Journal of Biogeography (J. Biogeogr.) (2004) **31**, 1227–1237

ORIGINAL ARTICLE

The diversity of life-form type, habitat preference and phenology of the endemics in the Goa region of the Western Ghats, India

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Abstract

Aim To carry out (1) a floristic survey of endemic flowering plants of the Western Ghats occurring in Goa, (2) identify their habitat preference and diversity of life-form type, (3) observe flowering phenology of the endemics and (4) to correlate factors that affect their phenological pattern.

Location Goa state is located between 15°48′ N and 14°53′54″ N and 74°20′13″ E and 73°40′33″ E, in the northern part of the Western Ghats, India.

Method A list of endemic plants from the study area was prepared using available floristic works and checklists of endemic plants of India. Based on preliminary field observations carried out in the study area, major habitats such as plateaus, moist deciduous forests, semi-evergreen forests, evergreen forests and mangroves were identified for the subsequent intensive survey of endemics. Voucher specimens for all the endemic species were collected, processed using conventional herbarium techniques and deposited in the Herbarium, Department of Botany, Goa University. Species were identified using local and regional floras and their identity was confirmed at various herbaria along the Western Ghats. Data on their life-form types, habitat and phenology was recorded in the field. Phenological observations were made every fortnight. A computerized data base was generated incorporating details on their life-form type, phenology and habitat.

Results A floristic survey of endemic plants of the Western Ghats in Goa resulted in the collection of 113 endemic species. Life-form analysis reveals that herbaceous endemics are the most dominant followed by trees, shrubs and climbers. Plateaus in the study area harbour the largest number of endemic species, especially herbs. Endemic trees are distributed in the semi-evergreen and evergreen forests. Endemic species in the study area show different peak and lean seasons of flowering depending on their life-form type, habitat and ecological factors like temperature and rainfall/moisture content in the soil.

Main conclusions The plateaus in the northern part of the Western Ghats are unique, being species rich with herbaceous endemics. These ephemerals are closely associated with the rainfall patterns thus; any change of moisture regime over the long-term will have an impact on the distribution of these endemics.

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Keywords

Endemic, Western Ghats, India, tropics, life-forms, flowering phenology, plateaus, moist deciduous, semi-evergreen, evergreen.

INTRODUCTION

Endemic taxa by their definition are species with restricted distribution, or are species with small geographical ranges (Crosby, 1994; Fjeldsa, 1994) and hence deserve conservation efforts. There has been much interest among biogeographers to explain why areas of endemism occur, whether it be by a unique combination of ecological factors or because of a

history of vicariance and speciation in isolation followed by continued range restriction (Nelson & Platnick, 1981; Wiley, 1981; Anderson, 1994; Humphries & Parenti, 1999; Crisp *et al.*, 2001). Plants show distinct patterns of occurrence in time and space. These patterns of occurrence and their phenology (frequency, duration and time) in the community is influenced directly or indirectly by climatic factors like photoperiod, temperature, humidity and rainfall/precipitation (Opler *et al.*, 1980; Van Schaik *et al.*, 1993; Bach, 2002; Bawa *et al.*, 2003) and also by the activities of pollinators, dispersers, predators and breeding cycles of many organisms (Myers *et al.*, 2000). Observations of the habitat and the phenology of endemic species in the ecosystem could be a useful tool in understanding their restricted distribution (Sarmiento, 1983; Schwartz & Walker, 1986), as phenology is an important adaptive trait (Chuine *et al.*, 2000). There is a long-lasting interest concerning the ecological conditions which provide a template for differentiation and/or persistence of restricted endemic species (Durry, 1974; Murray *et al.*, 2002).

The Western Ghats, with *c.* 1500–1600 endemic species [World Conservation Monitoring Centre (WCMC), 1992; Nayar, 1996], is one of the hot spots of biodiversity in India, whereas the Western Ghats/Sri Lanka together have 2100 endemic species (Myers *et al.*, 2000). In general, centres of species richness coincide with centres of endemism (Crisp *et al.*, 2001). The Western Ghats form an important biogeographical zone in Peninsular India, with a series of hill ranges running north–south along the west coast of India, extending from Tapti (21° N) to Kanniyakumari (8° N). The Western Ghats along with the west coast fall under the 'Malabar' botanical province (Clarke, 1898). The Ghats are divided into three parts: (1) Surat–Goa (northern part of the Western Ghats); (2) Goa–Nilgiris (central part of the Western Ghats); (3) South of Palghat (southern part of the Western Ghats) (Pascal, 1988). Chatterjee (1939) initiated the work on endemic plants of India as early as 1939, followed by Blasco (1970), and Ahmedullah & Nayar (1986) and Nayar (1996), provide exhaustive lists of the endemic species of the region. However, none of the studies has emphasized the ecology of the endemics. Ramesh & Pascal (1997) provided distribution maps for endemic trees in the evergreen and semi-evergreen forests of the Western Ghats. Gopalan and Henry (2000) evaluated the status of the strict endemics of the Agasthiyamali hills, in the southern part of the Western Ghats. The most recent work on endemism of the Western Ghats is by Mishra & Singh (2001) in *Endemic and threatened flowering plants of Maharashtra*. From the available literature it was determined that information on endemics and their life-form type in the Goa region of the Western Ghats was altogether lacking. The Goa region is dominated by moist deciduous forests and plateau vegetation unlike the southern part of the Western Ghats which is predominantly evergreen and semi-evergreen forest type.

