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Dispersal modes of woody species from the northern Western Ghats, India

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Abstract: The dispersal modes of 185 woody species from the northern Western Ghats (NWG) were investigated for their relationship with disturbance and fruiting phenology. The species were characterized as zoochorous, anemochorous and autochorous. Out of 15,258 individuals, 87 % showed zoochory as a mode of dispersal, accounting for 68.1 % of the total species encountered. A test of independence between leaf habit (evergreen/deciduous) and dispersal modes showed that more than the expected number of evergreen species was zoochorous. The cumulative disturbance index (CDI) was significantly negatively correlated with zoochory ($P < 0.05$); on the other hand no specific trend of anemochory with disturbance was seen. The pre-monsoon period (February to May) was found to be the peak period for fruiting of around 64 % of species irrespective of their dispersal mode. Further studies pertaining to dispersal strategies along a disturbance gradient can be initiated to develop insights into questions such as how disturbance affects community structure.

Resumen: Se investigó la relación de los modos de dispersión de 185 especies leñosas de la porción norte de los Gates Occidentales con el disturbio y la fenología de la fructificación. Las especies fueron caracterizadas como zoócoras, anemócoras y autócoras. Entre los 15,258 individuos, 87 % tuvieron dispersión zoócora, los cuales representaron 68.1 % del total de especies encontradas. Una prueba de independencia entre hábito foliar (perenne/deciduo) y los modos de dispersión mostró más especies perennifolias zoócoras que las esperadas al azar. El índice de disturbio acumulado estuvo correlacionado significativamente y negativamente con la zoocoria ($P < 0.05$); por el contrario no se observó ninguna tendencia específica de la anemocoria con el disturbio. El periodo premonzónico (febrero a mayo) fue el período pico de la fructificación de alrededor de 64 % de las especies, independientemente de su modo de dispersión. Nuevos estudios relacionados con las estrategias de dispersión podrán ofrecer respuestas a interrogantes tales como la forma en que el disturbio afecta a la estructura de la comunidad.

Resumo: O modo de dispersão de 185 espécies arbóreas donordestedos Ghats (GNT) foi

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investigado quanto à sua relação com o distúrbio e a fenologia da frutificação. As espécies foram caracterizadas como Zoocóricas, Anemocóricas e Autocóricas. Dos 15.258 indivíduos, 87 % apresentaram Zoocoria como um modo de dispersão, o que representa 68,1 % do total das espécies encontradas. Um teste de independência entre o hábito folhear (Sempreverde/Decídua) e modos de dispersão mostrou que mais do que o número esperado de espécies sempreverdes foi zoocórico. O índice de distúrbio cumulativo (CDI) foi significativamente correlacionado negativamente com zoocoria ($P < 0,05$); por outro lado, nenhuma tendência específica de anemocoria foi visto com o distúrbio. O período de pré-monção (Fevereiro a Maio) foi considerado o período de pico da frutificação de cerca de 64 % das espécies, independentemente do seu modo de dispersão. Estudos futuros relacionados com as estratégias de dispersão ao longo de um gradiente de perturbação podem ser iniciadas para desenvolver conhecimento sobre como distúrbio afecta a estrutura da comunidade.

Key words: Deciduous, dispersal modes, disturbance, evergreen, fruiting phenology, Northern Western Ghats, phenology.

Introduction

Dispersal of propagules is essential for the persistence of populations, and is a fundamental mechanism involved in the organization and maintenance of species richness in a habitat (Chave *et al*. 2002; Condit *et al*. 2002). Escape from predators, avoiding density-dependent mortality (Janzen-Connell Hypothesis), and finding suitable sites for germination are well documented advantages of effective seed dispersal (Clark *et al*. 2004; Howe & Smallwood 1982; van der Pijl 1972). Obviously the extent of these pressures in a habitat, and opportunities available for adopting a different mode of dispersal, would shape the diversity of dispersal modes shown by the plant community in a given habitat. Disturbances, especially those induced by human activities, are also known to alter the community and the dispersal modes shown (Ganeshaiah *et al*. 1998). Physical alterations to the habitat caused by logging and silvicultural measures are likely to affect seed dispersal (Khan *et al*. 2005) and hence the modes adopted by newly emerging communities. Forests impacted by human disturbances tend to have a thinner canopy and relatively drier environment (Daniels *et al*. 1995). The openness thus created by anthropogenic processes may adversely affect the activity of animal dispersers. It has been observed that the dominance of species with abiotic modes of dispersal (wind or mechanical) tends to increase with increased disturbance (Ganeshaiah *et al*. 1998).

In this paper, we have attempted to characterize the profile of the dispersal syndromes of a community of woody species in a relatively little explored area of the northern Western Ghats (NWG). More than half of the natural habitat in the NWG has now been cleared (World Wildlife Fund 2007). Lack of focused studies on dispersal modes, phenology of woody species and frugivore behaviour in fragmented forests of the NWG is a major challenge in understanding changes in the forest community under anthropogenic pressures like mining, deforestation and road construction. In view of this, we have attempted to (a) examine the dispersal spectrum of the woody species from the NWG; (b) test the relation if any between the dispersal mode and disturbances in the area; and (c) understand whether different dispersal modes are associated with the leaf habit (evergreen and deciduous) and with the phenology of the plant species.

Materials and methods

Study site

The Western Ghats, identified along with Sri Lanka as one of the 34 global Biodiversity Hotspots (Conservation International n.d. www.biodiversityhotspots.org/xp/Hotspots/ghats), are a mountain range 1500 km long running parallel to the west coast of India. The study area lies in the Western Ghats of Maharashtra (NWG; Fig. 1) which constitute about one-third of the total length of the Western Ghats and are located roughly between 73° E and 74° E longitude and 15° 30' N

