiosperm plant population in ten different girth and height classes in Trishna Wildlife Sanctuary (TWS).

GIRTH / AGE CLASS DISTRIBUTION (cm)	NUMBER OF INDIVIDUALS	DENSITY ha^{-1}	PERCENTAGE (%)	HEIGHT / CANOPY CLASS DISTRIBUTION (m)	NUMBER OF INDIVIDUALS	DENSITY ha^{-1}	PERCENTAGE (%)
≥10	6,598	527.84	60.26	≥1	911	72.88	8.32
>30	3,322	265.76	30.34	>3	4,709	376.72	43.01
>60	773	61.84	7.06	>6	2,217	177.36	20.25
>90	126	10.08	1.15	>9	1,282	102.56	11.71
>120	33	2.64	0.30	>12	1,221	97.68	11.15
>150	12	0.96	0.11	>15	288	23.04	2.63
>180	18	1.44	0.16	>18	173	13.84	1.58
>210	16	1.28	0.15	>21	89	7.12	0.81
>240	6	0.48	0.05	>24	37	2.96	0.34
>270	45	3.6	0.41	>27	22	1.76	0.20
Total	**10,949**	**875.92**	**100**	**Total**	**10,949**	**875.92**	**100**

Table 4. Woody angiosperm species (≥ 10 cm GBH) recorded in the Trishna Wildlife Sanctuary (TWS) of Tripura, Northeast India. Habit Type (WC — Woody Climber, T — Tree, WS — Woody Shrub, B — Bamboo, P — Palm, R — Rattan); DEN $ha.^{-1}$ — Density per ha; BA $m^2 ha.^{-1}$ — Basal Area per m^2 per ha.; IVI — Important Value Index; Population Group (PD — Predominant, D — Dominant, C — Common, R — Rare and VR — Very Rare); Voucher Number (See Materials and Methods for details).

SL. NO.	SPECIES	FAMILY	HABIT TYPE	DEN ha^{-1}	BA* m^2ha^{-1}	IVI	PG	VOUCHER NUMBER
1	*Acacia concinna* (Willd.) DC.	Leguminosae	WC	2.32	0.01	0.97	D	TR0176T16
2	*Acacia pennata* (L.) Willd.	Leguminosae	WC	9.44	0.04	2.79	PD	TR0174T13
3	*Acronychia pedunculata* (L.) Miq.	Rutaceae	T	1.92	0.03	0.96	C	TR0169T64
4	*Actinodaphne angustifolia* Nees.	Lauraceae	T	1.04	0.01	0.42	C	TR0170T23
5	*Actinodaphne obovata* (Nees) Blume.	Lauraceae	T	2	0.02	1.01	C	TR0170T11
6	*Aglaia* sp	Meliaceae	T	0.08	0.00	0.1	VR	TR0167T46
7	*Aglaia edulis* (Roxb.) Wall.	Meliaceae	T	0.4	0.00	0.28	R	TR0187T87
8	*Alangium chinense* (Lour.) Harms.	Cornaceae	T	0.32	0.01	0.17	R	TR0190T52
9	*Albizia chinensis* (Osbeck) Merr.	Leguminosae	T	0.48	0.01	0.31	R	TR0175T14

Table 4. *Continued.*

SL. NO.	SPECIES	FAMILY	HABIT TYPE	DEN ha^{-1}	BA* m^2ha^{-1}	IVI	PG	VOUCHER NUMBER
10	*Albizia lebbeck* (L.) Benth.	Leguminosae	T	0.32	0.00	0.27	R	TR0176T38
11	*Albizia lucidior* (Steud.) I.C.Nielsen.	Leguminosae	T	0.16	0.00	0.1	R	TR0167T37
12	*Albizia procera* (Roxb.) Benth.	Leguminosae	T	1.76	0.04	0.93	C	TR0184T66
13	*Alstonia scholaris* (L.) R. Br.	Apocynaceae	T	1.84	0.02	1.06	C	TR0168T57
14	*Ampelocissus barbata* (Wall.) Planch.	Vitaceae	WC	1.12	0.01	0.65	C	TR0183T50
15	*Anacardium occidentale* L.	Anacardiaceae	T	0.96	0.06	0.61	C	TR0177T3
16	*Anogeissus acuminata* (Roxb. ex DC.) Guill.	Combretaceae	T	0.08	0.00	0.08	VR	TR0184T64
17	*Antidesma acidum* Retz.	Phyllanthaceae	T	1.04	0.00	0.73	C	TR0183T81
18	*Antidesma bunius* (L.) Spreng.	Phyllanthaceae	WS	0.08	0.00	0.08	VR	TR0187T72
19	*Antidesma ghaesembilla* Gaertn.	Phyllanthaceae	T	0.4	0.00	0.11	R	TR0174T52
20	*Aphanamixis polystachya* (Wall.) R. Parker	Meliaceae	T	1.68	0.01	1.07	C	TR0175T21
21	*Aporosa octandra* (Buch.-Ham. ex D.Don) Vickery.	Phyllanthaceae	T	20	0.12	4.62	PD	TR0167T9
22	*Aporosa villosa* (Lindl.) Baill.	Phyllanthaceae	T	4.56	0.03	1.34	PD	TR0170T83
23	*Archidendron clypearia* (Jack) I.C.Nielsen.	Leguminosae	T	0.88	0.01	0.55	C	TR0173T6
24	*Ardisia neriifolia* Wall. ex A.DC.	Primulaceae	T	1.68	0.01	0.65	C	TR0168T73
25	*Ardisia paniculata* Roxb.	Primulaceae	T	0.24	0.00	0.16	R	TR0188T23
26	*Ardisia solanacea* (Poir.) Roxb.	Primulaceae	WS	0.24	0.00	0.16	R	TR0184T30
27	*Artocarpus chaplasha* Roxb.	Moraceae	T	6.48	0.20	3.51	PD	TR0170T6
28	*Artocarpus heterophyllus* Lam.	Moraceae	T	0.4	0.03	0.34	R	TR0177T8
29	*Artocarpus lakoocha* Roxb.	Moraceae	T	2.32	0.07	1.47	D	TR0181T45
30	*Baccaurea ramiflora* Lour.	Phyllanthaceae	T	0.96	0.01	0.51	C	TR0188T15
31	*Balakata baccata* (Roxb.) Esser.	Euphorbiaceae	T	2.08	0.08	1.61	D	TR0171T10
32	*Bambusa balcooa* Roxb.	Poaceae	B	4.24	0.02	0.97	PD	TR0177T7
33	*Bambusa polymorpha* Munro.	Poaceae	B	1.12	0.00	0.21	C	TR0179T34
34	*Bambusa tulda* Roxb.	Poaceae	B	120.88	0.45	17.69	PD	TR0174T29
35	*Bambusa vulgaris* Schrad.	Poaceae	B	0.08	0.00	0.08	VR	TR0181T53
36	*Beilschmiedia assamica* Meisn.	Lauraceae	T	0.08	0.00	0.08	VR	TR0174T30
37	*Bhesa robusta* (Roxb.) Ding Hou	Centroplacaceae	T	1.36	0.02	0.67	C	TR0167T55
38	*Bischofia javanica* Blume.	Phyllanthaceae	T	0.24	0.00	0.1	R	TR0192T84
39	*Boehmeria macrophylla* Hornem.	Urticaceae	T	0.56	0.00	0.13	R	TR0175T27
40	*Bombax ceiba* L.	Malvaceae	T	1.44	0.13	1.67	C	TR0170T1
41	*Bombax insigne* Wall.	Malvaceae	T	0.24	0.16	1.32	R	TR0167T8
42	*Borassus flabellifer* L.	Arecaceae	T	0.08	0.01	0.11	VR	TR0177T10
43	*Brassaiopsis glomerulata* (Blume) Regel.	Araliaceae	WS	0.24	0.00	0.16	R	TR0191T58
44	*Brassaiopsis griffithii* C.B.Clarke.	Araliaceae	WS	1.44	0.00	0.4	C	TR0191T45
45	*Breynia vitis-idaea* (Burm.f.) C.E.C.Fisch.	Phyllanthaceae	WS	0.24	0.00	0.16	R	TR0183T57
46	*Bridelia assamica* Hook.f.	Phyllanthaceae	T	0.4	0.00	0.19	R	TR0168T5
47	*Bridelia glauca* Blume	Phyllanthaceae	WS	1.04	0.00	0.41	C	TR0168T41
48	*Bridelia retusa* (L.) A.Juss.	Phyllanthaceae	T	3.44	0.02	1.48	D	TR0179T8
49	*Bridelia stipularis* (L.) Blume.	Phyllanthaceae	WS	2	0.01	0.83	C	TR0173T26
50	*Bridelia tomentosa* Blume.	Phyllanthaceae	T	0.56	0.00	0.22	R	TR0174T51
51	*Buchanania cochinchinensis* (Lour.) M.R.Almeida.	Anacardiaceae	T	0.24	0.01	0.13	R	TR0191T16
52	*Byttneria pilosa* Roxb.	Malvaceae	WC	0.08	0.00	0.08	VR	TR0179T32
53	*Caesalpinia bonduc* (L.) Roxb.	Leguminosae	WC	0.88	0.00	0.6	C	TR0183T18
54	*Calamus erectus* Roxb.	Arecaceae	R	1.04	0.01	0.29	C	TR0183T77
55	*Calamus floribundus* Griff.	Arecaceae	R	0.56	0.00	0.22	R	TR0169T41
56	*Calamus guruba* Buch.-Ham.	Arecaceae	R	0.16	0.00	0.09	R	TR0187T99