Information on the phenological patterns of tropical plants is scarce (Sarmiento & Monasterio, 1983) and this is even more the case for endemic plants of the Western Ghats. Although Krishnan (2002) carried out a few studies on the phenology of vegetation of the southern part of the Western Ghats, similar studies on the northern part of the Western Ghats are extremely limited. Therefore, for the present study, the state of Goa was chosen, as it forms a part of the north Western Ghats and also the northernmost limit of the evergreen forests in the Western Ghats. The objectives of this study were to carry out a floristic survey of the endemic flowering plants of the Western Ghats occurring in Goa, to identify their habitat preference and diversity of life-form type, to observe the flowering phenology of the endemics and to correlate the factors that affect their phenological pattern.

MATERIALS AND METHODS

Study area

The study site, Goa state, is located between 15°48′ N and 14°53′54″ N and 74°20′13″ E and 73°40′33″ E, with an area of 3702 km^2 (Fig. 1). The Western Ghats run in a north–south direction in the east and to the west is the Arabian Sea. The area forms a part of the north Western Ghats. The entire Goa state can be divided in to three main physiographic units: (1) hills and valleys along the Ghat zone, (2) a narrow coast line and (3) a mainland with plateaus between the hills and the coast, with climate characterized by the monsoons (Rao, 1985–86).

The southwest monsoon wind brings rain by the first week of June with an average rainfall of 3500 mm. The highest

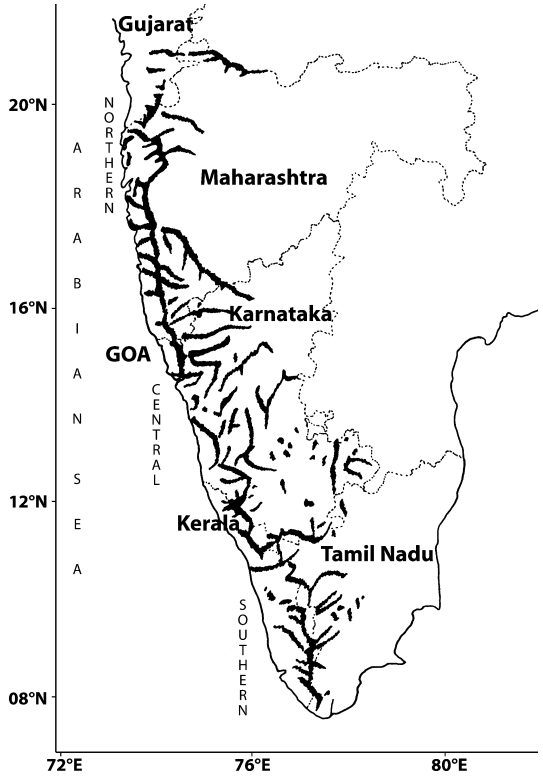

Figure 1 The Western Ghats and the study area (Goa).

rainfall occurs between June and July and the monsoon begins to withdraw by September. In addition, there are pre-monsoon and post-monsoon showers. The rainfall increases rapidly towards the Ghats from 2500 mm to 3000 mm along the coast to over 4000 mm in the Ghats. The average temperature ranges between 21 °C and 30 °C. The temperature rises from March to May and the maximum temperature rises to 36 °C. The days are very hot at 32 °C and the nights are cool at 18 °C during November and December. Data on rainfall and temperature for the Goa region was obtained from the meteorological department located at Altinho, Panjim, Goa.

Due to the proximity of the sea, the study area is humid, with humidity level ranging from 70% to 95% in monsoons.

Geologically the major portion of Goa consists of pre-cambian rocks, namely quartz–sericite. Lateritic soil derived from pink phyllites is the major soil type.

The major forest types in the study area are southern tropical wet evergreen forests, southern tropical semi-evergreen forests, south Indian moist deciduous forest, tidal swamp forests, tropical freshwater swamp forests and southern tropical dry deciduous forests (Champion & Seth, 1968). The moist deciduous forests and plateau vegetation are the most dominant habitats, compared with the evergreen and the semi-evergreen forests, which are restricted to a few patches at higher elevations and along streams.

