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Floristic attributes of small cardamom (*Elettaria cardamomum* (L.) Maton) growing areas in the Western Ghats of peninsular India

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Abstract. A field study was conducted in the Western Ghats of peninsular India to test the following two hypotheses: (1) lower floristic diversity for the cardamom hill reserves (CHR – a traditional agroforestry system of the tropics) compared to undisturbed evergreen forests and (2) a truncated vegetation structure for shade trees in the cardamom areas. The experimental sites involved three CHRs and an evergreen forest site.

The CHRs, regardless of their locations, were characterized by lower floristic diversity and density than the evergreen forest site. The undisturbed forest site at Ayyappancoil registered the highest floristic richness and diversity (Simpson's floristic diversity index, D = 0.93), followed by the well-managed CHR site, suggesting that managerial interventions may have a strong bearing on the floristic diversity of CHRs. The current suite of species in the CHRs included both heliophilic as well as shade-tolerant components. However, dominant tree species, their density and relative abundance exhibited marked variations among the CHR sites, albeit about one-third of the species were common at all sites.

Stand physiognomy was characterized by the dominance of a single layer of trees in the CHRs, while the wet evergreen forest exhibited a multilayered canopy structure. Some of the lower height classes were poorly represented in the cardamom areas, whereas the evergreen forests depicted an inverse 'J' shaped height distribution pattern. Implicit in the truncated stand structure of the CHR is the poor regeneration status, due to systematic removal of the lower size classes.

Introduction

Small cardamom (*Elettaria cardamomum* (L.) Maton; Family: Zingiberaceae), the 'queen of spice', is perhaps the most important cash crop of the Indian wet tropics after para rubber (*Hevea brasiliensis*), in terms of economic returns to the growers. Cardamom is grown extensively in the Western Ghats of peninsular India (approximately 81 000 ha; Spices Board, 1991). The traditional system of cardamom production in the Western Ghats represents a unique, but little studied agroforestry system. It involves growing a sciophytic commercial crop under the shade of trees in the natural forest, with little or no reliance on external inputs such as fertilizers and/or other chemicals.

Dominant trees in the evergreen and semi-evergreen forests selectively retained by the growers provide shade to the cardamom crop in this age-old cultural system. Shade trees also vary from place to place depending on local preferences and the silvicultural characteristics/requirements of trees.

Although shade trees abound in cardamom plantations, there is very little documented information on the relative performance of these species on cardamom productivity. The floristic structure, composition and regeneration status of these secondary successional stands (cardamom lands) are also not clearly understood. Such knowledge would be needed to provide silvicultural insights into the methods for conserving the existing forest resource, threatened by large scale deforestation [Cherian, 1977]. Furthermore, maintenance of optimal levels of shade in the cardamom areas, essential for ensuring sustained productivity of cardamom, also necessitates elucidating such information.

Clearing the forests for cardamom cultivation alters the floristic richness and vegetation structure. Our objectives were to characterize the vegetation structure of cardamom-growing areas in the Western Ghats and to compare the current suite of trees there with a native moist tropical forest and *inter alia* identify the popular shade trees for cardamom crop. Two hypotheses were tested in this context: (1) A lower floristic diversity for the CHRs compared to the undisturbed adjacent evergreen forest. (2) The vegetation structure of the cardamom areas will be dominated by few of the larger size classes as opposed to the typical inverse 'J' shaped distribution pattern of a natural evergreen forest.

Materials and methods

Ecological features of cardamom production

Cardamom is indigenous to the medium elevation wet evergreen and semi-evergreen forests of the Western Ghats of peninsular India. In ancient times cardamom was collected from forests, but later man started cultivating it as an understorey crop in the tropical forests. The process of cardamom cultivation involved selective removal of trees to facilitate light infiltration to the understorey and planting of the crop. Clearing the forests for cardamom cultivation, however, resulted in disturbance to the forest ecosystem [Cherian, 1977] and caused drastic changes in vegetation structure and physiognomy. Transforming the multi-tiered stand structure of the wet evergreen forests into a monolayered structure of the cardamom areas is the most dramatic effect in this respect.

Indiscriminate exploitation of natural forests and illicit felling of trees are also common in the cardamom-growing tracts of Western Ghats. Eroded and degraded soils and poor fertility status, besides pest and disease incidence, are consequential problems in this respect. Loss of canopy cover resulted in sub-optimal levels of shade for the cardamom crop leading to lower productivity. The Government treated such degraded forest lands as cardamom areas (on lease to private growers) – the 'cardamom hill reserves' (CHRs) in forestry parlance.