Table 4. *Continued.*

SL. NO.	SPECIES	FAMILY	HABIT TYPE	DEN ha^{-1}	BA* m^2ha^{-1}	IVI	PG	VOUCHER NUMBER
57	*Calamus leptospadix* Griff.	Arecaceae	R	1.36	0.00	0.39	C	TR0172T16
58	*Calamus tenuis* Roxb.	Arecaceae	R	0.88	0.00	0.18	C	TR0188T26
59	*Calamus viminalis* Willd.	Arecaceae	R	0.64	0.00	0.21	R	TR0174T61
60	*Callicarpa arborea* Roxb.	Lamiaceae	T	6.8	0.07	2.28	PD	TR0168T15
61	*Canthium dicoccum* (Gaertner) Merrill.	Rubiaceae	WS	0.16	0.00	0.15	R	TR0170T86
62	*Canthium angustifolium* Roxb.	Rubiaceae	WS	0.16	0.00	0.09	R	TR0183T33
63	*Canthium glabrum* Blume.	Rubiaceae	T	1.2	0.00	0.56	C	TR0170T39
64	*Carallia brachiata* (Lour.) Merr.	Rhizophoraceae	T	1.04	0.01	0.62	C	TR0182T24
65	*Careya arborea* Roxb.	Lecythidaceae	T	12.16	0.18	4.04	PD	TR0170T60
66	*Caryota obtusa* Griff.	Arecaceae	P	0.08	0.00	0.08	VR	TR0170T84
67	*Caryota urens* L.	Arecaceae	P	1.2	0.01	0.78	C	TR0176T31
68	*Cassia fistula* L.	Leguminosae	T	3.04	0.03	1.07	D	TR0171T22
69	*Cassia siamea* Lam.	Leguminosae	T	0.4	0.00	0.15	R	TR0178T1
70	*Castanopsis armata* (Roxb.) Spach.	Fagaceae	T	3.52	0.05	1.59	D	TR0181T44
71	*Castanopsis indica* (Roxb. ex Lindl.) A.DC.	Fagaceae	T	4.16	0.15	2.41	PD	TR0168T2
72	*Castanopsis lanceifolia* (Oerst.) Hickel & A.Camus.	Fagaceae	T	0.16	0.01	0.14	R	TR0183T45
73	*Castanopsis tribuloides* (Sm.) A.DC.	Fagaceae	T	2.96	0.06	1.38	D	TR0174T35
74	*Catunaregam spinosa* (Thunb.) Tirveng.	Rubiaceae	T	0.08	0.00	0.08	VR	TR0185T26
75	*Celastrus paniculatus* Willd.	Celastraceae.	T	1.44	0.04	1.11	C	TR0190T57
76	*Chaetocarpus castanocarpus* (Roxb.) Thwaites.	Peraceae	T	11.44	0.10	3.43	PD	TR0169T22
77	*Chisocheton paniculatus* Hiern .	Meliaceae	T	0.16	0.00	0.1	R	TR0174T9
78	*Cinnamomum* sp	Lauraceae	T	0.16	0.00	0.09	R	TR0170T38
79	*Cinnamomum bejolghota* (Buch.-Ham.) Sweet.	Lauraceae	T	2.24	0.01	0.92	D	TR0170T16
80	*Cinnamomum glanduliferum* (Wall.) Meisn.	Lauraceae	T	0.4	0.00	0.12	R	TR0189T12
81	*Cinnamomum iners* Reinw. ex Blume.	Lauraceae	T	0.64	0.01	0.42	R	TR0183T46
82	*Cleidion javanicum* Blume.	Euphorbiaceae	T	0.32	0.01	0.17	R	TR0185T34
83	*Combretum wallichii* DC.	Combretaceae	WC	0.48	0.00	0.26	R	TR0175T17
84	*Combretum flagrocarpum* C.B.Clarke.	Combretaceae	WC	0.8	0.00	0.3	R	TR0170T61
85	*Combretum album* Pers.	Combretaceae	WC	3.2	0.01	1.09	D	TR0176T35
86	*Combretum punctatum* Blume.	Combretaceae	WC	3.68	0.01	1.27	D	TR0167T64
87	*Cordia dichotoma* G.Forst.	Boraginaceae	T	0.16	0.00	0.09	R	TR0169T42
88	*Cordia fragrantissima* Kurz.	Boraginaceae	T	0.16	0.00	0.09	R	TR0170T37
89	*Cordia grandis* Roxb.	Boraginaceae	T	0.32	0.00	0.2	R	TR0192T17
90	*Croton joufra* Roxb.	Euphorbiaceae	T	0.24	0.00	0.11	R	TR0189T56
91	*Crypteronia paniculata* Blume.	Crypteroniaceae	T	8.8	0.17	3.44	PD	TR0183T74
92	*Cyathea gigantea* (Wall. ex Hook.) Holttum.	Cyatheaceae	F	0.48	0.00	0.28	R	TR0179T10
93	*Dalbergia stipulacea* Roxb.	Leguminosae	T	0.88	0.00	0.47	C	TR0171T5
94	*Dalbergia thomsonii* Benth.	Leguminosae	WC	2	0.01	0.68	C	TR0169T35
95	*Dalbergia volubilis* Roxb.	Leguminosae	WC	4.16	0.02	1.46	PD	TR0185T36
96	*Derris robusta* (DC.) Benth.	Leguminosae	T	0.88	0.02	0.56	C	TR0185T37
97	*Desmos chinensis* Lour.	Annonaceae	WS	0.08	0.00	0.08	VR	TR0188T10
98	*Desmos dumosus* (Roxb.) Saff.	Annonaceae	WS	0.24	0.00	0.1	R	TR0172T24
99	*Desmos longiflorus* (Roxb.) Saff.	Annonaceae	WS	0.72	0.00	0.36	R	TR0182T63
100	*Dillenia pentagyna* Roxb.	Dilleniaceae	T	4.88	0.25	3.64	PD	TR0188T48
101	*Dillenia scabrella* (D.Don) Roxb. ex Wall.	Dilleniaceae	T	0.16	0.00	0.15	R	TR0167T70
102	*Diospyros* sp	Ebenaceae	T	0.24	0.00	0.17	R	TR0188T6
103	*Diospyros lanceifolia* Roxb.	Ebenaceae	T	0.48	0.00	0.22	R	TR0168T23