Method

A list of endemic plants from the study area was prepared using available floristic works (Rao, 1985–86; Naithani *et al.*, 1997; Janarthanam *et al.*, 1999), and from checklists of endemic plants (Ahmedullah & Nayar, 1986; Nayar, 1996). Preliminary field observations were carried out in the study area to identify the major habitats for an intensive survey of endemics. The major identified habitats were plateaus, moist deciduous forests, semi-evergreen forests, evergreen forests and mangroves. These habitats were then intensively surveyed by undertaking fortnightly visits between January 1997 and January 2000. Voucher specimens were collected for all endemic species, processed using conventional herbarium techniques and deposited in the Herbarium, Department of Botany, Goa University. The species were identified using local and regional floras and their identity was confirmed at the Botanical Survey of India, Western Circle (BSI, Pune), MH (Coimbatore), RHT (Tiruchirapalli), JCB (Bangalore), CALI (Calicut), BLAT (Mumbai) and HIFP (Pondicherry). Data on their life-form types, habitat and phenology (flowering) was recorded in the field. Phenologial observations were made fortnightly for all the endemics occurring in different habitats during the 3-year study period. Phenology data was combined and tabulated on a monthly basis per endemic plant species to obtain an overall impression of the phenological pattern of the endemic species of the Western Ghats in Goa. A computerized data base was generated incorporating details on their life-form type, phenology and habitat.

RESULTS

A floristic survey of endemic plants of the Western Ghats in Goa resulted in the collection of 113 endemic species of which 78 (68.03%) are dicotyledons and 35 (30.97%) are monocotyledons. The family Poaceae has the largest number of endemic species (13 species) followed by Acanthaceae and Rubiaceae with eight species each. An analysis of the life-form types indicates that the endemic herbs (58.4%) dominate the study area, followed by trees (20.35%), shrubs (14.15%) and climbers (7.07%) (Fig. 2). The present study added six endemic species (Appendix 1) to the existing lists on endemics of the Western Ghats by Ahmedullah & Nayar (1986) and Nayar (1996). Of the 113 endemics collected in the study area, 39 endemic species are new reports for the Goa region (Appendix 1). New additions are from the plateaus, the moist deciduous forests and open areas.

Data on the habitat of the endemics showed that herbs are abundant on the plateaus, followed by moist deciduous forests, semi-evergreen forests and least in the evergreen forest. Endemic trees are restricted to the semi-evergreen and evergreen forests. Endemic shrubs were observed predominantly in the semi-evergreen and the moist deciduous forests compared with the plateaus and evergreen forests (Fig. 2). Members of the family Poaceae, Fabaceae and Eriocaulaceae were dominant on the plateaus, whereas Rubiaceae and Acanthaceae were dominant in the moist deciduous forests. The families Ebenaceae, Euphorbiaceae and Orchidaceae dominate the semi-evergreen forests whereas Orchidaceae dominates the evergreen forests.

A matrix was drawn to find the number of endemic species that are exclusively restricted to one or other (major) habitat identified in the study area (Fig. 3). It was observed that 64 species are exclusively distributed in one or other habitat and the remaining species are common to two or more habitats. The plateaus harbour the largest number of endemics (41 species) of which 26 are exclusively restricted to this habitat. There are nine species each in the moist deciduous forests and the semi-evergreen forests, and seven species in the evergreen forests are exclusively endemics. Eleven species are common between the plateaus and the moist deciduous forests, 16 between the moist deciduous forests and semi-evergreen forests and 11 species occurred between the semi-evergreen forests and evergreen forests.

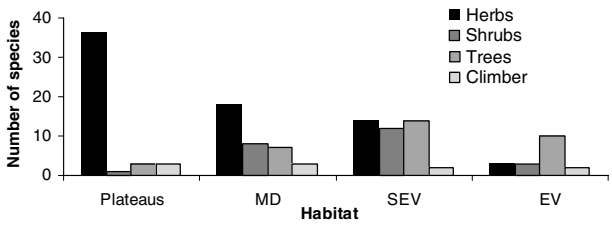

Figure 2 Habitat wise distribution of 113 endemics across different life-forms. MD, moist deciduous forest; SEV, semi-evergreen forest; EV, evergreen forest.

A	26							
B	11	9						
C	2	16	9					
D	0	0	11	7				
E	2	0	0	0	3			
F	0	0	2	0	0	7		
G	7	7	0	0	0	0	2	
H	0	0	0	0	0	0	0	1
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**

Figure 3 Distribution of endemic species of Western Ghats in different habitats of Goa. See Appendix 1 for habitat definitions.

Monthly phenological observations on endemics in different habitats (Fig. 4) determined that endemics on the plateaus show peak flowering in the month of September and this coincides also with the peak flowering of herbs. In the moist deciduous forest, peak monthly phenological was observed in November and in the semi-evergreen forests one peak was observed in March and another in November. Whereas endemics in the evergreen forests did not show any distinct peak season except in November, which was then followed by a uniform pattern of flowering with a plunge from June to September.

The monthly phenological pattern of the endemic species of different life-forms showed that for herbs the peak flowering was in September, for trees it was March, and for shrubs it was December and January; climbers did not show any definite peak season (Fig. 5).

It was observed that the largest number of endemic shrubs flower in the month of January and show a gradual sloping of the graph on either side. These endemic shrubs are mostly located in the semi-evergreen and the moist deciduous forests. Further observations on the phenology of the endemic trees in different habitats (Fig. 6) showed different peak flowering seasons. Trees on the plateaus showed early peak flowering in January followed by trees in the moist deciduous forests between January and February, and in the semi-evergreen forests during March. Endemics in the evergreen forests showed peak flowering between April and May, which is the hottest season in the Western Ghats.