According to Cherian [1986] cardamom productivity is particularly low in the leased areas, which account for about 20% of the cardamom plantations of Kerala owing to poor soil management and shade regulation. The ownership pattern of CHRs (land belonging to State Revenue Department, trees on the land belonging to the State Forest Department and the cardamom crop being owned by the growers) also is a disincentive towards good practice.

Although in the traditional system of cardamom production little or no chemical fertilizers were applied, with the advent of modern technology, farmers have started using chemical fertilizers to supplement the inherent site fertility. Furthermore, to ensure reasonable levels of cardamom productivity, a regular schedule of cultural practices consisting of weeding, mulching, trashing, shade regulation, fertilizer application and irrigation is considered essential [KAU, 1993]. Unless overstorey shade is regulated by pruning, lopping, pollarding and/or planting quick-growing tree species in the larger canopy gaps, cardamom productivity cannot be sustained. However, shade regulation of cardamom plantation is a grossly neglected aspect [FAO, 1984].

Site selection

After a reconnaissance of the cardamom-growing tracts in the High Ranges of Kerala, three representative sites, one each at Pampadumpara (between 9°25′ and 9°57′ N latitude, 76°20′ and 76°21′45″ E longitude; altitude ~1000 m), Kumili (between 8°30′ and 8°45′ N latitude and 77°0′ and 77°5′ E longitude; altitude ~1000 m) and Santhanpara, Devikolam (between 10°5′ and 10°10′ N latitude and 77°5′ and 77°10′ E longitude; altitude: 2041 m) were selected for the study. An undisturbed patch of evergreen forest falling in the adjacent Ayyappancoil Forest Range (between 9°45′ and 9°50′ N latitude and 77°0′ and 77°10′ E longitude; altitude: 1202 m) was also selected for a comparison of the floristic and edaphic attributes of these two distinct vegetation types.

The CHRs included in the study exhibited wide variations in crop management practices such as shade regulation and soil management. At Pampadumpara, shade trees were regularly pruned/lopped and/or pollarded just before the onset of monsoons to provide about 40–50% shade to the crop. Fast-growing tree species are also planted in the larger openings, if any. Besides, cultural practices like weeding, mulching, trashing and fertilizer application (ca. 75:75:150 kg N, P_2O_5 and K_2O ha^{-1} yr^{-1}) were done regularly at this site. Other two CHR sites, however, had low to medium intensity management, with infrequent weeding, shade regulation and soil management. No attempt was, however, made at these sites to plant tree species to cover the large canopy gaps, although timber extraction at irregular intervals was common.

Edaphic and climatic attributes

The terrain of the study areas is very rugged and the soils are inceptisols of varying depths. The climate is typically hot and humid with a mean annual precipitation above 2800 mm. Maximum mean daily temperature (at Pampadumpara) during the hottest month (March) is about 35 °C and mean daily minimum during the coldest month (January) is about 16 °C. All CHRs originally supported natural evergreen/semi-evergreen forests, which were partially deforested in the process of cardamom cultivation.

In order to characterize the soil profile development under the two vegetation types, profile pits (one each) were dug to a depth of 1 m at representative spots characteristic of the vegetation types (at Devikolam and Ayyappancoil, CHR and evergreen forest respectively). After morphological examination [SSF, 1992], the horizon-wise soil samples were taken to the laboratory, where they were air dried and ground to pass through a 2 mm sieve for chemical analysis.

Morphological examination of the two selected soil profiles did not reveal any characteristic differences, except minor variations in soil colour. The top horizon (20–0 cm) of Devikolam profile (CHR) was dark brown (7.5 YR 4/4), while the evergreen forest site at Ayyappancoil had a dark yellowish brown (5 YR 3/4) surface horizon. Both 0–20 cm and 20–40 cm horizons were dark reddish brown (5 YR 4/4) and dark yellowish brown (5 YR 3/4), respectively at Devikolam and Ayyappancoil. The 40–60 cm horizon also was reddish brown (5 YR 4/4) in the CHR while it was yellowish red (5 YR 4/6) at the evergreen site. The 60–80 cm horizon was reddish brown (5 YR 4/4) at Devikolam and yellowish red (5 YR 4/6) at Ayyappancoil.