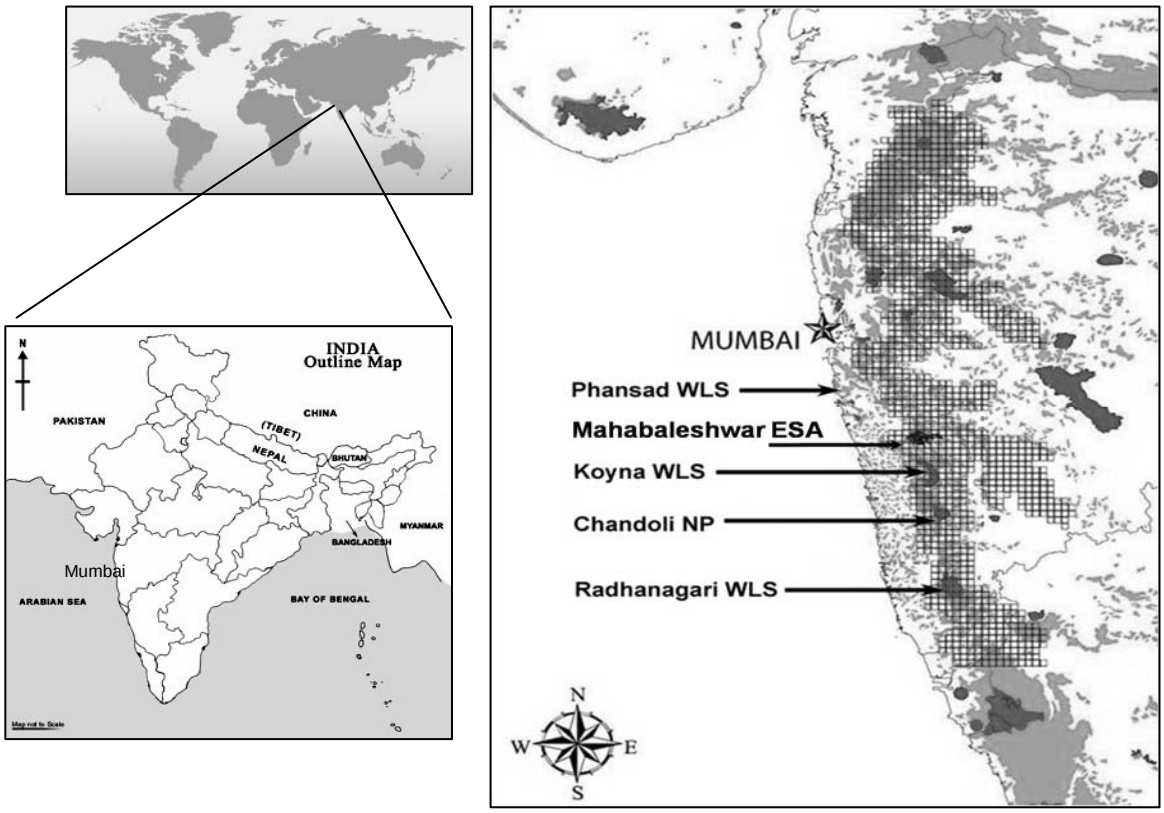


Fig 1. Map of study area. The 6.25 km x 6.25 km grids shown were set up to survey plant resources by Department of Biotechnology, Government of India. Samples for the present study were taken from the 41 cells of this grid falling within the five special areas marked (Phansad WLS, Mahabaleshwar ESA, Koyna WLS, Chandoli NP and Radhanagari WLS).

and 20° 30' N latitude (Ghate *et al.*1997). In this area, the precipitation (2140 mm - 5000 mm) mainly falls between June and September, with the dry period lasting from 6 to 8 months. The vegetation in this area consists of fragmented patches, in contrast to continuous stretches of forests in the southern Western Ghats. The flora of this region is classified under the standard *Memecylon-Syzygium-Actinodaphne* floristic series (Pascal 1988). However, variations in this series as a response to local conditions have been recorded with respect to protection and disturbance (Kanade *et al*. 2008).

The study was confined to three Protected Areas (PAs) in the NWG, namely Koyna Wildlife Sanctuary (WLS), Chandoli National Park (NP) and Radhanagari WLS, together with Mahabaleshwar, an Eco-Sensitive Area (ESA), and Phansad Wildlife Sanctuary, near the coast. (Fig. 1).

Sampling and data analysis

The present study was carried out as a part of a national-level survey project entitled, 'Mapping and quantitative assessment of geographic distribution and population status of plant resources of Western Ghats', supported by the Department of Biotechnology of the Government of India. For this, the entire Western Ghats were divided into grids of 6.25 km x 6.25 km (Fig. 1). All grid cells falling within the Protected Areas in Maharashtra, namely the Koyna Wildlife Sanctuary, the Chandoli National Park, the Radhanagari Wildlife Sanctuary, the Mahabaleshwar Eco-sensitive Area and the Phansad Wildlife Sanctuary, were considered during the study (Fig. 1). Forty-one grid cells in all were sampled. The number of transects varied depending upon the landscape heterogeneity within each grid cell; if the vegetation was uniform throughout the grid cell then only one belt transect of 5 m × 1000 m (0.5 ha) was laid (amounting to 0.01 % sampling); otherwise two or three transects were recorded with a total area of 0.5 ha, depending on the heterogeneity. The total area included in the study was 20.5 ha. All woody plants with girth at breast height (gbh) ≥ 15 cm were enume-

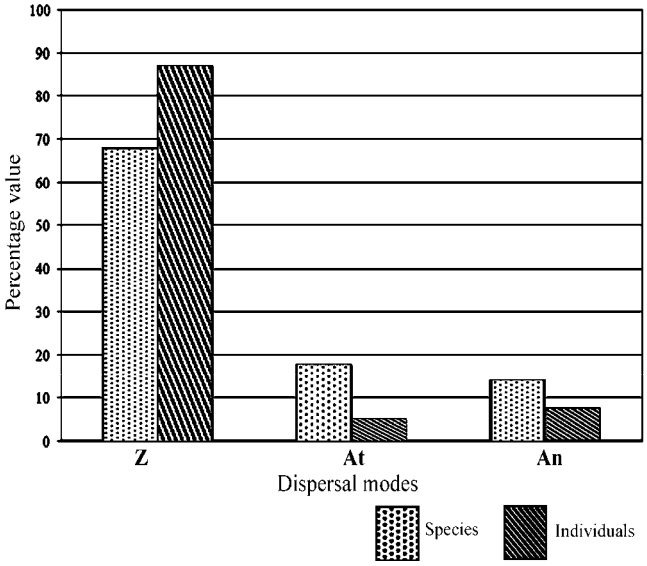


Fig. 2. Percentages of species and individuals recorded with different dispersal modes (Z: Zoochorous; At: Autochorous; An: Anemochorous).

rated along the belts. Dispersal modes were assigned to each species based on first-hand observations of the morphology of the dispersal units, the fruit types and by consulting relevant literature (Ganesh & Davidar 2001; Lokesha *et al*. 1991; Uma Shaanker *et al*. 1990). Accordingly the species were classified as Anemochorous (An, wind-dispersed), Autochorous (At, mechanically dispersed) and Zoochorous (Z, animal-dispersed). The animal-dispersed species were mainly dispersed by mammals and birds. Myrmechory was not observed during the study, neither was any secondary mode of dispersal included for diplochorous species. Along with the dispersal modes, the evergreen (E) or deciduous (D) nature of the species, and their fruiting period, were also recorded. Depending on the fruiting period, the species were then classified as Pre-Monsoon (Pre M), Monsoon (M) and Post-Monsoon (Post M) (Bhat 1992).