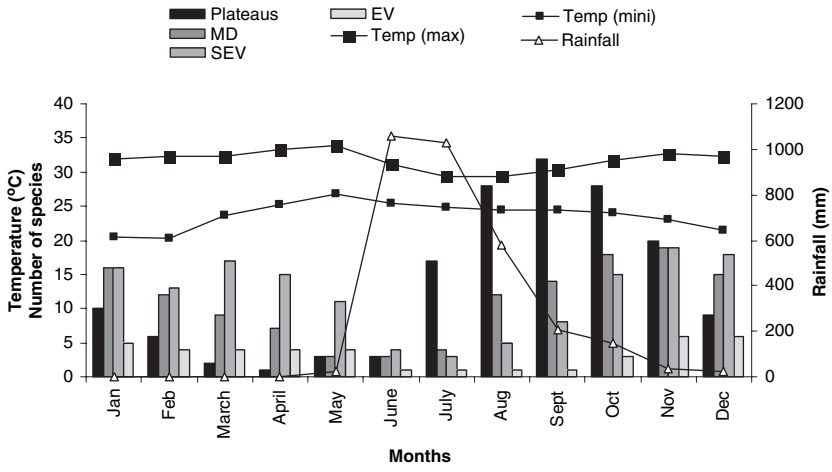

Figure 4 Flowering phenology of endemic species of major habitats and their relationship to temperature and rainfall. MD, moist deciduous forest; SEV, semi-evergreen forest; EV, evergreen forest.

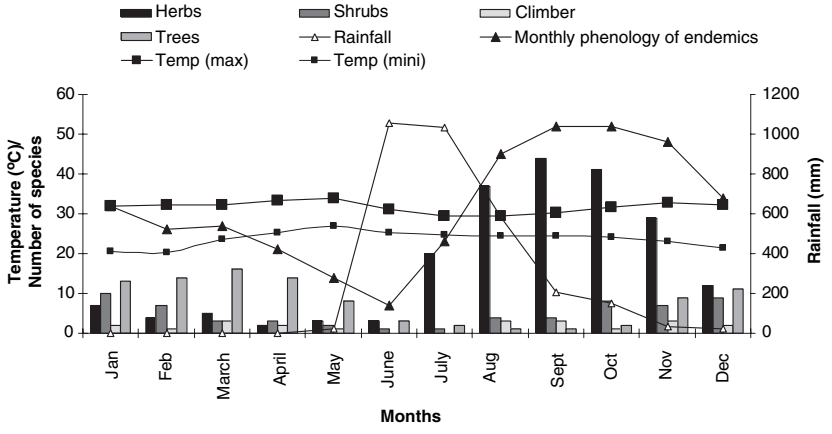

Figure 5 Flowering phenology of endemic species in different life-forms and their relationship to temperature and rainfall.

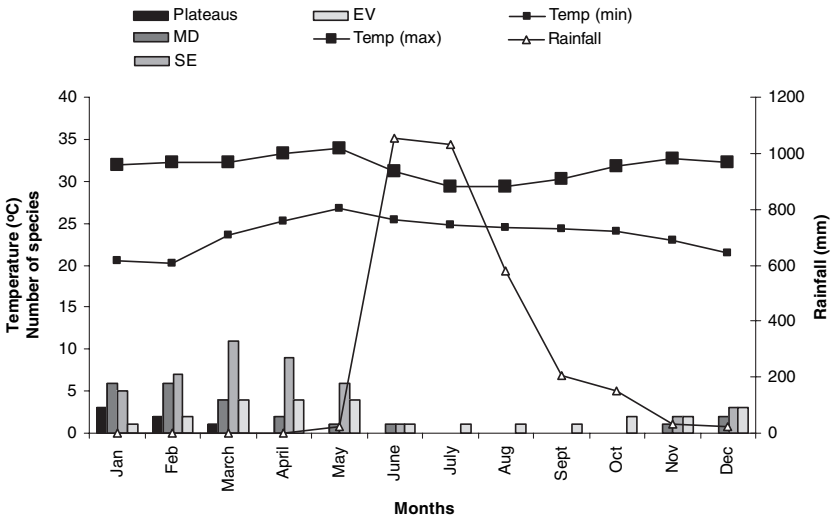

Figure 6 Flowering phenology of endemic trees in different habitats and their relationship to temperature and rainfall. MD, moist deciduous forest; SEV, semi-evergreen forest; EV, evergreen forest.

DISCUSSION

In the present study, it was observed that state of Goa occupies just 2% area of the Western Ghats but harbours *c.* 7% of the endemic flowering plant species of the Western Ghats. The state of Goa is rich in biodiversity and has *c.* 1500 species. The Goa region of the Western Ghats differs from the southern part of the Western Ghats due to its altitude variation, amount of rainfall and length of the dry season. Because these are the main factors of species niche differentiation, this may explain the high level of endemism.