Both sites had a non-sticky or slightly sticky (wet) and non-plastic silty loam texture with very friable, medium weak granular structure, having rapid permeability and a clear smooth boundary with an abundance of fine roots, in the top horizon. The lower horizons were generally characterized by slightly plastic silty clay texture with moderate weak subangular blocky structure, moderate permeability and diffuse wavy boundaries.

Regarding physico-chemical properties of the soil, the CHRs were characterized by marked reduction in the soil organic matter and available K status. The organic C contents of different CHR horizons were 1.47, 0.85, 0.67, 0.61 and 1.1%, respectively for the 20–0, 0–20, 20–40, 40–60 and 60–80 cm soil layers (from the surface). The corresponding figures for the evergreen site were 2.71, 1.56, 0.77, 0.65 and 0.39%. Higher organic matter status of the evergreen forests may be due to higher detritus flow from the trees. On the other hand, the cardamom hill reserves are characterized by greater degree of exposure and higher rate of organic matter turnover, quite apart from the reduced inflow of organic matter through litterfall owing to the loss of canopy cover. The soil pH values were 6.58 and 6.86, respectively, for the CHR and evergreen forest site (20–0 cm layer).

Phytosociological analyses

Fifty random 10 × 10 m quadrats were established at each of the study areas. All trees (≥ 10 cm girth at breast height (GBH)) in the 0.5 ha sample plot were enumerated by measuring the height using a Suunto optical reading clinometer. The relative crown position of individual trees at the Pampadumpara site was also evaluated by visually grouping the trees into crown classes such as dominants (trees that form the uppermost leaf canopy and have their leading shoots free), codominants (the slightly shorter dominants), intermediates (trees that do not form part of the uppermost canopy but the leading shoots of which are not definitely overtopped by the neighbouring trees) and suppressed (trees with their leading shoots overtopped by their neighbours). Girth at breast height (GBH) of all trees (≥ 10 cm GBH) at the Pampadumpara site also was measured.

Using the enumeration details, the following parameters were worked out: relative frequency, density, relative density [Curtis and McIntosh, 1950]. Simpson's floristic diversity index [Simpson, 1949] and Sorenson's similarity index [Sorenson, 1948]. In addition, basal area, relative basal area and importance value index (IVI) were worked out for the Pampadumpara site [Curtis and McIntosh, 1950].

Results and discussion

Floristic richness and diversity

Floristic attributes (number of tree species, density and diversity) of the cardamom sites exhibited wide variations (Table 1). Highest tree density and the largest number of species were observed at the undisturbed evergreen forest site (Ayyappancoil). At other locations (CHRs) the number of species decreased in the order: Pampadumpara, Devikolam and Kumili (Table 1). The density-dependent Simpson's floristic diversity index (D) was 0.93 for the

Table 1. Floristic diversity indexes of trees (≥ 10 cm GBH) in the cardamom hill reserves (CHR) and evergreen forests of High Ranges in the Western Ghats of Kerala (plot size 5000 m^2).

Site	No. of species	No. individuals	Simpson's diversity index
Pampadumpara (CHR)	40	261	0.860
Kumili (CHR)	22	352	0.697
Devikolam (CHR)	25	350	0.701
Ayyappancoil (Forest)	42	988	0.933

evergreen Ayyappancoil forest site, implying that only 7 out of the 100 pairs taken at random is composed of the same species, which is on par with other wet evergreen forest formations in the Western Ghats (D > 0.90; Pascal, 1988). The relatively low floristic diversity indexes of the CHRs can be attributed to the continued anthropogenic pressure, characteristic of cardamom plantations. In the normal course, when a virgin forest is converted into a cardamom plantation, the lower and middle strata trees are systematically removed to facilitate light infiltration into the understorey. This, in turn, may have a depressing effect on the floristic richness and diversity of the cardamom areas.

Surprisingly, the well-managed cardamom plantation at Pampadumpara recorded the highest floristic diversity index for CHRs, despite having the lowest tree density (522 trees ha^{-1}). Although middle and lower canopy layers are eliminated in a CHR, when larger canopy gaps appear due to mortality of the overstorey trees, new tree species including exotic, fast-growing multipurpose trees are introduced by growers to provide shade to the crop. This, however, is a function of the management intensity and may increase the floristic richness and diversity attributes. Introduction of new tree species may provide a plausible explanation for the increase in floristic diversity index observed at Pampadumpara. Increase in floristic diversity with a concomitant reduction in tree density can be possibly explained by the distribution of fewer number of individuals among many species (Table 1). This, however, indicates the weakness of floristic diversity indexes used alone to explain stand details.