Chi-square contingency tables were set up to relate the different modes of dispersal of species with their phenology and vegetation type, and these attributes were tested for independence (Zar 1999).

Each transect was assessed for the intensity of human disturbance which it had suffered. Evidence of this was based on observation of (1) Lopping, (2) Cut stumps, (3) Collection of litter, (4) Soil removal, (5) Grazing, (6) Fire, and (7) Weeds. For each of these seven features, the degree of disturbance shown was assessed at four levels: 0 = No significant impact, 1 = Low impact i.e. impact may not be clearly discernible to layman unless observed carefully, 2 = Moderate impact i.e. impact visible but not threatening to the environmental element, 3 = High impact i.e. threatening the very existence of a species; high level of habitat degradation.

A Cumulative Disturbance Index (CDI) was calculated for the locality by adding the seven scores, giving a maximum CDI of 21. The effect of disturbance on the dispersal modes was seen by considering together the localities having same CDI and summing the species and individuals in these localities. The table thus formed showed the numbers of species and individuals with different CDI score in the rows, and the dispersal types Z, At and An as the columns.

Results

Dispersal spectrum of the woody species from NWG

During the survey conducted in Protected Areas in the northern Western Ghats (41 kilometres of transect length, giving a sample area of 20.5 ha), we recorded 185 woody plant species[1] among 15,258 individuals. Among these woody species, there was a predominance of the zoochorous mode of dispersal (68.1 %) followed by autochory (17.83 %) and anemochory (14 %; Fig. 2). About 87 % of the individuals in the study area were zoochorous; the most abundant species exhibiting this mode was *Memecylon umbellatum*[1] (3887 individuals) followed by *Syzygium cumini*. Seeds of *M. umbellatum* and *S. cumini* were observed in the excreta of the Sloth Bear [(*Melursus ursinus* (Shaw)], while fruits of *Canthium dicoccum* were consumed by the common Palm Civet [(*Paradoxurus hermaphroditus* (Pallas)], which could be its probable disperser. Small seeded fruits of *C. dicoccum* and *Nothapodytes nimmoniana* were consumed by small birds like bulbuls (*Hypsipetes leucocephalus* (Gmelin) (black bulbuls), *Iole indica* (Jerdon) (yellow browed bulbuls) and *Pycnonotus jocosus* (Linnaeus) (red whiskered bulbuls) whereas large-seeded *Dysoxylum binectariferum* is likely to be consumed by larger birds like hornbills (*Anthracoceros coronatus* (Boddaert) (Malabar pied hornbill), *Ocyceros birostris* (Scopoli)

[1] A full list of species recorded, with authorities, will be found in the Appendix Table 1.

Table 1. Dispersal modes across ten most diverse families in the study area. (Z: Zoochorous, An: Anemochorous and At: Autochorous).

Families	No. of species	Dispersal modes		
		Z	An	At
Euphorbiaceae	17	9	-	8
Moraceae	14	14	-	-
Rubiaceae	11	8	-	3
Fabaceae	9	-	5	4
Flacourtiaceae	7	7	-	-
Lauraceae	7	7	-	-
Rutaceae	7	7	-	-
Meliaceae	6	3	1	2
Mimosaceae	6	-	2	4
Anacardiaceae	6	6	-	-

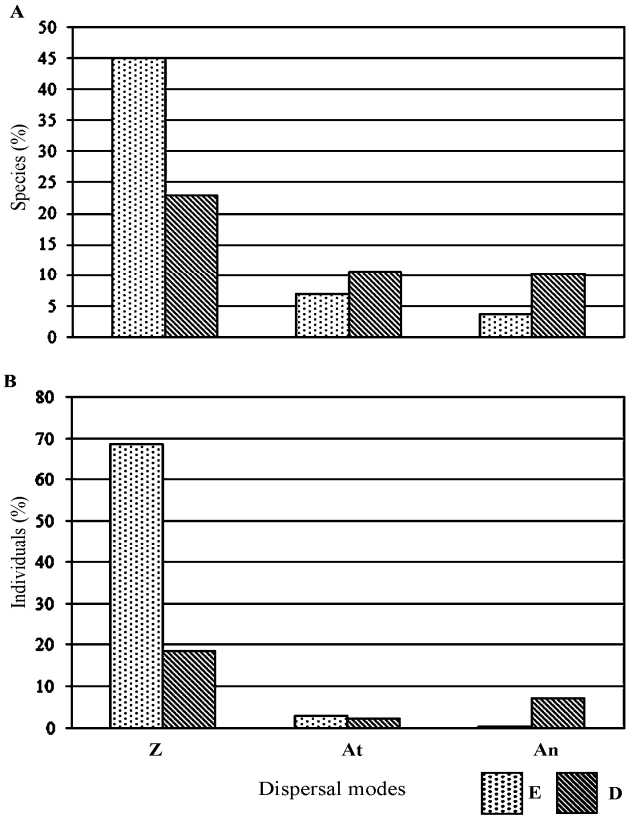


Fig. 3. Distribution of species (A) and individuals (B) in species with different leaf habits (evergreen/ deciduous) and dispersal modes (Z: Zoochorous, At: Autochorous and An: Anemochorous).

(Indian grey hornbills), and *Ocyceros griseus* (Latham) (Malabar grey hornbills) found in the study area.

The autochorous species (17.83 %) contributed around 5 % of the individuals, the most abundant being *Glochidion ellipticum* and *Gnidia glauca*. The most abundant anemochorous species were *Terminalia elliptica* and *Terminalia paniculata*, which accounted for more than half of the anemochorous individuals.

During the study, we encountered 22 species endemic to the Western Ghats and 17 Rare Endangered and Threatened (RET) species (IUCN 2010; Ved *et al*. 2001). Of the endemic species, 73 % were zoochorous, as were 64.7 % of the RET species. Among the 52 families recorded, Anacardiaceae, Lauraceae, Melastomataceae, Myrtaceae and Oleaceae were exclusively zoochorous, while Bignoniaceae, Lythraceae and Malvaceae, only represented by a few species, were exclusively anemochorous. Listed in Table 1 are the ten most diverse families, recorded during the study which accounted for nearly 50 % of the total species and 29 % of the total individuals recorded.

Dispersal modes and evergreen/deciduous habit

The study area was dominated by evergreen (55.68 %) species, as against deciduous (44.32 %) ones. Out of 126 zoochorous species, 65.88 % were evergreen (E) and 34.12 % deciduous (D; Fig. 3), A test of independence for the different modes of dispersal in evergreen and deciduous species showed that more than the expected number of evergreen species were dispersed by animals, and fewer by wind or autochory; while the reverse was true for deciduous species (χ^2 = 51.67, d.f. = 2, $P < 0.001$; Table 2). The numbers of individuals showed a similar relation between dispersal type and the deciduous/evergreen habit. Deciduous species showed more than the expected number of individuals with anemochorous and autochorous dispersal modes, whereas the number of evergreen individuals which were zoochorous was higher than expected (χ^2 = 3103.03, d.f. = 2, $P < 0.001$). It is thus clear that there is a tendency for evergreen species to be zoochorous, and for deciduous species to be anemo- or autochorous.