The family Poaceae has the largest number of endemic species (13 species), followed by Acanthaceae, Rubiaceae and Fabaceae with eight endemic species each, and Orchidaceae with six endemic species. Poaceae is the dominant family along the Western Ghats followed by Acanthaceae, Rubiaceae and Fabaceae (Arora, 1964; Nayar, 1980, 1984, 1996; Karthikeyan, 1983, 1996; Parthasarthy, 1983; Ahmedullah & Nayar, 1986; Nair & Daniel, 1986; Sreekumar & Nair, 1991; Vajravelu & Vivekananthan, 1996; Venu, 1998). Thus it appears that the number of endemics in each family is generally proportional to the number of species in that family. However, although not species rich in the study area, families such as Araceae, Eriocaulaceae and Lentibulariaceae are abundant on the plateaus. This explains where there are a large number of endemics. Recent reversionary works and critical studies on these families (Janarthanam & Henry, 1992; Yadav *et al.*, 1993; Ansari & Balakrishnan, 1994; Hetterscheid *et al.*, 1994) have added to the number of endemic species. In the present floristic survey, of the 113 endemics colleted in Goa part of the Western Ghats, six endemic species are new additions to the existing endemic plant list of the Western Ghats (Ahmedullah & Nayar, 1986; Nayar, 1996) and 39 endemic species were not collected by earlier workers from Goa. Thus, it can be concluded that taxonomists studying regional floras make major contributions towards the study of the endemic flora (Kruckeberg & Rabinowitz, 1985).

In the northern part of the Western Ghat, endemic flora is rich in herbaceous forms unlike the evergreen forests of the southern part of the Western Ghats where trees are predominant over herbs (Ganesh *et al.*, 1996). However, Krishnan & Davidar (1996) and Ramesh & Pascal (1991) observed that shrub flora in the Western Ghats is richer in endemics as compared to the tree flora. In the present study, the largest number of endemic species were observed on the plateaus followed by the moist deciduous, semi-evergreen and evergreen forests in that order. The plateaus and the moist deciduous forest occupy the major portion of the land area in the state of Goa (Gune, 1979). From the plateaus 36.2% of the endemics were collected. Although rich in species diversity, plateaus are highly neglected habitats due to their dry barren appearance during the drier months, thus they are considered as waste lands. Hard lateritic rocks, characteristic of the plateaus have very little water holding capacity and support mostly annuals during the monsoons. A floristic survey of the plateaus along the Western Ghats during the monsoons could be a potential hunting ground for endemics/new species/new reports, etc. In addition, endemic herbaceous species on the plateaus have a narrow distribution range mostly restricted to the northern and central part of the Western Ghats, thus deserving conservation efforts.

As reviewed by Sarmiento & Monasterio (1983) for the American tropics, information on phenological patterns of tropical plants is scarce. This is even more the case for endemics of the Western Ghats. The phenology of endemic species in the study area showed peak and lean seasons. Similar peak and lean seasons were observed with regard to tree species in the Neotropics (Smythe, 1970; Frankie *et al.*, 1974; Croat, 1978; Milton, 1980; Milton *et al.*, 1982). Such fluctuations are often correlated with environmental factors such as rainfall patterns (Milton, 1980; Bach, 2002). Ramesh & Pascal (1991) observed that the length of the dry season plays an important role in the distribution of species along the Western Ghats and not the amount of rainfall. The length of the dry season and the length of the wet season depend on the duration of the monsoon and not on the amount of rainfall. In Goa, rainfall steadily increases from

the month of May, is the highest during the month of June and July and then shows a steady decrease from August to October (Fig. 2).

The flowering of the endemic herbaceous species starts in June with the availability of moisture and reaches its peak in the month of September when there is enough moisture in the soil. It shows a steady decrease in flowering with the reduction in soil moisture.

A rapid growth response was observed on the plateaus after the first rain showers, an observation similar to that of Bourliere & Hadley (1983) made on savanna grasses. The plateaus, composed of lateritic rocks, have very little water holding capacity and are generally dry. The phenological patterns shown by the herbaceous endemics is in accordance with the general flowering pattern of the herbs observed by Sivaraj & Krishnamurthy (1989) along the Shevary hills in the Eastern Ghats and Braganza (1998) on the plateaus of Goa. Thus the phenology of herbaceous flora in the plateaus is mostly controlled by rainfall pattern in addition to other environmental factors.