Furthermore, about one-third of the current suite of species at Pampadumpara was similar to that of the remaining sites including the wet evergreen forest site of Ayyappancoil (Sorenson's similarity index ranging from 27.60% to 31.7%; Table 2). Kumili and Devikolam had a higher percentage of similar tree species (Sorenson's similarity index ~85%). This is not surprising as the entire cardamom hill reserves originally supported evergreen/semi-evergreen forest formations. Although site-to-site variations are apparent, many of the CHR shade trees are relics/survivors of this original community, selectively retained by the planters.

Table 2. Sorenson's similarity indexes (%) of trees (≥ 10 cm GBH) in the cardamom hill reserves (CHR) and evergreen forests of high ranges in the Western Ghats of Kerala (plot size 5000 m^2).

Site	Pampadumpara	Kumili	Devikolam	Ayyappancoil
Pampadumpara (CHR)	00.00	–	–	–
Kumili (CHR)	29.00	00.00	–	–
Devikolam (CHR)	27.60	85.10	00.00	–
Ayyappancoil (Forest)	31.70	43.80	47.80	00.00

Dominant floristic elements of CHRs

The floristic spectrum of Pampadumpara consisted of total of 40 tree species, It consisted of both evergreen and deciduous components (Tables 1 and 3). Asteraceae, Lauraceae, Moraceae and Fabaceae had the largest four family-wise importance value index (IVI). *Vernonia arborea*, a medium sized tree of the family Asteraceae registered the highest density (146 trees ha^{-1}; 28% of the individuals) and IVI (94.6: Table 3). This tree yields a pale brown, smooth, durable, straight grained and moderately hard wood suitable for wooden boxes, match boxes and house building, but splits easily and, therefore, is most commonly used as fuel wood [CSIR, 1976]. The basal area of the Pampadumpara stand was 24.84 m^2 ha^{-1}, about 46% of which was made up of *V. arborea* alone. *Artocarpus heterophyllus*, another prominent multipurpose tree, with 21% of the individuals formed the second most important shade tree at Pampadumpara. Other predominant species (having a density of more than 10 trees ha^{-1}) were: *Actinodaphne malabarica, Persea macrantha, Cinnamomum malabatrum, Cedrela toona, Prunus ceylanica, Erythrina lithosperma, Bischofia javanica, Chionanthus malabarica, Macaranga peltata* and *Mallotus albus*. As many as 20 species were, however, represented only once or twice. This included six exotics (*Grevillea robusta, Maesopsis eminii, Swietenia macrophylla, Paraserianthes falcataria, Acacia auriculiformis* and *Spathodea companulata*) and several deciduous species (e.g. *Tectona grandis,*

Table 3. Relative frequency, density, relative density, basal area, relative basal area and importance value index (IVI) of important shade trees (≥ 10 cm GBH and having density ≥ 10 trees ha^{-1}) in the cardamom plantations at Pampadumpara.

Species	Relative frequency (%)	Density (no. ha^{-1})	Relative density (%)	Basal area (m^2 ha^{-1})	Relative basal area (%)	IVI (%)
Vernonia arborea Ham.	20.99	146	27.97	11.35	45.64	94.6
Artocarpus heterophyllus Lamk.	16.02	112	21.46	2.19	8.80	46.3
Actinodaphne malabarica Balak	6.08	26	4.98	0.62	2.49	13.6
Persea macrantha (Nees) Kosterm.	6.63	26	4.98	1.06	4.27	15.9
Cinnamomum malabatrum (Burm. f) Bl.	4.42	20	3.83	0.14	0.57	8.8
Cedrela toona Roxb.	3.31	16	3.07	0.74	2.98	9.4
Erythrina lithosperma Bl. ex Miq.	3.86	14	2.68	1.01	4.05	10.6
Prunus ceylanica (Wt) Miq.	2.76	14	2.68	0.48	1.93	7.4
Bischofia javanica Bl.	2.21	12	2.30	0.06	0.25	4.8
Chionanthus malabarica (Wall ex G. Don) Bedd.	3.31	12	2.30	0.15	0.60	6.2
Macaranga peltata (Roxb.) M.-A.	1.66	10	1.92	0.24	1.00	4.6
Mallotus albus auct. non M.-A.	2.76	10	1.92	0.51	2.05	6.7
Others	–	104	–	6.29	–	–
Total		522		24.84		

Gmelina arborea, Grewia tiliifolia, Lagerstromea microcarpa, Pterocarpus marsupium etc.). A significant proportion of the shade trees at this site was, however, planted by growers, presumably to offset the ill-effects of larger canopy gaps created by mortality of overstorey trees. Further, it can also be deduced from Table 3 that the main criteria for introduction of new species into the CHRs are their potential for rapid growth and ability to produce multiple outputs such as timber, fuelwood and green manure, besides providing shade to the cardamom crop.