Disturbance and dispersal modes

The Cumulative Disturbance Index (CDI) of the study areas ranged from 1 (lowest) to 13 (highest). As the disturbance index increased, the proportion of zoochorous individuals decreased (r = 0.652, n = 11, $P < 0.05$; Fig. 4), whereas the numbers of anemochorous and autochorous individuals did not show any significant pattern when

Table 2. Number of species (a) and individuals (b) with different dispersal modes (Z: Zoochorous, At: Autochorous, An: Anemochorous) and different leaf habit (E: Evergreen, D: deciduous). Values in parentheses are those expected if habit and dispersal mode were independent.

(a)

Dispersal modes		No. of species	
		E	D
Z	Obs.	83	43
	Exp.	(70)	(56)
At	Obs.	13	20
	Exp.	(18)	(15)
An	Obs.	7	19
	Exp.	(14)	(12)

$\chi^2 = 51.67$, d.f. = 2, $P < 0.001$
N = 185

(b)

Dispersal modes		No. of individuals	
		E	D
Z	Obs.	10469	2824
	Exp.	(9543)	(3750)
At	Obs.	442	353
	Exp.	(571)	(224)
An	Obs.	43	1127
	Exp.	(840)	(330)

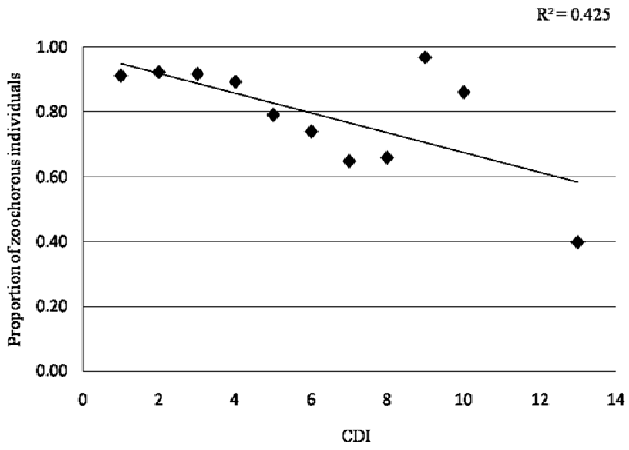
$\chi^2 = 3103.03$, d.f. = 2, $P < 0.001$
N = 15258

plotted against the disturbance index. In the species counts, no correlation was found between the CDI of the transect and the different dispersal modes of the species.

Most dominant species like *M. umbellatum*, *Olea dioica* and *S. cumini* were zoochorous and occurred in the forest patches with various levels of disturbance. As the degree of disturbance increased, the abundance of autochorous species like *Glochidion ellipticum* and *Gnidia glauca* which are commonly found at the forest edges and in openings, increased. Certain pioneer and zoochorous species like *Actinodaphne angustifolia* and *Macaranga peltata* were present even in comparatively undisturbed forests (with low CDI).

Dispersal modes and fruiting season

The fruiting season of the species encountered was documented on the basis of personal observations, relevant scientific literature and the regional flora (Singh *et al*. 2001; Yadav & Sardesai



($r = 0.652$, $P < 0.05$)

Fig. 4. Relationship between proportion of zoochorous individuals and Cumulative Disturbance Index (CDI). The correlation was significant at $P < 0.05$.

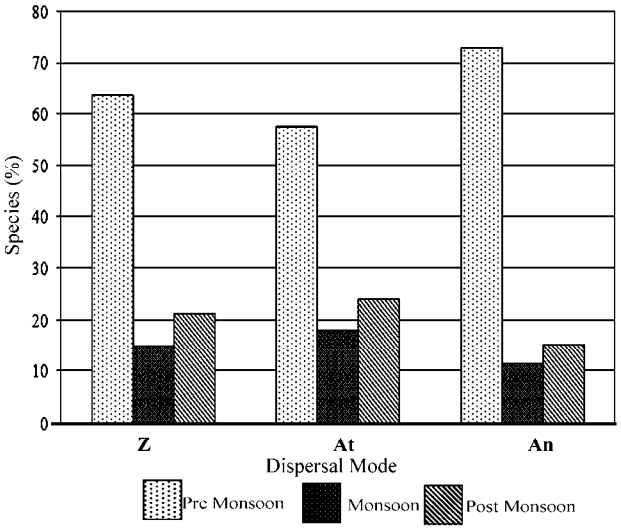


Fig. 5. Fruiting season (Pre-monsoon, Monsoon, Post-monsoon) pattern across dispersal modes (Z = Zoochorous, At = Autochorous, An = Anemochorous). The majority of plants, irrespective of their dispersion mode, showed a fruiting peak during the pre monsoon period, i.e from February to May.

2002). It was observed that the majority of species in all dispersal modes fruited during the pre-monsoon period, i.e. during the months from February to May (Fig. 5). Out of 26 anemochorous species, 73 % showed a fruiting peak during the pre-monsoon period, which is more than the proportion of zoochorous (64 %) and autochorous (58 %) species fruiting during this period; this difference, however, did not reach significance. Frui-

Table 3. Relation between fruiting season and evergreen (E) or deciduous (D) habit of species. (Pre M: Pre-monsoon fruiting, M: Monsoon fruiting, Post M: Post-monsoon fruiting).

Nature of Species		Pre M	M	Post M
E	Obs.	70	9	24
	Exp.	(66)	(16)	(22)
D	Obs.	48	19	15
	Exp.	(52)	(12)	(17)

$\chi^2 = 8.11$, d.f. = 2, $P < 0.05$
N = 185

Values in parentheses are the values expected on the assumption of no relationship.

ting in the monsoon period was less across all the dispersal modes. Among the 22 endemic species, 16 fruited during the pre monsoon period. As many as 43 families had a fruiting peak pre-monsoon. All the species in the families Anacardiaceae and Meliaceae had a fruiting season with only a single peak during that period. It was also found that the fruiting season differed between evergreen and deciduous species (Table 3). The fruit colour differed with the dispersal mode. Animal-dispersed species had ripened fruits predominantly with bright colours ranging from yellow to purple, whereas fruit in the majority of the autochorous and anemochorous species were brown or black.