Table 4. *Continued.*

SL. NO.	SPECIES	FAMILY	HABIT TYPE	DEN ha^{-1}	BA* m^2ha^{-1}	IVI	PG	VOUCHER NUMBER
104	*Diospyros malabarica* (Desr.) Kostel.	Ebenaceae	T	0.08	0.00	0.08	VR	TR0182T28
105	*Diospyros montana* Roxb.	Ebenaceae	T	0.16	0.00	0.1	R	TR0190T17
106	*Diospyros racemosa* Roxb.	Ebenaceae	T	0.16	0.00	0.09	R	TR0188T18
107	*Dipterocarpus gracilis* Blume.	Dipterocarpaceae	T	2.32	0.02	0.75	D	TR0192T73
108	*Dipterocarpus turbinatus* C.F.Gaertn	Dipterocarpaceae	T	48.64	3.28	29.72	PD	TR0192T23
109	*Discospermum abnorme* (Korth.) S.J.Ali & Robbr.	Rubiaceae	T	0.08	0.00	0.08	VR	TR0188T32
110	*Dracaena angustifolia* (Medik.) Roxb.	Asparagaceae	WS	0.24	0.00	0.16	R	TR0170T42
111	*Drimycarpus racemosus* (Roxb.) Hook.f. ex March-and.	Anacardiaceae	T	0.88	0.01	0.43	C	TR0187T85
112	*Duabanga grandiflora* (DC.) Walp.	Lythraceae	T	0.24	0.01	0.3	R	TR0169T66
113	*Dysoxylum* sp	Meliaceae	T	0.16	0.00	0.1	R	TR0170T45
114	*Dysoxylum excelsum* Blume.	Meliaceae	T	1.28	0.01	0.54	C	TR0187T54
115	*Dysoxylum gotadhora* (Buch.-Ham.) Mabb.	Meliaceae	T	0.24	0.01	0.22	R	TR0175T4
116	*Ehretia acuminata* R.Br.	Boraginaceae	T	0.24	0.00	0.1	R	TR0185T44
117	*Elaeocarpus* sp	Elaeocarpaceae	T	1.44	0.02	0.91	C	TR0185T61
118	*Elaeocarpus floribundus* Blume.	Elaeocarpaceae	T	0.64	0.01	0.25	R	TR0168T62
119	*Elaeocarpus obtusus* Blume.	Elaeocarpaceae	T	0.32	0.00	0.19	R	TR0169T61
120	*Elaeocarpus prunifolius* Wall. ex Müll.Berol.	Elaeocarpaceae	T	1.92	0.04	1.14	C	TR0170T18
121	*Elaeocarpus tectorius* (Lour.) Poir.	Elaeocarpaceae	T	2.08	0.02	0.92	D	TR0181T22
122	*Engelhardia spicata* Lesch. ex Blume.	Juglandaceae	T	5.2	0.07	2.02	PD	TR0181T40
123	*Entada phaseoloides* (L.) Merr.	Leguminosae	WC	0.32	0.00	0.18	R	TR0184T68
124	*Erioglossum rubiginosum* (Roxb.) Blume.	Sapindaceae	T	2	0.02	1.22	C	TR0174T50
125	*Erioglossum* sp	Sapindaceae	T	0.08	0.00	0.08	VR	TR0183T31
126	*Erythrina arborescens* Roxb.	Leguminosae	T	0.8	0.01	0.46	R	TR0168T65
127	*Erythrina variegata* L.	Leguminosae	T	0.08	0.00	0.08	VR	TR0170T67
128	*Eugenia macrocarpa* Schltdl. & Cham.	Myrtaceae	T	1.36	0.01	0.49	C	TR0175T9
129	*Eurya acuminata* DC.	Pentaphylacaceae	T	2.32	0.02	1.32	D	TR0181T54
130	*Ficus* sp	Moraceae	T	0.64	0.02	0.49	R	TR0186T11
131	*Ficus* sp	Moraceae	T	0.16	0.00	0.1	R	TR0181T35
132	*Ficus altissima* Blume	Moraceae	T	0.08	0.00	0.09	VR	TR0192T41
133	*Ficus auriculata* Lour.	Moraceae	T	1.36	0.01	0.7	C	TR0185T50
134	*Ficus benghalensis* L.	Moraceae	T	0.16	0.17	1.41	R	TR0190T59
135	*Ficus benjamina* L.	Moraceae	T	1.04	0.01	0.57	C	TR0187T11
136	*Ficus curtipes* Corner	Moraceae	T	0.24	0.10	0.82	R	TR0181T17
137	*Ficus drupacea* Thunb.	Moraceae	T	0.08	0.00	0.08	VR	TR0181T34
138	*Ficus fistulosa* Reinw. ex Blume.	Moraceae	T	0.16	0.00	0.09	R	TR0190T38
139	*Ficus heteropleura* Blume.	Moraceae	T	0.08	0.00	0.08	VR	TR0187T49
140	*Ficus hirta* Vahl.	Moraceae	T	0.24	0.00	0.12	R	TR0190T11
141	*Ficus hispida* L.f.	Moraceae	T	5.2	0.05	2.05	PD	TR0169T25
142	*Ficus microcarpa* L.f.	Moraceae	T	0.24	0.03	0.39	R	TR0167T105
143	*Ficus nervosa* B.Heyne ex Roth.	Moraceae	T	2.16	0.03	1.09	D	TR0179T23
144	*Ficus racemosa* L.	Moraceae	T	0.56	0.01	0.4	R	TR0183T9
145	*Ficus religiosa* L.	Moraceae	T	0.24	0.18	1.54	R	TR0186T52
146	Ficus rumphii Blume.	Moraceae	T	0.48	0.11	1.08	R	TR0186T48
147	*Ficus semicordata* Buch.-Ham. ex Sm.	Moraceae	T	0.48	0.01	0.24	R	TR0170T28
148	*Ficus tinctoria* G.Forst.	Moraceae	T	0.08	0.00	0.08	VR	TR0167T76
149	*Ficus variegata* Blume.	Moraceae	T	0.4	0.01	0.15	R	TR0170T9
150	*Ficus virens* Aiton.	Moraceae	T	0.96	0.04	0.64	C	TR0187T84

Table 4. *Continued.*

SL. NO.	SPECIES	FAMILY	HABIT TYPE	DEN ha^{-1}	BA* m^2ha^{-1}	IVI	PG	VOUCHER NUMBER
151	*Firmiana colorata* (Roxb.) R.Br.	Malvaceae	T	0.48	0.00	0.4	R	TR0189T20
152	*Fissistigma bicolor* (Roxb.) Merr.	Annonaceae	T	0.48	0.00	0.26	R	TR0191T60
153	*Fissistigma verrucosum* (Hook. f. & Thomson) Merr.	Annonaceae	T	0.96	0.00	0.39	C	TR0183T36
154	*Flacourtia indica* (Burm. f.) Merr.	Salicaceae	T	0.64	0.00	0.35	R	TR0174T62
155	*Flueggea virosa* (Roxb. ex Willd.) Royle.	Phyllanthaceae	T	0.4	0.01	0.22	R	TR0170T77
156	*Garcinia cowa* Roxb. ex Choisy.	Clusiaceae	T	3.12	0.02	1.3	D	TR0174T75
157	*Garcinia sopsopia* (Buch.-Ham.) Mabb.	Clusiaceae	T	0.16	0.01	0.15	R	TR0183T37
158	*Garcinia xanthochymus* Hook. f. ex T. Anderson	Clusiaceae	T	0.4	0.00	0.21	R	TR0187T64
159	*Gardenia resinifera* Roth.	Rubiaceae	T	3.6	0.04	1.54	D	TR0179T29
160	*Garuga pinnata* Roxb.	Burseraceae	T	2.56	0.03	1.3	D	TR0168T31
161	*Gigantochloa nigrociliata* (Buse.) Kurz .	Poaceae	B	0.96	0.00	0.18	C	TR0189T29
162	*Glochidion ellipticum* Wight.	Phyllanthaceae	T	4	0.02	1.28	D	TR0169T32
163	*Glochidion heyneanum* (Wight & Arn.) Wight.	Phyllanthaceae	T	1.68	0.01	0.62	C	TR0167T27
164	*Glochidion lanceolarium* (Roxb.) Voigt.	Phyllanthaceae	T	0.72	0.00	0.31	R	TR0189T17
165	*Glochidion multiloculare* (Rottler ex Willd.) Voigt.	Phyllanthaceae	T	0.8	0.01	0.48	R	TR0190T31
166	*Glochidion sphaerogynum* (Müll. Arg.) Kurz.	Phyllanthaceae	T	2.96	0.02	1.25	D	TR0181T51
167	*Glochidion zeylanicum* (Gaertn.) A. Juss.	Phyllanthaceae	T	0.72	0.00	0.31	R	TR0171T13
168	*Glycosmis mauritiana* (Lam.) Tanaka.	Rutaceae	T	0.08	0.00	0.08	VR	TR0175T41
169	*Gnetum montanum* Markgr.	Gnetaceae	WC	1.36	0.01	0.67	C	TR0191T57
170	*Grewia hirsuta* Vahl.	Malvaceae	T	2	0.02	0.75	C	TR0185T17
171	*Grewia polygama* Roxb.	Malvaceae	T	0.16	0.01	0.13	R	TR0178T3
172	*Gynocardia odorata* R.Br.	Achariaceae	T	0.16	0.00	0.09	R	TR0174T56
173	*Heteropanax fragrans* (Roxb.) Seem.	Araliaceae	WC	0.08	0.00	0.08	VR	TR0167T2
174	*Heteropanax fragrans* (Roxb.) Seem.	Araliaceae	T	0.08	0.00	0.08	VR	TR0183T47
175	*Hevea brasiliensis* (Willd. ex A.Juss.) Müll. Arg.	Euphorbiaceae	T	10.56	0.63	5.78	PD	TR0188T20
176	*Hibiscus macrophyllus* Roxb. ex Hornem.	Malvaceae	T	0.56	0.00	0.29	R	TR0177T1
177	*Holigarna caustica* (Dennst.) Oken.	Anacardiaceae	T	1.36	0.02	0.53	C	TR0179T21
178	*Horsfieldia amygdalina* (Wall.) Warb.	Myristicaceae	T	1.04	0.01	0.68	C	TR0167T72
179	*Hymenodictyon orixense* (Roxb.) Mabb.	Rubiaceae	T	0.72	0.00	0.37	R	TR0182T26
180	*Knema linifolia* (Roxb.) Warb.	Myristicaceae	T	0.56	0.00	0.29	R	TR0181T30
181	*Lagerstroemia parviflora* Roxb.	Lythraceae	T	6.8	0.05	2.16	PD	TR0187T80
182	*Lagerstroemia speciosa* (L.) Pers.	Lythraceae	T	0.16	0.00	0.17	R	TR0176T32
183	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	T	7.68	0.18	3.58	PD	TR0190T40
184	*Leea aequata* L.	Vitaceae	T	1.2	0.00	0.43	C	TR0185T56
185	*Leea compactiflora* Kurz.	Vitaceae	T	0.08	0.00	0.08	VR	TR0170T13
186	*Leea indica* (Burm. f.) Merr.	Vitaceae	T	0.24	0.00	0.16	R	TR0185T38
187	*Leea robusta* Roxb.	Vitaceae	T	0.16	0.00	0.09	R	TR0184T58
188	*Lithocarpus elegans* (Blume) Hatus. ex Soepadmo	Fagaceae	T	1.92	0.03	1	C	TR0174T33
189	*Litsea cubeba* (Lour.) Pers.	Lauraceae	T	0.56	0.00	0.34	R	TR0188T50
190	*Litsea glutinosa* (Lour.) C.B. Rob.	Lauraceae	T	2.88	0.02	1.35	D	TR0171T29
191	*Litsea monopetala* (Roxb.) Pers.	Lauraceae	T	2	0.02	1.04	C	TR0168T30
192	*Litsea panamanja* (Buch.-Ham. ex Nees) Hook. f.	Lauraceae	T	0.48	0.00	0.13	R	TR0172T28
193	*Macaranga* sp	Euphorbiaceae	T	1.6	0.01	0.66	C	TR0170T66
194	*Macaranga denticulata* (Blume) Müll.Arg.	Euphorbiaceae	T	3.68	0.03	1.21	D	TR0170T41
195	*Macaranga peltata* (Roxb.) Müll.Arg.	Euphorbiaceae	T	1.36	0.01	0.52	C	TR0174T45
196	*Macropanax undulatus* (Wall. ex G.Don) Seem.	Araliaceae	T	1.2	0.01	0.45	C	TR0172T17
197	*Maesa indica* (Roxb.) A. DC.	Primulaceae	T	0.08	0.00	0.08	VR	TR0170T10