The cardamom hill reserves of Kumili and Devikolam sites registered an intermediate stand density of 704 (22 species) and 700 (25 species) trees ha^{-1}, respectively. Dominant floristic elements at both sites included late seral evergreen species such as *Cullenia exarillata, Palaquium ellipticum, Mesua nagassarium, Canarium strictum* and the like (Tables 4 and 5). Presumably they are survivors from the original forest community. Deciduous early seral trees such as *Trema orientalis* and *Erythrina indica* were also abundant at these sites. Bombacaceae, Sapotaceae, Ulmaceae, Fabaceae, Clusiaceae and Burseraceae formed the dominant natural orders.

The evergreen forest site at Ayyappancoil recorded a much higher tree density (1976 trees ha^{-1}; ≥ 10 cm GBH) and it contained 42 tree species (Table 6). Presence of heliophilic components (*Aporusa lindleyana, Hydnocarpus pentandra, Alstonia scholaris* and others) suggest that these forests are not

Table 4. Relative frequency, density and relative density of important shade trees (≥ 10 cm GBH and having density ≥ 10 trees ha^{-1}) in the cardamom hill reserves at Kumili.

Species	Relative frequency (%)	Density (no. ha^{-1})	Relative density (%)
Cullenia exarillata Robyns	13.4	110	15.6
Palaquium ellipticum (Dalz.) Engl.	13.4	104	14.8
Trema orientalis (L.) Bl	7.5	60	8.5
Erythrina indica Lamk.	7.8	58	8.2
Mesua nagassarium (Burm. f.) Kosterm.	7.8	56	8.0
Canarium strictum Roxb.	7.1	44	6.3
Macaranga peltata (Roxb.) M.-A.	7.1	44	6.3
Artocarpus heterophyllus Lamk.	6.3	40	5.7
Ficus hispida L.f.	4.9	34	4.4
Bischofia javanica Bl.	5.6	32	4.6
Mangifera indica L.	5.6	32	4.6
Artocarpus hirsutus Lam.	3.4	22	3.1
Cedrela toona Roxb.	3.4	18	2.6
Myristica dactyloides Gaertn.	1.1	12	1.7
Garuga pinnata Roxb.	1.9	10	1.4
Others	–	28	–
Total		704	

Table 5. Relative frequency, density and relative density of important shade trees (≥ 10 cm GBH and having density ≥ 10 trees ha^{-1}) in the cardamom hill reserves at Santhanpara, Devikolam.

Species	Relative frequency (%)	Density (no. ha^{-1})	Relative density (%)
Cullenia exarillata Robyns.	13.2	102	14.6
Palaquium ellipticum (Dalz.) Engl.	10.5	84	12.0
Mesua nagassarium (Burm. f.) Kosterm.	10.2	70	10.0
Cedrela toona Roxb.	7.9	64	9.1
Macaranga peltata (Roxb.) M.-A.	6.8	46	6.7
Trema orientalis (L.) Bl.	6.0	42	6.0
Canarium strictum Roxb.	5.6	38	5.4
Artocarpus heterophyllus Lamk.	5.3	36	5.1
Artocarpus hirsutus Lamk.	5.3	28	4.0
Mangifera indica L.	3.8	26	3.7
Ficus hispida L.f.	3.8	22	3.1
Myristica dactyloides Gaertn.	2.3	20	2.9
Bischofia javanica Bl.	3.8	20	2.9
Erythrina indica Lamk.	2.6	18	2.6
Syzigium cumini (L.) Skeels	2.3	16	2.3
Acrocarpus fraxinifolius Wt. & Arn.	2.3	12	1.7
Calophyllum polyanthum Wall ex Choisy	1.5	12	1.7
Carallia brachiata (Lour) Merr.	1.9	10	1.4
Others		34	
Total		700	

altogether free from anthropogenic disturbances, and that, in turn, may help the regeneration and survival of such components.