Discussion

Dispersal spectrum of woody plant species in the northern western ghats

The dominance of zoochory (68.1 %) in woody plants, as observed during this study, was reported earlier by others working in tropical forests; e.g. in Barro Colorado Island, Panama (72 % - 76 %: Frankie *et al.* 1974), in Arunachal Pradesh of North East India (78 %: Datta & Rawat 2008) and (closer to the present study) in the northern Western Ghats (Watve *et al.* 2003). Ganesh & Davidar (2001) showed, in the wet forests of Kakachi in the southern Western Ghats, that birds were the commonest agent of dispersal, followed by mammals.

The predominance of zoochory could be attributed to the two specific advantages it provides to species in this highly heterogeneous ecosystem of the northern Western Ghats. A first advantage of zoochory is that the propagules are dispersed to a much greater distance by birds and mammals than by anemo- and autochory. Second, the propagules have a higher likelihood of reaching habitats suitable to them, because their animal dispersers largely restrict their foraging efforts to specific habitats of their preference, which in this case would be of those plants from which they gather the fruits and seeds. Consequently, in such heterogeneous ecosystems, the propagules of zoochorous plants have a higher probability of survival and establishment (Ozinga *et al.* 2004). Zoochorous species were characterized by bright coloured, ripe fruits or arils, which helps to attract the animal vectors.

The under-represented anemochorous species (14 %) in these forests generally occurred along the forest edges and in gaps. Clearly, in such open habitats their dispersal ability is enhanced, because of the reduced hindrance to wind movement. In more arid environments such as grasslands, mechanisms for wind and mechanical dispersal predominate.

Disturbance and dispersal modes

Disturbance creates gaps and open spaces in the forest, and pioneering species that occupy such open spaces would generally be anemochorous. Accordingly the proportion of anemochorous species and/or individuals may be expected to increase with disturbance. Conversely, the proportion of zoochory can be expected to decrease with disturbance. We tested for the latter, as the overall representation of anemochory was less in the study sites. Our results showed that, though the proportion of zoochorous species did not change, their population decreased with disturbance. This could be attributed to the possible immigration of propagules from sites immediately adjacent to the areas of disturbance (Ganeshaiah *et al.*1998).

Human activities like mining, road construction and deforestation tend to reduce the populations both of a species and of its biotic vectors. Lokesha *et al.* (1991) showed that animal-dispersed species are more prone to become rare and endangered than those dispersed passively or by wind. Because some fruit-eating animals are likely to be more severely affected by forest fragmentation than others, it is likely that any effect of forest fragmentation on tree populations will vary with the identity of effective dispersal agents that eat their fruits (Cordeiro & Howe 2001). However, we could not find any specific trend for either the number of endemic species or of their individuals,

in response to disturbance, probably because of the poor representation of these species in the study sites.

Dispersal modes and fruiting season

All species peaked in their fruiting during the dry, pre-monsoon period. Arbeláez & Parrado-Rosselli (2005), and Sundarapandian *et al*. (2005) also reported a marked fruiting peak during the dry season prior to the monsoons. Such phenology is favoured because it enhances both seed germination and seedling establishment in the beginning of the wet season and avoids exposing the growing seedlings to unfavourable conditions (van Schaik *et al.*1993). Increased fruiting during the pre-monsoon period is also reported in anemochorous species in the dry forests of western Brazil (Ragusa-Netto & Silva 2007).

However, a proportion of the species, though relatively few, fruit during the post-monsoon period. Some of these species may be endowed with a hard seed coat and are resistant, like *Emblica officinalis* and *Terminalia chebula* (Bhat 1992). The chi-square test performed (Table 3) indicates that the fruiting season of a species is related to its leaf habit (evergreen vs. deciduous). In the case of deciduous plants, it was found that the flowering period coincides with the deciduous phase, which gives the advantage of attracting pollinators (Singh & Singh 1992); this may also be the case with dispersal phenomenon. In fact, anemochorous species such as *Albizzia lebbeck, Bombax ceiba* and*, Holoptelia integrifolia* were found to be fruiting in their deciduous phase, perhaps because the absence of leaves facilitates exposure of propagules to wind, and thus enhances their dispersal. Similarly, leafless conditions also favour seed dispersal in some autochorous species (Bullock & Solis-Magallanes 1990; van Schaik *et al.* 1993). Interestingly, trees dispersing their seed in full foliage conditions need to invest about five times more in seed production, for their seeds to escape the canopy and potentially have the chance of long-distance dispersal equivalent to that of seeds dispersing in leafless conditions (Nathan & Katul 2005).

Seed dispersal is one of the most important spatial demographic processes which directly or indirectly influence population dynamics, species interactions, and colonization of new habitats. It can thus be interesting to study in detail the dispersal strategies of woody plant species, their evergreen and deciduous habit, and their pattern of fruiting phenology in protected as well as non-protected areas. Long-term study of changes in patterns of fruiting phenology with changing climatic variables and disturbance intensity is needed in the highly fragmented forests of the northern Western Ghats.

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Appendix Table 1. List of species and their dispersal attributes.

The 185 species encountered during the study are listed in the Appendix along with the families to which they belong. The species attributes viz. DM = Dispersal Mode, DU = Dispersal Unit, E/D = Evergreen/Deciduous habit and FC = Fruit Colour are given. The dispersal mode abbreviations are An = Anemochorous (Wind dispersed), At = Autochorous (Mechanical) and Z = Zoochorous (Animal dispersed).