Table 4. *Continued.*

SL. NO.	SPECIES	FAMILY	HABIT TYPE	DEN ha^{-1}	BA* m^2ha^{-1}	IVI	PG	VOUCHER NUMBER
198	*Maesa montana* A. DC.	Primulaceae	T	0.08	0.00	0.08	VR	TR0181T42
199	*Maesa ramentacea* (Roxb.) A. DC	Primulaceae	T	6.96	0.04	2.04	PD	TR0185T64
200	*Mallotus nudiflorus* (L.) Kulju & Welzen	Euphorbiaceae	T	0.16	0.00	0.11	R	TR0190T10
201	*Mallotus philippensis* (Lam.) Müll. Arg.	Euphorbiaceae	T	7.68	0.06	2.64	PD	TR0184T29
202	*Mallotus repandus* (Willd.) Müll. Arg.	Euphorbiaceae	T	1.12	0.01	0.36	C	TR0169T18
203	*Mallotus roxburghianus* Müll. Arg.	Euphorbiaceae	T	0.88	0.01	0.35	C	TR0173T23
204	*Mallotus tetracoccus* (Roxb.) Kurz.	Euphorbiaceae	WS	0.96	0.00	0.4	C	TR0191T11
205	*Mangifera indica* L.	Anacardiaceae	T	0.08	0.01	0.17	VR	TR0170T69
206	*Mangifera sylvatica* Roxb.	Anacardiaceae	T	0.16	0.00	0.09	R	TR0177T9
207	*Markhamia stipulata* (Wall.) Seem.	Bignoniaceae	T	1.68	0.02	1.01	C	TR0167T92
208	*Melastoma malabathricum* L.	Melastomataceae	WS	1.04	0.00	0.33	C	TR0191T41
209	*Melocanna baccifera* (Roxb.) Kurz.	Poaceae	B	4.8	0.01	0.72	PD	TR0173T20
210	*Memecylon celastrinum* Kurz.	Melastomataceae	WS	0.08	0.00	0.08	VR	TR0171T35
211	Memecylon umbellatum Burm. f.	Melastomataceae	WS	0.32	0.00	0.18	R	TR0175T35
212	*Meyna spinosa* Roxb. ex Link.	Rubiaceae	T	0.56	0.01	0.36	R	TR0183T27
213	*Microcos paniculata* L.	Malvaceae	T	31.92	0.29	7.36	PD	TR0183T49
214	*Micromelum integerrimum* (Buch.-Ham. ex DC.) Wight & Arn. ex M. Roem.	Rutaceae	WS	0.88	0.00	0.45	C	TR0171T3
215	*Miliusa roxburghiana* Hook.f. & Thomson	Annonaceae	WS	0.24	0.00	0.16	R	TR0183T76
216	*Millettia pachycarpa* Benth.	Leguminosae	WC	0.08	0.00	0.08	VR	TR0168T25
217	*Mitragyna rotundifolia* (Roxb.) Kuntze.	Rubiaceae	T	9.6	0.07	2.8	PD	TR0167T45
218	*Neolamarckia cadamba* (Roxb.) Bosser	Rubiaceae	T	0.88	0.02	0.41	C	TR0168T50
219	*Ochna integerrima* (Lour.) Merr.	Ochnaceae	T	0.16	0.00	0.15	R	TR0168T16
220	*Olax acuminata* Wall. ex Benth.	Olacaceae	WS	1.04	0.00	0.42	C	TR0188T30
221	*Oreocnide integrifolia* (Gaudich.) Miq.	Urticaceae	WS	3.04	0.02	1.03	D	TR0182T16
222	*Oroxylum indicum* (L.) Kurz	Bignoniaceae	T	0.48	0.00	0.28	R	TR0170T26
223	*Palaquium polyanthum* (Wall. ex G.Don) Baill.	Sapotaceae	T	1.36	0.01	0.53	C	TR0187T75
224	*Pandanus foetidus* Roxb.	Pandanaceae	WS	1.2	0.00	0.55	C	TR0170T88
225	*Pandanus tectorius* Parkinson ex Du Roi	Pandanaceae	WS	0.4	0.00	0.12	R	TR0170T87
226	*Phyllanthus emblica* L.	Phyllanthaceae	T	8.32	0.04	2.42	PD	TR0186T25
227	*Polyalthia simiarum* (Buch.-Ham. ex Hook. f. & Thomson) Benth.	Annonaceae	T	0.24	0.00	0.1	R	TR0177T11
228	*Pterospermum acerifolium* (L.) Willd.	Malvaceae	T	0.64	0.01	0.51	R	TR0187T73
229	*Pterospermum lanceifolium* Roxb.	Malvaceae	T	0.16	0.00	0.09	R	TR0168T79
230	*Pterospermum sagisagittatum* Roxb. ex DC.	Malvaceae	T	3.6	0.04	1.72	D	TR0167T54
231	*Saraca asoca* (Roxb.) Willd.	Leguminosae	T	6.88	0.04	1.81	PD	TR0173T15
232	*Saurauia napaulensis* DC.	Actinidiaceae	T	0.24	0.00	0.1	R	TR0186T2
233	*Saurauia roxburghii* Wall.	Actinidiaceae	T	0.88	0.00	0.37	C	TR0168T71
234	*Schefflera venulosa* (Wight & Arn.) Harms	Araliaceae	WC	0.08	0.00	0.08	VR	TR0174T53
235	*Schima wallichii* Choisy.	Theaceae	T	55.92	1.44	18.31	PD	TR0181T63
236	*Semecarpus anacardium* L.f.	Anacardiaceae	T	0.08	0.00	0.08	VR	TR0171T2
237	*Shorea assamica* Dyer.	Dipterocarpaceae	T	0.4	0.00	0.13	R	TR0168T82
238	*Shorea robusta* Gaertn.	Dipterocarpaceae	T	142.32	1.42	27.19	PD	TR0187T81
239	*Sloanea* sp	Elaeocarpaceae	T	0.64	0.01	0.26	R	TR0167T68
240	*Spatholobus parviflorus* (DC.) Kuntze	Leguminosae	WC	0.88	0.00	0.58	C	TR0169T37
241	*Spondias axillaris* Roxb.	Anacardiaceae	T	0.24	0.00	0.1	R	TR0186T36
242	*Spondias pinnata* (L. f.) Kurz.	Anacardiaceae	T	0.16	0.00	0.19	R	TR0184T34
243	*Sterculia lanceifolia* Roxb.	Malvaceae	T	0.24	0.00	0.11	R	TR0170T40
244	*Sterculia villosa* Roxb.	Malvaceae	T	4.56	0.03	1.34	PD	TR0169T26