Endemic trees were observed flowering from November to May with the peak during March. This pattern of flowering is similar to that observed in trees of the tropical moist deciduous forests, which flower in the dry season (Rawitscher, 1948; Webb, 1959; Boaler, 1966; Daubenmire, 1972; Longman & Jenik, 1974; Borchert, 1980; Reich & Borchert, 1982). Borchert (1980) hypothesized that during early drought, transpiration water loss exceeds water absorption by roots and tree water declines causing leaf senescence and subsequent leaf shedding. After the reduction in transpiration water loss, slow absorption of residual soil moisture increases tree water potential and permits bud breaking. This is clearly observed in endemic trees in different habitats of the study area, which show different peak flowering seasons coinciding with the water availability in the respective habitats. Trees on the plateaus show an early peak in flowering from January followed by trees in the moist deciduous forests in the month of January to February. This is because the plateaus are open areas covered with lateritic rocks and have very little water holding capacity, hence they dry out early compared to other habitats. The moist deciduous forests in Goa are again characterized by lateritic substrate sharing the same phenomena as plateaus, whereas trees in the semi-evergreen and the evergreen forests flower in the months of March and May, respectively. These habitats are characterized by an absence of lateritic substrate and are at higher altitude. As a result of the higher elevations they also receive mist, which provides additional moisture (Ramesh & Pascal, 1997). Endemic trees in the evergreen forests are mostly observed along the streams, an observation also made by de Bie *et al.* (1998) in west African savanna. It appears that the moisture content of the soil is the main determinant of phenological patterns, as shown by these endemics in different life-forms. These observations are similar to that of Prins (1988). Therefore, it can be expected that phenological patterns shown by the endemics of different life-forms may vary along the latitudinal and altitudinal gradients along the southern part of the Western Ghats because of associated variation in the length of the dry season and the amount of rainfall. However, within the study area it was observed that the general phenology of the endemics of different life-form types matches the phenology of the widespread species. Thus, the endemic species do not differ much from the widespread species in terms of resource acquisition and establishment ability. Within the broad biotic and abiotic events of its ecosystem the microhabitat needed for instillation by an endemic species may be relatively low, or they may have low establishing capacity thus leading to their restricted distribution. Further studies on the phytogeography of these endemic species (which are underway) would provide better insight into the understanding of their restricted distribution.

In conclusion, the present study demonstrates that the state of Goa, which forms northern part of the Western Ghats, is rich in endemic flora, this especially being the case for herbs that are predominant in the plateau regions. However, these plateaus are relatively under explored due to their dry and barren appearance (Joshi & Janarthanam, 1997), unlike the evergreen forests of the southern part of Western Ghats where most of the work on endemics is concentrated. Further studies on the plateaus along the Western Ghats is very likely to result in the addition of considerably more new species to the existing endemic plant list for the Western Ghats. From this study, we can conclude that the vegetation of the plateaus in the northern part of the Western Ghats are unique, being species rich with herbaceous plants that are rich in endemics. Also, these endemic flora are restricted predominantly to the northern and central part of the Western Ghats. Being ephemerals and closely associated with the rainfall pattern, any change of moisture regime over the long-term will have an impact on the distribution of these endemics.

ACKNOWLEDGMENTS

The study was made possible by a research grant provided by the Goa State Council for Science and Technology, Goa, India. We are also thankful for the support provided by Dr S. Rajkumar during extensive field work in the study area. We would also like to thank the Directors and/or those in charge of BSI, BLAT, CALI, HIFP, JCB, MH and RHT.

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BIOSKETCHES

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Appendix 1 Life-form, habital and phenology of the endemics in the Goa region of the Western Ghats, India.