No.	Species	Family	D M	D U	E/D	FC
1	*Acacia auriculiformis* L.	Mimosaceae	An	Entire fruit	E	Black
2	*Acacia catechu* (L.f.) Willd.	Mimosaceae	At	–	D	Brown
3	*Actephila excelsa* (Dalz.) Muell.-Arg.	Euphorbiaceae	At	–	E	Green
4	*Actinodaphne angustifolia* Nees *	Lauraceae	Z	Entire fruit	E	Red
5	*Aglaia elaeagnoidea* (A. Juss.) Bth	Meliaceae	Z	Entire fruit	E	Buff
6	*Aglaia lawii* (Wight)Sald.*	Meliaceae	Z	Entire fruit	E	Buff
7	*Agrostistachys indica* Dalz.	Euphorbiaceae	Z		E	Red
8	*Albizia chinensis* (Osb.) Merr.	Mimosaceae	At	Seed with part of fruit	E	Brown
9	*Albizia lebbeck* (L.) Willd.	Mimosaceae	An	Seed with part of fruit	D	Yellow
10	*Albizia odoratissima* (L.f.) Benth.	Mimosaceae	At	Seed with part of fruit	D	Brown
11	*Allophyllus cobbe* (L.) Raeusch	Sapindaceae	Z	Entire fruit	E	Red
12	*Alseodaphne semecarpifolia* Nees	Lauraceae	Z	Entire fruit	E	Black
13	*Alstonia scholaris* (L.) R. Br.#	Apocynaceae	An	Seed	E	Brown
14	*Anacardium occidentale* L.	Anacardiaceae	Z	Entire fruit	D	Brown nut with orange-red false fruit
15	*Antiaris toxicaria* (Pers.) Lesch.	Moraceae	Z	Entire fruit	D	Red
16	*Aporosa lindleyana* (Wight) Baill.	Euphorbiaceae	Z	Seed with pulp	D	Yellow-Red
17	*Artocarpus heterophyllus* Lam.	Moraceae	Z	Seed with fleshy bracts	E	Greenish Yellow
18	*Artocarpus lakoocha* sensu Gamble	Moraceae	Z	Seed with fleshy bracts	D	Yellow
19	*Atalantia racemosa* Wt.	Rutaceae	Z	Entire fruit	E	Cream
20	*Bauhinia racemosa* Lamk.	Caesalpiniaceae	At	Seed	D	Brown
21	*Beilschmiedia dalzellii* (Meissn.) Kosterm	Lauraceae	Z	Entire fruit	E	Blue
22	*Blachia denudata* Bth.*	Euphorbiaceae	At	Seed	E	Greenish brown
23	*Bombax ceiba* L.	Bombacaceae	An	Seed	D	Brown
24	*Boswellia serrata* Roxb. ex Coleb.	Burseraceae	At		D	Brown
25	*Bridelia retusa* (L.) Spreng.	Euphorbiaceae	Z	Entire fruit	D	Purple
26	*Bridelia scandens* (Roxb.)Willd.	Euphorbiaceae	Z	Entire fruit	D	Black
27	*Butea monosperma* Lamk.(Taub)	Fabaceae	An	Seed with part of fruit	D	Brown
28	*Callicarpa tomentosa* (L.)Murr.	Verbenaceae	Z	Entire fruit	E	Black
29	*Calycopteris floribunda* (Roxb.)Poir.	Combretaceae	An	Winged fruit	D	Brown

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Appendix Table 1. Continued.

No.	Species	Family	D M	D U	E/D	FC
30	*Canthium dicoccum* (Gaertn.) Teys. & Binn.	Rubiaceae	Z	Entire fruit	E	Black
31	*Carallia brachiata* (Lour.) Merr.	Rhizophoraceae	Z	Entire fruit	E	Red
32	*Careya arborea* Roxb.	Lecythidaceae	Z	Entire fruit	D	Greenish yellow-brown
33	*Carissa congesta* Wt.	Apocynaceae	Z	Entire fruit	D	Purple
34	*Caryota urens* L.	Arecaceae	Z	Entire fruit	E	Red
35	*Casearia championii* Thw.	Flacourtiaceae	Z	Highly coloured fruit displaying seed	E	Yellow
36	*Casearia graveolens* Dalz.	Flacourtiaceae	Z	Entire fruit, Seed	D	Yellow
37	*Casearia rubescens* Dalz.	Flacourtiaceae	Z	Seed	E	Yellow
38	*Casearia tomentosa* Roxb.	Flacourtiaceae	Z	Seed	E	Yellow
39	*Cassia fistula* L.	Caesalpiniaceae	Z	Seed with pulp	D	Black
40	*Cassia siamea* Lamk.	Caesalpiniaceae	At	Seed	D	Brown
41	*Cassine paniculata* (Wt. & Arn.) L. Callen.	Celastraceae	Z	Entire fruit	E	–
42	*Casuarina equisetifolia* J.R. & G. Forst.	Casuarinaceae	At	Entire nut	D	Brown
43	*Catunaregam spinosa* (Thumb.) Tirveng.	Rubiaceae	Z	Entire fruit	D	Brown
44	*Celastrus paniculatus* Eilld.#	Celastraceae	Z	Entire fruit	D	Yellow
45	*Celtis timorensis* Span.	Ulmaceae	Z	Entire fruit	E	Green
46	*Chionanthus mala-elengi* (Dennst.) Grees	Oleaceae	Z	Entire fruit	E	Black
47	*Chrysophyllum cainito* L.	Sapotaceae	Z		E	Purple
48	*Chukrasia tabularis* Juss.	Meliaceae	An	Winged seeds	E	Black
49	*Cinnamomum verum* Rostl.	Lauraceae	Z	Fruit	E	Purple
50	*Clausena anisata* (Willd.) Hook. F. ex Benth.	Rutaceae	Z	–	D	Green
51	*Clausena indica* (Dalz.) Oliver	Rutaceae	Z	Fruit	D	Cream
52	*Cleidion spiciflorum* (Burm.f.) Merr.	Euphorbiaceae	At		E	Brown
53	*Colebrookea oppositifolia* J.E. Smith	Lamiaceae	At	Nutlet	E	Black
54	*Cordia dichotoma* Forst. F.	Boraginaceae	Z	Fruit	D	Cream
55	*Dalbergia lanceolaria* L.f.	Fabaceae	An	Seed with part of fruit	D	Brown
56	*Dalbergia pinnata* L.	Fabaceae	An	Seed with part of fruit	D	Brown
57	*Dalbergia sissoo* Roxb. ex DC.	Fabaceae	An	Seed with part of fruit	E	Brown
58	*Dichapetalum gelonioides* (Roxb.)Engl.	Dichapetalaceae	Z	Seed	E	Brown
59	*Dillenia indica* L.	Dilleniaceae	Z	Fruit	E	Greenish yellow
60	*Dillenia pentagyna* Roxb.	Dilleniaceae	Z	seed with pulp	D	Orange
61	*Dimocarpus longan* Lour.	Sapindaceae	Z	seed with pulp	E	Red
62	*Dimorphocalyx lawianus* (Muell.-Arg.) Hook.f.*	Euphorbiaceae	At	Entire fruit	E	Green

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Appendix Table 1. Continued.