Table 4. *Continued.*

SL. NO.	SPECIES	FAMILY	HABIT TYPE	DEN ha^{-1}	BA* m^2ha^{-1}	IVI	PG	VOUCHER NUMBER
245	*Stereospermum tetragonum* DC.	Bignoniaceae	T	4	0.10	1.88	D	TR0168T58
246	*Streblus asper* Lour.	Moraceae	T	1.68	0.02	0.96	C	TR0168T64
247	*Styrax serrulatus* Roxb.	Styracaceae.	T	0.24	0.00	0.11	R	TR0189T55
248	*Suregada multiflora* (A. Juss.) Baill.	Euphorbiaceae	T	2.72	0.01	1.27	D	TR0168T46
249	*Symplocos ferruginea* Roxb.	Symplocaceae	T	0.32	0.00	0.25	R	TR0169T2
250	*Symplocos racemosa* Roxb.	Symplocaceae	T	1.6	0.01	0.64	C	TR0189T18
251	*Syzygium cumini* (L.) Skeels	Myrtaceae	T	1.12	0.00	0.49	C	TR0172T21
252	*Syzygium fruticosum* DC.	Myrtaceae	T	0.48	0.01	0.23	R	TR0184T72
253	*Syzygium grande* (Wight) Walp.	Myrtaceae	T	2.24	0.01	0.61	D	TR0175T34
254	*Syzygium nervosum* A.Cunn. ex DC.	Myrtaceae	T	5.52	0.06	2.52	PD	TR0170T64
255	*Syzygium praecox* (Roxb.) Rathakr. & N.C.Nair	Myrtaceae	T	2.48	0.03	1.12	D	TR0183T67
256	*Syzygium syzygioides* (Miq.) Merr. & L.M.Perry	Myrtaceae	T	0.48	0.00	0.14	R	TR0183T39
257	*Tamarindus indica* L.	Leguminosae	T	0.08	0.00	0.08	VR	TR0167T77
258	*Tectona grandis* L.f.	Lamiaceae	T	18.56	0.30	4.39	PD	TR0184T63
259	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	T	21.68	0.73	9.32	PD	TR0190T1
260	*Terminalia chebula* Retz.	Combretaceae	T	0.4	0.00	0.27	R	TR0169T12
261	*Terminalia citrina* Roxb. ex Fleming	Combretaceae	T	0.24	0.00	0.11	R	TR0181T57
262	*Tetracera sarmentosa* (L.) Vahl	Dilleniaceae	WC	0.16	0.00	0.09	R	TR0170T89
263	*Toona ciliata* M.Roem.	Meliacaea	T	1.68	0.03	0.82	C	TR0187T47
264	TR0168T21	TR0168T21	WC	0.32	0.00	0.11	R	TR0168T21
265	TR0170T27	TR0170T27	WC	0.24	0.00	0.1	R	TR0170T27
266	TR0188T31	TR0188T31	WC	0.08	0.00	0.08	VR	TR0188T31
267	*Trema orientalis* (L.) Blume	Cannabaceae	T	1.36	0.02	0.6	C	TR0174T38
268	*Tricalysia* sp	Rubiaceae	T	0.24	0.00	0.1	R	TR0170T8
269	TR0184T32	Meliacaea	T	0.16	0.00	0.11	R	TWS17T32
270	TR0185T40	Euphorbiaceae	T	0.08	0.00	0.08	VR	TWS18T40
271	TR0185T41	Euphorbiaceae	T	0.08	0.00	0.08	VR	TWS18T41
272	TR0187T82	TR0187T82	T	0.24	0.00	0.12	R	TWS20T82
273	*Uncaria sessilifructus* Roxb.	Rubiaceae	WC	0.48	0.00	0.12	R	TR0167T74
274	*Vitex altissima* L.f.	Lamiaceae	T	1.04	0.04	0.94	C	TR0171T33
275	*Vitex peduncularis* Wall. ex Schauer	Lamiaceae	T	4.8	0.03	2.04	PD	TR0168T63
276	*Vitex pinnata* L.	Lamiaceae	T	0.56	0.01	0.5	R	TR0181T8
277	*Wallichia oblongifolia* Griff.	Arecaceae	P	0.16	0.00	0.09	R	TR0174T77
278	*Wendlandia tinctoria* (Roxb.) DC.	Rubiaceae	T	0.4	0.00	0.2	R	TR0170T43
279	*Wendlandia wallichii* Wight & Arn.	Rubiaceae	T	0.16	0.00	0.1	R	TR0167T33
280	*Willughbeia edulis* Roxb.	Apocynaceae	WC	0.48	0.00	0.29	R	TR0187T62
281	*Wrightia antidysenterica* (L.) R.Br.	Apocynaceae	T	23.6	0.19	5.51	PD	TR0187T90
282	*Xantolis assamica* (C.B.Clarke) P.Royen	Sapotaceae	T	0.8	0.01	0.46	R	TR0182T29
283	*Xylosma controversa* Clos.	Salicaceae	T	0.32	0.00	0.17	R	TR0170T22
284	*Zanthoxylum* sp.	Rutaceae	T	0.24	0.00	0.11	R	TR0185T42
285	*Zanthoxylum limonella* (Dennst.) Alston	Rutaceae	T	0.16	0.00	0.16	R	TR0186T51
286	*Ziziphus funiculosa* Buch.-Ham. ex Wall.	Rhamnaceae	WS	1.28	0.01	0.73	C	TR0169T49
287	*Ziziphus oenopolia* (L.) Mill.	Rhamnaceae	WS	0.48	0.00	0.28	R	TR0171T34
288	*Ziziphus rugosa* Lam.	Rhamnaceae	T	4.48	0.02	1.36	PD	TR0169T21
289	*Ziziphus xylopyrus* Hochst. ex A.Rich.	Rhamnaceae	T	0.16	0.00	0.09	R	TR0187T58
		Total # families: 64		875.92	13.87	300		

*Basal Area (BA)-0.00 is <0.01

exposure to anthropogenic pressure. Since, large forest areas of TWS were converted for settlements due to sudden immigration (especially during 1970s and 1980s), sanctuary forest areas and its natural resources were encroached upon and heavily exploited, and presently most of the remaining forests areas now represent the characteristics of a secondary forest ecosystem. However, as the sanctuary shares its boundary with the international border of Bangladesh on three sides, these remaining forests and forest resources are under pressure through continuous extraction of timber, fuel wood, bamboo and collection of other Non-Timber Forest Products (NTFPs) by forest dependent people living in and around TWS.

Species richness and diversity

Overall, 289 woody species (≥10 cm GBH) were identified from 12.50 ha. sampling area of this sanctuary, compared with 312 angiosperm plant species listed from tropical dry evergreen forests of peninsular India (Udayakumar and Parthasarathy 2010); 449 angiosperm species from Nanmangalam Reserve Forest in Southern India (Nehru *et al.* 2012) and greater than 272 tree species ≥30 cm GBH from tropical forests of southern Eastern Ghats, Tamil Nadu, India (Pragasan *et al.* 2009); 247 species from Kalakad-Mundanthurai Tiger Reserve of southern Western Ghats in India (Richard and Muthukumar 2012); 241 tree species from five different forest types of North Andaman Islands (Prasad *et al.* 2009); 180 species from tropical dry evergreen Forests of Sendirakillai Sacred Grove in Tamil Nadu, South India (Gnanasekaran *et al.* 2012). The value of Shannon's diversity index is generally higher in tropical forests, reported as 5.06 and 5.40 for young and old stands respectively (Knight 1975). In Indian forests, it ranges from 0.83 to 4.1 (Visalakshi 1995). Present mean value of Shannon's diversity index (3.23) was greater, being a protected area than earlier reports in different tree communities of Tripura (Majumdar *et al.* 2012c), where mean Shannon's diversity was 3.00 (range 1.76–3.57). Mean Simpson's dominance index of the present study was 0.12, which falls within an earlier reported range (0.04 -0.30) in Tripura (Majumdar *et al.* 2012c). The value of this index ranges between 0 and 1; where greater values indicate high stand dominance with few species, or 0 represents infinite diversity, and 1 no diversity. Therefore, the bigger the value of Simpson's dominance index, the lower diversity. The range of dominance index reported for tropical forest of India varies from 0.21 to 0.92. Te present mean dominance index (0.12) was comparatively greater than the average value of dominance index in tropical forests of 0.06 (Knight 1975). An evenness index is an indication of numeric equality between the communities and the value should range from 0 to 1; values close to 0 indicate a community is very uneven; and thus, when there is less variation in communities between species the value of this index should be close to 1. However, in the present study mean Pielou's evenness index was 0.78, which indicated less variation in species composition and number within the communities. Species richness index (2.83) was relatively high, which reflects that much of the value of diversity is attributable to the species that are relatively rare (Pandey and Shukla 2003).

Stand density, basal area and population grouping

Overall mean stem density for the present study was 875.92 ha.$^{-1}$; however, Ashton (1964), Campbell *et al.* (1992) and Richards (1996) found that the stem density at ≥10cm girth class varied from 245-859 stem ha.$^{-1}$ in tropical forest. The present stem density was quite lower than some other Indian forests; Kumar *et al.* (2006) 724 - 980 trees ha.$^{-1}$ and Pande (1999) 1150 - 1920 trees ha.$^{-1}$. Mean basal area for the present study was recorded as 13.87 m^2 ha^{-1}, close to moist deciduous forest of Western Ghats 14.7 m^2 ha.$^{-1}$ (Seth and Kaul 1978) and 12.83 m^2 ha.$^{-1}$ (Sundarapandian and Swamy 1997). Stand density decreased with increasing girth and height class intervals, as calculated in Table 3, and tree density decreased with increasing GBH classes, which is a typical characteristic of tropical forest ecosystem (Sukumar *et al.* 1992). Although 60.26% of total density was within the range of ≥10 to <30 cm GBH i.e. in advance sapling growth stages. Though TWS is an important protected area of Tripura, only 0.88% trees were recorded as mature population (> 150 cm GBH) and contributed 7.76 ha^{-1} of the total density in the forest stand, which was quite minimum compared to its geographical area and rich wildlife resources. A low number of mature trees in larger GBH classes in these forests suggested extensive historic logging (Majumdar *et al.* 2012c). However, 86.12% of the total tree density was aggregated between >3 to >12 m tree height; *i.e.* between understory and middle story of the canopy. While, only 1.35% trees were in the upper canopy (>21 m height) as mature voluminous tree; which may suggest frequent canopy gaps in those forests. This may have enhanced the aggregation of local oligarchic or invasive species; which colonized rapidly within the gaps of these forests. Hence, diversity and population structure in this PA may be influenced by the slow invasiveness of some species viz. *W. antidysenterica*, *M. paniculata, B. malabarica*, *S. cerasoides*, *G. assamica*, *Antidesma* spp., *B. retusa*, *C. fistula, and Ziziphus spp. C. oblongifolius*, *M. phillippensis* and bamboo species, etc.