Species	Family	Habit	Habitat	Flowering months
Barleria strigosa Willd. var. *terminalis* (Nees) Clarke*,†	Acanthaceae	Shrub	B, C	November–February
Gymnostachyum glabrum (Dalz.) T. Ander.*	Acanthaceae	Shrub	B, C	December–February
Haplanthodes neilgherryensis (Wight) Majumdar	Acanthaceae	Herb	A, G	January–April
Justicia wynaadensis (Nees) Wall. ex T. Anders.	Acanthaceae	Herb	A, B, C	November–March
Mackenziea integrifolia (Dalz.) Bremek	Acanthaceae	Shrub	B	December–January
Neuracanthus sphaerostachyus (Nees) Dalz.†	Acanthaceae	Under shrub	B, F	August–December
Nilgirianthus barbatus (Nees) Bremek.‡	Acanthaceae	Shrub	D (Myristica swamp)	January–February
Thelepaepale ixiocephala (Benth.) Bremek.	Acanthaceae	Shrub	B, C	October–January
Wiesneria triandra (Dalz.) Micheli†	Alismataceae	Herb	A (water pools)	July–October
Holigarna arnottiana Hook. f.	Anacardiaceae	Tree	A, B	February–April
Holigarna ferrugiana	Anacardiaceae	Tree	A, B	February–April
Holigarna grahamii (Wight) Kurz.	Anacardiaceae	Tree	C, D	January–June
Ancistrocladus heyneanus Wall. Ex Graham‡,§	Ancistrocladaceae	Climbing shrub	C, F	March–May
Sageraea laurina Dalz.	Annonaceae	Tree	B, C	December–February
Amorphophallus commutatus (Schott) Engl.	Araceae	Herb	A, B	May–October
Amorphophallus konkanensis Hetterscheid, Yadav & Patil*,†	Araceae	Herb	A	June–July
Arisaema sivadasanii Yadav, Patil & Janarthanam*,†,‡	Araceae	Herb	B	July–October
Cryptocoryne cognata Schott†	Araceae	Herb	G (streams)	September–November
Arenga wightii Griff.‡	Arecaceae	Tree	D	November–January
Calamus thwaitesii Becc. & Hook. f	Arecaceae	Climber	C, D	February–March
Hyphaene dichotoma (Wight) Furtado	Arecaceae	Tree	H	January–April
Brachystelma malwanense Yadav & Singh*,†,‡	Asclepiadaceae	Herb	G	March
Ceropegia attenuata Hook.†	Asclepiadaceae	Herb	A	August–October
Ceropegia fantastica Sedgw.†	Asclepiadaceae	Climber	A, B	August–September
Heterostemma dalzellii Hook. f.*,†	Asclepiadaceae	Climber	B, G	August–September
Tylophora dalzellii Hook.f	Asclepiadaceae	Climber	A, G	August–November
Phyllocephalum ritchiei (Hook. f.) Narayana‡	Asteraceae	Herb	B, C	September–October
Phyllocephalum tenue (Clarke) Narayana	Asteraceae	Herb	B, C	August–November
Senecio belgaumensis (Wight) Clarke	Asteraceae	Herb	A, B, C	October–December
Impatiens kleiniformis Sedgw.	Balsaminaceae	Herb	B, C	October–November
Impatiens pulcherrima Dalz.	Balsaminaceae	Herb	C	November–December
Begonia crenata Dryand.	Begoniaceae	Herb	A (marshy areas), B	July–October
Adelocaryum coelestinum (Lindl.) Brand	Boraginaceae	Herb	B, C	September–November
Moullava spicata (Dalz.) Nicolson	Caesalpinaceae	Climber	A, B	November–January
Capparis rheedii DC.	Capparidaceae	Shrub	C	March–May
Calophyllum calaba L.	Clusiaceae	Tree	C	October–March
Garcinia indica (Dupetite – Thouars) Choiss.	Clusiaceae	Tree	A, B	November–August
Garcinia talbotii Raiz. ex Santapau	Clusiaceae	Tree	D	December–May
Murdannia versicolor (Dalz.) Brueckner	Commelinaceae	Herb	A, G	August–October
Fimbristylis dauciformis Govind.‡	Cyperaceae	Herb	A (marshy areas), E	July–December
Fimbristylis lawiana (Boeck.) Kern†	Cyperaceae	Herb	A, G	July–August
Hopea ponga (Dennst.) Mabberley	Dipterocarpaceae	Tree	C (along stream)	February–April
Diospyros angustifolia (Miq.) Kosterman	Ebenaceae	Tree	B, C, D (along streams)	March–May
Diospyros paniculata Dalz.	Ebenaceae	Tree	C, D	March–April
Diospyros pruriens Dalz.	Ebenaceae	Tree	C, D	April–May
Diospyros saldanhae Kosterman	Ebenaceae	Tree	C, F	March–May
Eriocaulon cuspidatum Dalz.	Eriocaulaceae	Herb	A	August–November
Eriocaulon dalzellii Koern.‡	Eriocaulaceae	Herb	A (Water pools), F	August–November
Eriocaulon eurypeplon Koern.‡	Eriocaulaceae	Herb	A (water puddles)	July–September
Eriocaulon fysonii Ansari & Balakr.†	Eriocaulaceae	Herb	A (water puddles)	August–November
Eriocaulon lanceolatum Miq. ex Koernick‡	Eriocaulaceae	Herb	A (water puddles)	July–February