No.	Species	Family	D M	D U	E/D	FC
63	*Diospyros candolleana* Wt.*	Ebenaceae	Z		E	Black
64	*Diospyros ebenum* Koen.#	Ebenaceae	Z	Entire fruit	E	–
65	*Diospyros montana* Roxb.	Ebenaceae	Z	Entire fruit	D	Brown
66	*Diospyros nigrescens* (Dalz.) Sald.	Ebenaceae	Z	Entire fruit	E	-
67	*Diospyros sylvatica* Roxb.	Ebenaceae	Z	Entire fruit	E	Green
68	*Drypetes roxburghii* (Wall.) Hurusawa	Euphorbiaceae	Z	Entire fruit	E	Green/black
69	*Drypetes venusta* (Wight) Pax & Hoffm.	Euphorbiaceae	Z	Entire fruit	E	Brown
70	*Dysoxylum binectariferum* (Roxb.)	Meliaceae	Z	–	E	Red
71	*Elaeagnus conferta* Roxb.#	Elaeagnaceae	Z	Entire fruit	E	Pink
72	*Elaeocarpus serratus* L.	Elaeocarpaceae	Z	Entire fruit	D	Yellow
73	*Emblica officinalis* Gaertn.	Euphorbiaceae	Z	Entire fruit	D	Yellow
74	*Erythrina stricta* Roxb.	Fabaceae	At	Seed	D	Brown
75	*Erythrina suberosa* Roxb.	Fabaceae	At	Seed	D	Brown
76	*Eucalyptus globosus* Lab.	Myrtaceae	At	–	D	Black
77	*Ficus amplissima* J. E. Sm.	Moraceae	Z	Fig (specialized infl.)	D	–
78	*Ficus arnottiana* (Miq.) Miq.	Moraceae	Z	Fig (specialized infl.)	E	Red
79	*Ficus exasperata* Vahl	Moraceae	Z	Fig (specialized infl.)	D	Yellow
80	*Ficus hispida* L.f.	Moraceae	Z	Fig (specialized infl.)	E	Yellow
81	*Ficus microcarpa* L. f.	Moraceae	Z	Fig (specialized infl.)	D	Black
82	*Ficus nervosa* Heyne.ex Roth	Moraceae	Z	Fig (specialized infl.)	E	–
83	*Ficus racemosa* L.	Moraceae	Z	Fig (specialized infl.)	D	Red
84	*Ficus talbotii* King	Moraceae	Z	Fig (specialized infl.)	E	–
85	*Ficus tinctoria* Forst. F.	Moraceae	Z	Fig (specialized infl.)	E	–
86	*Ficus tsjahela* Burm.f	Moraceae	Z	Fig (specialized infl.)	D	–
87	*Ficus virens* Ait.	Moraceae	Z	Fig (specialized infl.)	D	–
88	*Flacourtia latifolia* (Hook.f. & Thoms.) Cooke	Flacourtiaceae	Z	Entire Fruit	D	Brown
89	*Flacourtia montana* Grah.*	Flacourtiaceae	Z	Entire Fruit	E	Purple
90	*Garcinia indica* (Thou.) Chois.*#	Clusiaceae	Z	Entire fruit	E	Red
91	*Garcinia talbotii* Raiz. ex Sant*	Clusiaceae	Z	Entire fruit	E	Yellow
92	*Garcinia xanthochymus* Hook.f.	Clusiaceae	Z	Entire fruit	E	Yellow
93	*Garuga pinnata* Roxb.	Burseraceae	Z	Entire fruit	D	Yellow
94	*Glochidion ellipticum* Wt.*#	Euphorbiaceae	At	Seed	E	Yellow
95	*Glycosmis pentaphylla* (Retz.) DC.	Rutaceae	Z	Entire fruit	E	Cream
96	*Gnidia glauca* (Fresen.) Gilg.	Thymelaeaceae	At	Entire fruit	D	–
97	*Grevillea robusta* A.Cunn.ex R.Br.	Proteaceae	An	–	E	–
98	*Grewia asiatica* L.	Tiliaceae	Z	Entire fruit	D	Black
99	*Grewia nervosa* (Lour) Panigr.	Tiliaceae	Z	Entire fruit	D	Red
100	*Grewia tiliifolia* Vahl	Tiliaceae	Z	Entire fruit	D	Brown
101	*Haldina cordifolia* (Roxb.) Ridsd.	Rubiaceae	At	Seed	D	Brown
102	*Heterophragma quadriloculare* (Roxb.) K. Schum.	Bignoniaceae	An	Seed	D	Black

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Appendix Table 1. Continued.

No.	Species	Family	D M	D U	E/D	FC
103	*Holarrhena pubescens* Busch.-Ham. Wall. Ex G. Don#	Apocynaceae	An	Seed	D	Brown
104	*Holigarna arnottiana* Hk. f.	Anacardiaceae	Z	Entire fruit	E	Black
105	*Holigarna grahamii* (Wt.) Kurz.*	Anacardiaceae	Z	Entire fruit	E	Brown
106	*Holoptelea integrifolia* (Roxb.) Planch.	Ulmaceae	An	Entire fruit	D	Brown
107	*Homalium ceylanicum* (Gardn.) Benth.	Flacourtiaceae	Z	–	E	–
108	*Ixora brachiata* Roxb.*	Rubiaceae	Z	Entire fruit	E	Purplish-black
109	*Ixora nigricans* R.Br. Ex Wt. & Arn.	Rubiaceae	Z	Entire fruit	E	Black
110	*Ixora pavetta* Andr.	Rubiaceae	Z	Entire fruit	E	Red
111	*Knema attenuata* (Wall) Warb.* #	Myristicaceae	Z	Entire fruit	E	Brown
112	*Kydia calycina* Roxb.	Malvaceae	An	Winged Fruit	D	Brown
113	*Lagerstroemia microcarpa* Wight.	Lythraceae	An	Winged seed	D	Brown
114	*Lagerstroemia parviflora* Roxb.	Lythraceae	An	Winged seed	D	Brown
115	*Lannea coromandelica* (Houtt.) Merr.	Anacardiaceae	Z	Entire fruit	D	Red
116	*Leea indica* (Burm.f.) Merr.	Leeaceae	Z	Entire fruit	E	Black
117	*Lepisanthes tetraphylla* (Vahl) Radlk	Sapindaceae	At	Seed	E	Brownish
118	*Ligustrum perrottetii* A.DC.	Oleaceae	Z	Entire fruit	E	Black
119	*Litsea josephii* S.M. Almeida*	Lauraceae	Z		E	Purple
120	*Macaranga peltata* (Roxb.) Muell.-Arg.	Euphorbiaceae	Z	Entire fruit	E	Yellow
121	*Maesa indica* (Roxb.) DC.	Myrsinaceae	Z	Entire fruit	E	Whitish
122	*Mallotus philippensis* (Lam.) Muell.-Arg.	Euphorbiaceae	Z	Seed	E	Red
123	*Mallotus stenanthus* Muell.- Arg.*	Euphorbiaceae	At	Seed	E	Brown
124	*Mammea suriga* (Buch.-Ham. ex Roxb.) Kosterm.*	Clusiaceae	Z	Entire fruit	E	Brown
125	*Mangifera indica* L.	Anacardiaceae	Z	Entire fruit	E	Yellow
126	*Manilkara hexandra* (Roxb.) Dubard	Sapotaceae	Z	Entire fruit	E	Yellow
127	*Maytenus rothiana* (Welp.) L.Callen*	Celastraceae	Z	Seed	E	Orange
128	*Meiogyne pannosa* (Dalz.) Sinclair*	Annonaceae	Z	Seed	E	–
129	*Memecylon talbotianum* Brand.*	Melastomtaceae	Z	Entire fruit	E	Yellow
130	*Memecylon umbellatum* Burm.f.	Melastomtaceae	Z	Entire fruit	E	Black
131	*Meyna laxiflora* Robyns	Rubiaceae	Z	Entire fruit	E	Brown
132	*Mimusops elengi* L.	Sapotaceae	Z	–	E	Yellow
133	*Mitragyna parvifolia* (Roxb.) Kunth	Rubiaceae	At	Seed	D	Black
134	*Moullava spicata* (Dalz.)Nicols.*	Caesalpiniaceae	At	–	E	–
135	*Murraya koenigii* (L.) Spreng.	Rutaceae	Z	Entire fruit	D	Black
136	*Murraya paniculata* (L.) Jack.	Rutaceae	Z	Entire fruit	E	Red
137	*Myristica dactyloides* Lam. #	Myristicaceae	Z	Seed with aril	E	Brown
138	*Neolamarckia cadamba* (Roxb.) Bosser	Rubiaceae	At	Seed in capsule in fleshy inflo	D	Yellow
139	*Neolitsea cassia* (L.) Kosterm	Lauraceae	Z	–	E	–
140	*Nothapodytes nimmoniana* (Grah.) Mabb.	Icacinaceae	Z	Entire Fruit	D	Purple