Population grouping of the present study suggested that 35 species were in a predominant group (> 50 individuals), which contributed 659.68 ha.$^{-1}$ density, 10.84 m^2 ha.$^{-1}$ basal area and 188.72% IVI. Among the predominant group, *S. robusta, S. wallichii, D. turbinatus, T. grandis, T. bellirica, C. arborea, W. antidysenterica, M. paniculata* etc. were the main ecologically important tree species of this sanctuary. The dominant group (> 25 individuals) represented 27 species viz. *S. grande, A. lakoocha, G. pinnata, C. tribuloides, G. sphaerogymum, C. fistula G. cowa, B. retusa, C. armata, G. resinifera, P. semisaggitum, M. denticulate, G. assamicum, S. personatum* etc. This dominant group contributed 78.56 ha.$^{-1}$ density, 0.83 m^2 ha.$^{-1}$ basal area and 33.80% IVI. Common group (> 10 individuals) of plants represented 70 species and had 91.52 ha^{-1} density, 1.02 m^2 ha.$^{-1}$ basal area and 45.11% IVI. Species like *S. cumini, M. undulates, Z. funiculosa, E. macrocarpa, M. peltada, T. orientalis, B. ceiba, M. allatus, G. heyneanum , M. stipulate, S. asper, T. ciliate, A. procera, A. scholaris, L. spicata, A. obovata, G. hirsute, L. monopetala* and *Ficus* spp. etc. were intense in the common group. Although, 124 species were recorded in the rare group

(< 10 individuals) which contributed 43.52 ha.$^{-1}$ density, 1.15 m^2 ha.$^{-1}$ basal area and 29.65% IVI. *C. fragrantissima, D. scabrella, D. montana, G. odorata, M. sylvatica, S. pinnata, D. bineetariferum, P. simiarum, T. citrine, S. ferruginea, X. controversum, A. edulis, C. glanduliferum, T. chebula, A. chinensis, C. gigantean, D. lanceaefolia, H. macrophyllus , K. angustifolia* etc. was listed as rare species in the present study. The very rare group (< 2 individuals) represented 33 species and contributed 2.64 ha.$^{-1}$ density, 0.04 m^2 ha.$^{-1}$ basal area and 2.73% IVI. *B. assamica, D. peregrine, F. drupacea, F. heteropleura, H. fragrans, M. celastrimum, S. anacardium, T. singularis, X. spinosa* etc. were recorded with single individual. Species with very low population density could be treated as threatened species of this sanctuary. However, many widespread species tend to be locally abundant in a particular forest stand with relatively very few individuals in other stands (Hubbel and Foster 1983). Notwithstanding, those singleton species (<2 individuals), there is an immediate need for the restoration of satisfactory populations within this natural habitat.

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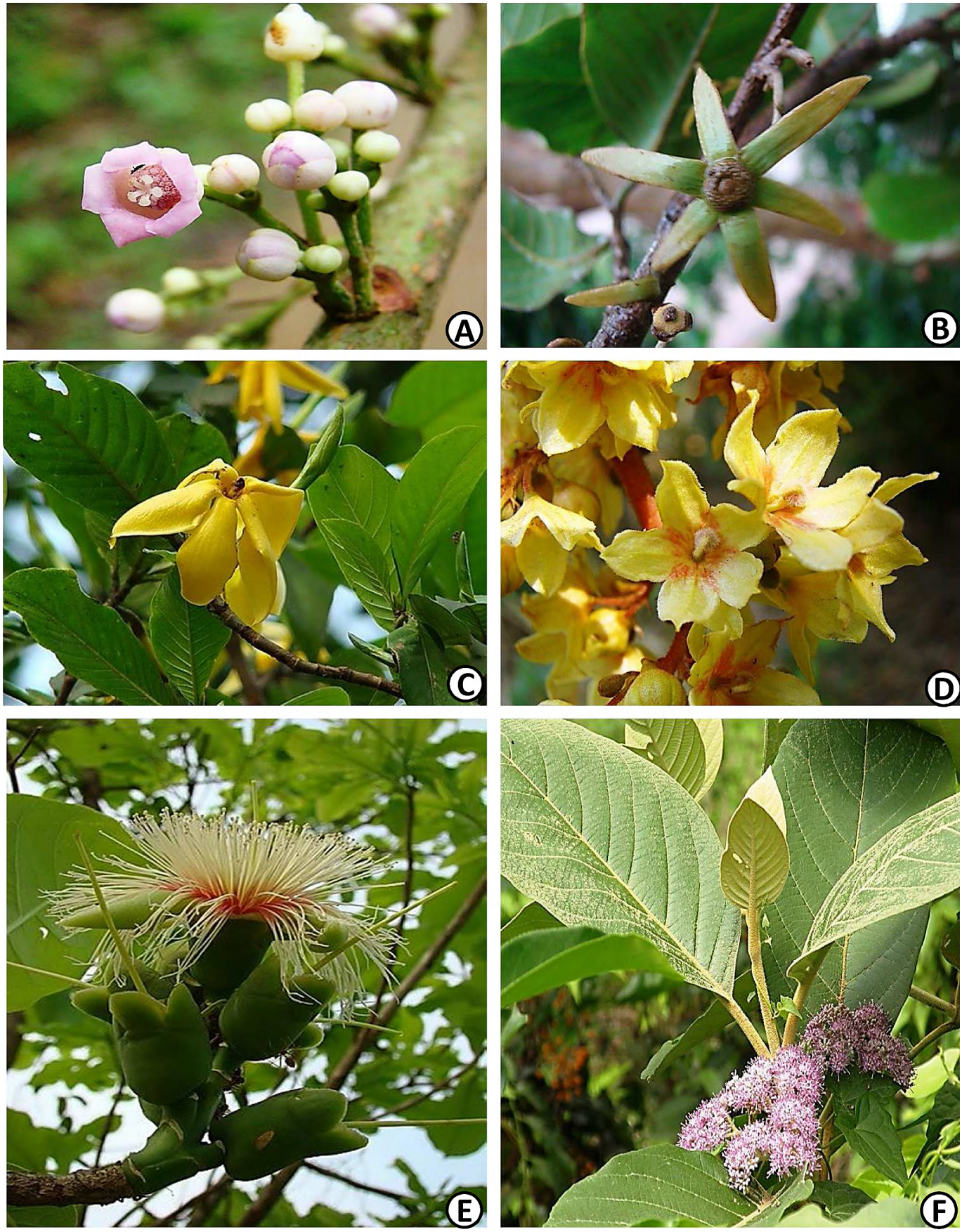

Figure 3. A) *Saurauia roxburghii* (Actinidiaceae); B) *Polyalthia simiarum* (Annonaceae); C) *Gardenia resinifera* (Rubiaceae); D) *Sterculia villosa* (Malvaceae); E) *Careya arborea* (Lecythidaceae); F) *Callicarpa arborea* (Lamiaceae) (Photo by K. Majumdar).