Appendix 1 *continued*

Species	Family	Habit	Habitat	Flowering months
Eriocaulon redactum Rhuland‡	Eriocaulaceae	Herb	A (water puddles)	July–September
Eriocaulon stellulatum Koern.	Eriocaulaceae	Herb	C (wet open areas)	November–December
Bruxanellia indica Dennst. ex Kostel	Euphorbiaceae	Shrub	B, C	October–March
Dimorphocalyx glabellus Thw. var. *lawianus* (Hook. f.) T. Chakrab. & Balakr	Euphorbiaceae	Shrub	C	January–April
Drypetes venusta (Wight) Pax & Hoffm.‡	Euphorbiaceae	Tree	C, D	November–February
Euphorbia notoptera Boiss.†	Euphorbiaceae	Herb	A	September–November
Phyllan thus talbotii Sedgwick	Euphorbiaceae	Shrub	F	August–October
Crotalaria filipes Benth.	Fabaceae	Herb	A	September–November
Crotalaria lutescens Dalz.	Fabaceae	Herb	A	September–November
Derris heyneana (Wight & Arn.) Benth.	Fabaceae	Climber	B	March–April
Geissaspis tenella Benth.	Fabaceae	Herb	A	July–November
Indigofera dalzellii Cooke	Fabaceae	Herb	A	July–October
Spatholobus purpureus Benth. ex Baker‡	Fabaceae	Climber	D	November–January
Hydnocarpus pentandra (Buch. – Ham.) Oken	Flacourtaceae	Tree	B	November–March
Trithuria konkanensis Yadav & Janarthanam†,‡	Hydathyllaceae	Herb	A	August–September
Eusteralis tomentosa (Dalz.) Panig.	Lamiaceae	Herb	E	November–March
Cryptocarya lawsonii Gamble‡	Lauraceae	Tree	D	November–March
Litsea coriacea (Heyne ex Meisner) Hook. f	Lauraceae	Shrub	C	October–February
Litsea ghatica Saldanha‡	Lauraceae	Shrub	C	October–November
Utricularia lazulina Taylor‡	Lentibulariaceae	Herb	A	July–September
Utricularia malabarica Janathanam & Henry†	Lentibulariaceae	Herb	A	August–November
Utricularia praeterita Taylor	Lentibulariaceae	Herb	A	August–October
Lagerstroemia microcarpa Wight	Lythraceae	Tree	B	November–April
Rotala macrandra Koehne‡	Lythraceae	Herb	E, F	November–January
Rotala malampuzhensis Nair‡	Lythraceae	Herb	E, F	July–October
Decaschistia trilobata Wight	Malvaceae	Herb	B, C	October–November
Memecylon talbotianum Brandis	Melastomataceae	Tree	C	March–May
Sonerila rheedii Wight & Arn.‡	Melastomataceae	Herb	B	September–October
Artocarpus hirsutus Lam.	Moraceae	Tree	A, B	January–February
Gymnacanthera farquhariana (Hook. & Thom.) Warburg	Myristicaceae	Tree	D	April–November
Knema attenuata (Wall. ex Hook. f., & Thoms.)Warb.,	Myristicaceae	Tree	C, D	November–December
Eugenia macrocephala Duthie	Myrtaceae	Tree	C, D	February–March
Aerides dalzelliana (Sant.) Garay‡	Orchidaceae	Herb	C, D	May–June
Dendrobium ovatum (Willd.) Kranzl.§	Orchidaceae	Herb	B, G	December
Eria dalzellii (Hook. ex Dalz.) Lindl.‡	Orchidaceae	Herb	B, C	August
Oberonia brachyphylla Blatter & McCann‡	Orchidaceae	Herb	C, D	March–April
Porpax jerdoniana (Wight) Rolfe‡	Orchidaceae	Herb	C, D	July–September
Arthraxon lanceolatus (Roxb.) Hochst var. *meeboldii* (Stapf.) Welzen†	Poaceae	Herb	B, G	November–December
Arundinella metzii Hochst. ex Miq.	Poaceae	Herb	B	October–December
Dimeria woodrowii Stapf†,‡	Poaceae	Herb	A	August–November
Glyphochloa acuminata (Hack.) Clayton var. woodrowii (Bor) Clayton	Poaceae	Herb	A	August–October
Glyphochloa goaensis (Rao & Hemadri) Clayton†	Poaceae	Herb	A	July–October
Glyphochloa talbotii (Hook. f.) Clayton†	Poaceae	Herb	A	September–November
Ischaemum dalzellii Stapf ex Bor‡	Poaceae	Herb	B	July–August
Ischaemum jayachandranii Ansari *et al.*‡	Poaceae	Herb	E	December–January
Ischaemum travancorense Stapf ex C. E. C. Fischer‡	Poaceae	Herb	A	October–January
Ophiuros bombaiensis Bor‡	Poaceae	Herb	E	September–October
Panicum paianum Nair & Patunkar var. *paianum*†,‡	Poaceae	Herb	G	August–September
Paspalum canarae (Steud.) Veldk. var. *fimbriatum* (Bor.) Veldk.	Poaceae	Herb	B	November–December
Griffithella hookeriana (Tulasne) Warming	Podostemaceae	Herb	F	October–November

Appendix 1 *continued*

Species	Family	Habit	Habitat	Flowering months
Ventilago bombaiensis Dalz.	Rhamnaceae	Shrub	C, D	December–February
Hedyotis maheshwarii (Sant. & Merch.) Rao & Hemadri	Rubiaceae	Herb	G	July–September
Ixora brachiata Roxb. ex DC	Rubiaceae	Shrub	B, C	October–January
Mussaenda laxa Hutchin. ex Gamble	Rubiaceae	Shrub	A, B	August–November
Neanotis foetida (Dalz.) Lewis.	Rubiaceae	Herb	A	September–October
Neanotis rheedei (Wall. ex Wight & Arn.) W. H. Lewis	Rubiaceae	Herb	B	August–October
Psychotria dalzellii Hook. f.,	Rubiaceae	Shrub	B, C	April–September
Tricalysia sphaerocarpa (Dalz.) Gamble‡	Rubiaceae	Tree	D	October–November
Lindernia estaminodosa (Blatt. & Hallb.) Mukherjee‡	Scrophulariaceae	Herb	F, G	June–October
Lindernia manilaliana Sivarajan‡	Scrophulariaceae	Herb	A	July–October
Torenia bicolor Dalz.	Scrophulariaceae	Herb	E, F	August–November
Zingiber neesanum (Graham) Ramamoorthy	Zingiberaceae	Herb	C	July–October

*Species added to the endemic plant list of Western Ghats; †restricted to Northern Western Ghats; ‡endemic species of Western Ghats which were not collected by earlier worker from Goa; §Mentioned by Rao (1985–86), but not collected in the study area.
Habitats: A, plateaus; B, moist deciduous; C, semi evergreen; D, evergreen; E, fields; F, streams; lakes and river; G, open areas other than plateaus; H, beach.