Contd...

Appendix Table 1. Continued.

No.	Species	Family	D M	D U	E/D	FC
141	*Nothopegia castanaefolia* (Roth) Ding Hou* #	Anacardiaceae	Z	Entire Fruit	E	Purple
142	*Olea dioica* Roxb.	Oleaceae	Z	Entire Fruit	E	Purple
143	*Oroxylum indicum* (L.) Vent. #	Bignoniaceae	An	Seed	D	Brown
144	*Osyris quadripartita* S alzn. ex Dcne.	Santalaceae	Z	Entire fruit	D	Yellow
145	*Ougenia oojeinensis* (Roxb.) Hochr.	Fabaceae	At	–	D	Green
146	*Persea macrantha* (Nees) Kostern #	Lauraceae	Z	Entire fruit	E	Green
147	*Pongamia pinnata* (L.) Pierre	Fabaceae	At	Seed	E	Brown
148	*Prunus ceylanica* (Wt.) Miq.	Rosaceae	Z	Entire fruit	E	Red
149	*Psychotria truncata* Wall.*	Rubiaceae	Z	–	E	Black
150	*Pterocarpus marsupium* Roxb.#	Fabaceae	An	Entire fruit	D	Brown
151	*Pterospermum acerifolium* L.(Willd.)	Sterculiaceae	An	Entire fruit	E	Brown
152	*Sageraea laurifolia* (Grah.) Blatt. & McCann.* #	Annonaceae	Z	Entire fruit	E	-
153	*Sapium insigne* Benth.	Euphorbiaceae	Z	Entire fruit	D	Black
154	*Saraca asoca* (Roxb.) de Wilde #	Caesalpiniaceae	At	–	E	Brown
155	*Schleichera oleosa* (Lour.) Oken	Sapindaceae	Z	–	D	Brown
156	*Scutia myrtina* (Burm. f.) Kurz.	Rhamnaceae	Z	Entire fruit	E	Black
157	*Securinega leucopyrus* (Willd.) M.-A.	Euphorbiaceae	Z	Entire fruit	D	White
158	*Sterculia guttata* Roxb.	Sterculiaceae	Z	Seed	D	Orange
159	*Stereospermum chelenoides* (L.f.) DC.	Bignoniaceae	An	–	D	-
160	*Stereospermum colais* (Buch.- Ham. ex Dillw.) Mabber	Bignoniaceae	An	–	D	Yellow
161	*Symplocos cochinchinensis* (Lour.)	Symplocaceae	Z	Entire fruit	E	Blue
162	*Symplocos racemosa* Roxb.#	Symplocaceae	Z	Entire fruit	E	Blue
163	*Syzygium caryophyllatum* (L.) Alston	Myrtaceae	Z	Entire fruit	E	Purple
164	*Syzygium cumini* (L.) Skeels.	Myrtaceae	Z	Entire fruit	E	Purple
165	*Syzygium phillyraeoides* (Trim.)	Myrtaceae	Z	Entire fruit	E	Red
166	*Syzygium rubicundum* Wt. & Arn.	Myrtaceae	Z	Entire fruit	E	Black
167	*Tabernaemontana alternifolia* (Roxb.) Nicols & Suresh. #	Apocynaceae	Z	Seed with coloured aril displayed on coloured fruit	D	Yellow
168	*Tectona grandis* L.f.	Verbenaceae	At	Fruit in balloon like calyx	D	Yellow
169	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	Z	Entire fruit	D	Brown
170	*Terminalia chebula* Retz.	Combretaceae	Z	Entire fruit	D	Brown
171	*Terminalia elliptica* Will.	Combretaceae	An	Winged fruit	D	Yellow
172	*Terminalia paniculata* Roth.	Combretaceae	An	Winged fruit	D	Red
173	*Toddalia asiatica* (L.) Lamk.	Rutaceae	Z	Entire fruit	E	Yellow
174	*Trichilia connaroides* (Wt. & Arn.) Bentvel.	Meliaceae	At	–	D	Reddish
175	*Turpinia pomifera* (Roxb.)Wall.ex DC.	Staphyleaceae	Z	–	E	Purple

Contd...

Appendix Table 1. Continued.

No.	Species	Family	D M	D U	E/D	FC
176	*Turraea villosa* Bennet	Meliaceae	At	Seed	D	Brownish
177	*Vitex altissima* L.	Verbenaceae	An	Seed	E	Black
178	*Wendlandia thyrsoidea* (R. & S.) Steud. Nom.	Rubiaceae	Z	–	D	-
179	*Woodfordia fruticosa* L.(Kurz.)	Lythraceae	At	Entire Fruit	D	-
180	*Wrightia tinctoria* (Roxb.) R. Br.	Apocynaceae	An	Seed	D	Brown
181	*Xantolis tomentosa* (Roxb.) Raf.	Sapotaceae	Z	Entire Fruit	E	Green
182	*Xylia xylocarpa* (Roxb.)Taib.	Mimosaceae	At	Seed	E	Brown
183	*Ziziphus mauritiana* Lamk.	Rhamnaceae	Z	Entire fruit	D	Orange
184	*Ziziphus rugosa* Lamk.	Rhamnaceae	Z	Entire fruit	D	Cream
185	*Ziziphus xylopyrus* (Retz.) Willd.	Rhamnaceae	Z	Entire fruit	D	Green

*Species endemic to Western Ghats, # RET species