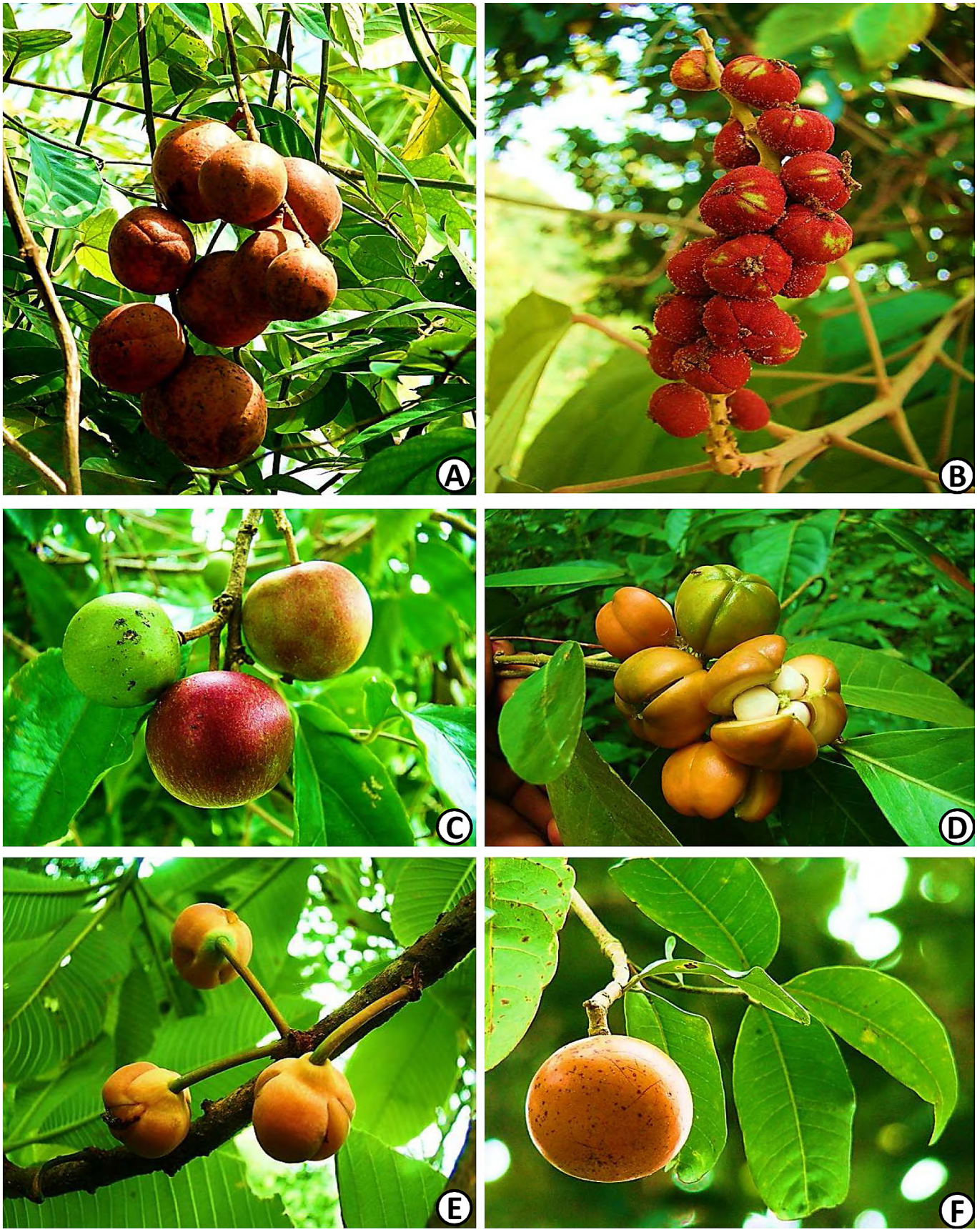

Figure 4. A) *Chisocheton paniculatus* (Meliaceae); B) *Mallotus philippensis* (Euphorbiaceae); C) *Flacourtia indica* (Phyllanthaceae); D) *Suregada multiflora* (Euphorbiaceae); E) *Dillenia scabrella* (Dilleniaceae); F) *Willughbeia edulis* (Apocynaceae) (Photo by K. Majumdar).

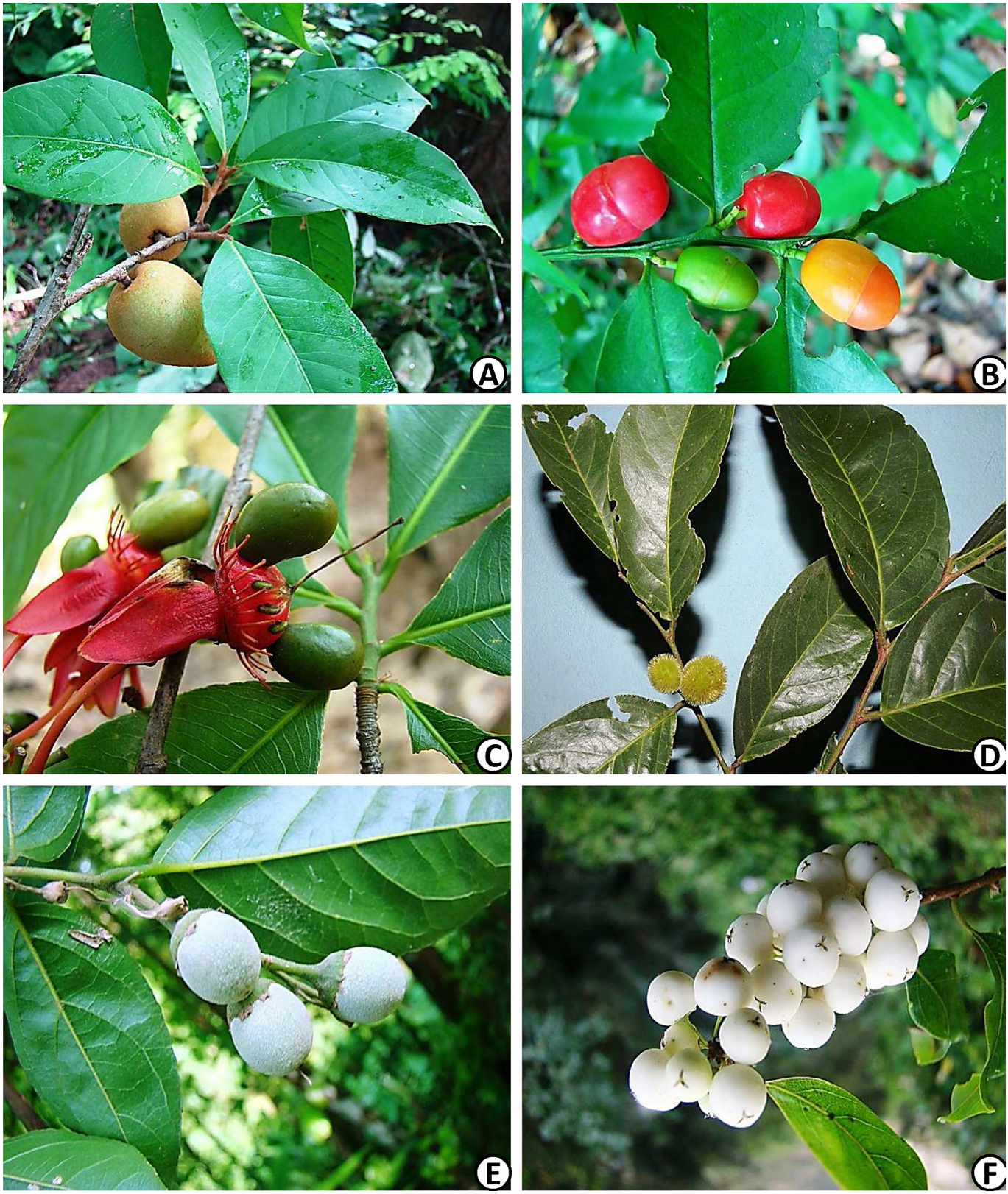

Figure 5. A) *Xantolis assamica* (Sapotaceae); B) *Olax acuminata* (Olacaceae); C) *Ochna integerrima* (Ochnaceae); D) *Chaetocarpus castanocarpus* (Peraceae); E) *Styrax serrulatus* (Styracaceae); F) *Flueggea virosa* (Phyllanthaceae) (Photo by K. Majumdar).

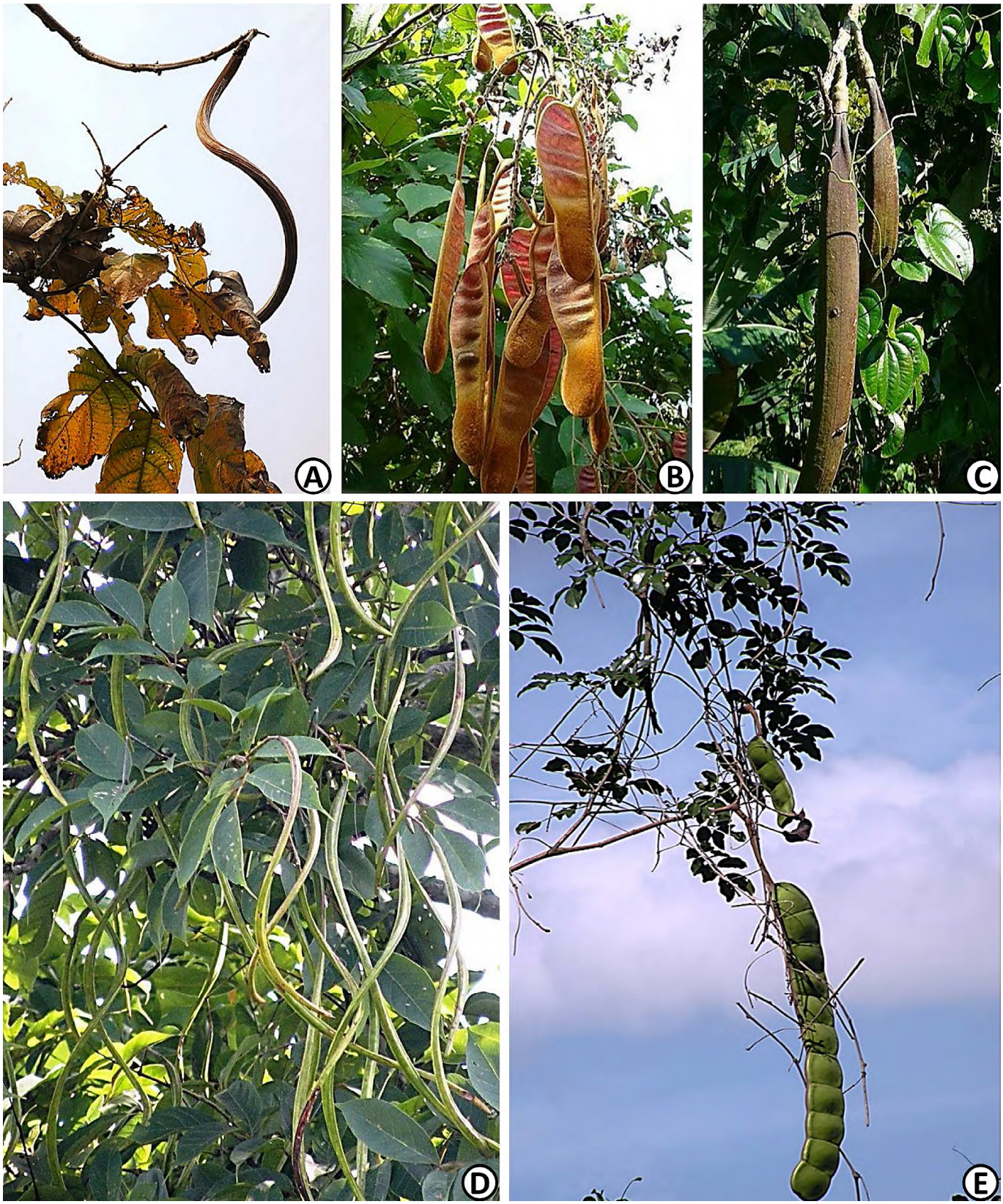

Figure 6. A) *Markhamia stipulata* (Bignoniaceae); B) *Spatholobus parviflorus* (Leguminosae); C) *Oroxylum indicum* (Bignoniaceae); D) *Stereospermum tetragonum* (Bignoniaceae); E) *Entada phaseoloides* (Leguminosae) (Photo by K. Majumdar).

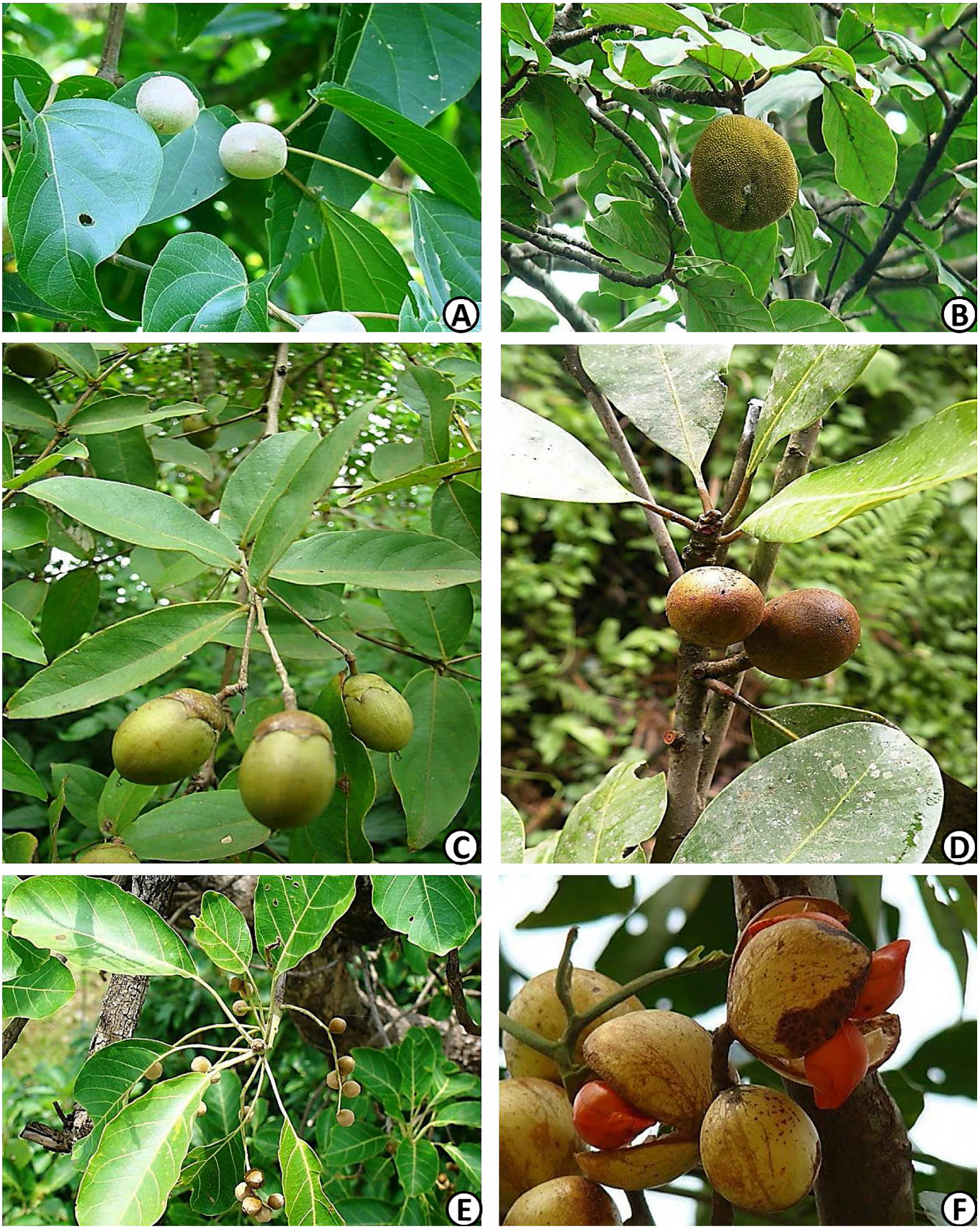

Figure 7. A) *Mallotus nudiflorus* (Euphorbiaceae); B) *Artocarpus chaplasha* (Moraceae); C) *Lagerstroemia parviflora* (Lythraceae); D) *Palaquium polyanthum* (Sapotaceae); E) *Terminalia bellirica* (Combretaceae); F) *Aphanamixis polystachya* (Meliaceae) (Photo by K. Majumdar).

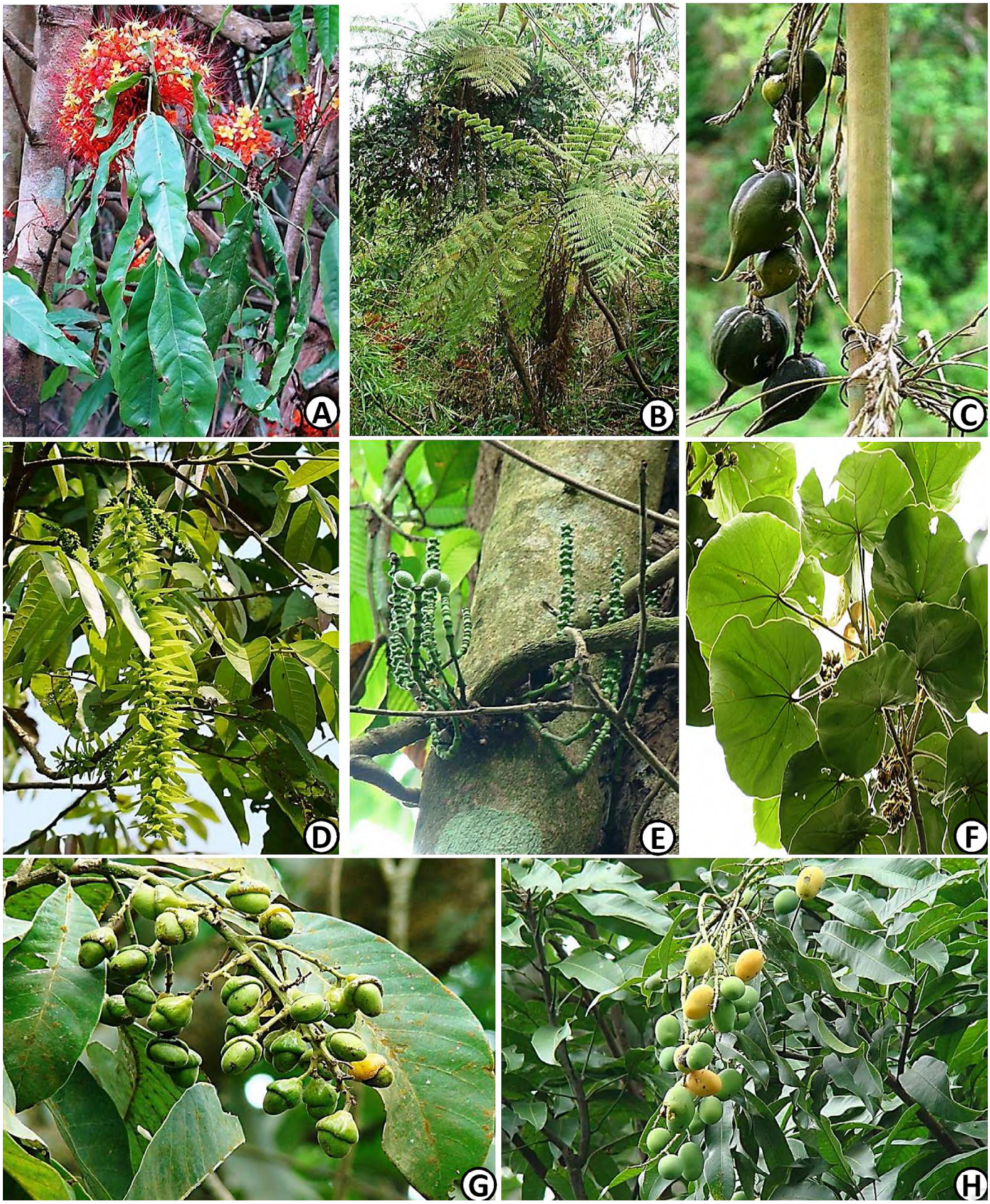

Figure 8. A) *Saraca asoca* (Leguminosae); B) *Cyathea gigantea* (Cyatheaceae); C) *Melocanna baccifera* (Poaceae); D) *Engelhardia spicata* (Juglandaceae); E) *Gnetum montanum* (Gnetaceae); F) *Hibiscus macrophyllus* (Malvaceae); G) *Semecarpus anacardium* (Anacardiaceae); H) *Mangifera sylvatica* (Anacardiaceae) (Photo by K. Majumdar).