The data presented in Tables 3–5 clearly highlight the dominance of a few tree species in the cardamom hill reserves. At Pampadumpara, only five out of the total 40 species had importance value indexes (IVI) greater than 10. Implicit in the high IVI of a fewer number of species is clearly the high relative density, basal area and frequency [Curtis and McIntosh, 1950] of these species and their eventual dominance in the community. The dominant species at this site are, by and large, shade intolerants. Prominent among them are: *V. arborea, A. heterophyllus, P. macrantha, C. malabatrum, Trema orientalis* and *Macaranga peltata.* Presumably the seedlings and saplings of sciophytic tree species cannot survive in the drastically modified environment of an intensely managed CHR. Nonetheless, the two remaining CHRs were generally characterized by dominance of shade-tolerant species of the late successional category. This is particularly true at Devikolam, having a relatively low to medium management intensity. The undisturbed evergreen forest, however, consisted of a blend of early, mid and late seral stages.

From the successional point of view, the creation of large gaps may stimulate shifts in the regeneration pattern of trees resulting in the abundance

Table 6. Relative frequency, density and relative density of important trees (≥ 10 cm GBH and having density ≥ 10 trees ha^{-1}) in the natural evergreen forests at Ayyappancoil.

Species	Relative frequency (%)	Density (no. ha^{-1})	Relative density (%)
Aporusa lindleyana (Wt.) Baill.	5.5	198	10.0
Hydnocarpus pentandra (Bunch Ham) Oken	5.2	140	7.0
Alstonia scholaris (L.) R.Br.	5.2	114	5.8
Litsea stocksii Hk.f.	4.4	108	5.5
Clerodendron viscosum Vent.	3.4	106	5.4
Antidesma bunis (L.) Spreng.	3.4	94	4.8
Vernonia arborea Ham.	3.9	92	4.7
Cullenia exarillata Robyns	4.4	84	4.3
Mesua nagassarium (Burm. f.) Kosterm.	3.9	84	4.3
Holigarna arnottiana Hk.f.	3.4	72	3.6
Careya arborea Roxb.	1.8	56	2.8
Buchanania axillaris (Desr.) Ramam.	3.9	54	2.7
Artocarpus hirsutus Lam.	2.9	52	2.6
Palaquium ellipticum (Dalz.) Engl.	3.1	52	2.6
Wrightia tinctoria (Roxb). R.Br.	1.8	52	2.6
Vitex altissima L.	2.3	48	2.4
Canarium strictum Roxb.	3.1	44	2.2
Carallia brachiata (Lour.) Merr.	2.6	44	2.0
Cedrela toona Roxb.	1.8	40	2.0
Anthocephalus chinensis (Lamk.) Rich. ex Walp.	3.1	38	1.9
Myristica dactyloides Gaertn.	2.1	38	1.9
Hopea parviflora Bedd.	3.1	32	1.6
Cinnamomum malabatrum (Burn. f) Bl.	1.3	30	1.5
Persea macrantha (Nees.) Kosterm.	2.3	30	1.5
Vateria indica L.	2.6	28	1.4
Ficus callosa Willd.	2.6	24	1.2
Mastixia arborea (W.) Bedd.	1.6	24	1.2
Calophyllum polyanthum Wall ex. Choisy	1.6	22	1.1
Eleocarpus serratus L.	1.8	22	1.1
Garcinia gummi-gutta (L.) Robs.	1.3	20	1.1
Ficus hispida L.	1.0	20	1.0
Mangifera indica L.	1.3	18	0.9
Michelia champaca L.	1.8	18	0.9
Bischofia javanica Bl.	1.8	18	0.9
Syzigium cumini (L.) Skeels	0.8	14	0.7
Garcinia travancorica Bedd.	1.0	12	0.6
Spondias indica (Wt. & Arn.) Airy Shew & Forman	1.0	12	0.6
Artocarpus heterophyllus Lamk.	1.0	10	0.5
Others	–	16	–
Total		1976	

of heliophilic and shade-intolerant species. Predominance of such species at Pampadumpara supports this contention (Table 3). According to Pascal [1988] the early colonizers (e.g. *Vernonia arborea* and others) are characterized by rapid growth rate; they produce tender wood and are normally absent in the homoeostatic phases except for a few adult individuals scattered in the formation. Their seeds are probably present on the forest floor even before the opening, but they normally do not grow under a dense forest cover. Their germination is initiated by the microclimatic modifications caused by canopy openings. Early colonizers also reinvade the site through the stochastic processes such as 'seed rain' [Whitmore, 1983] and they decide further shifts in dominance.

In addition, species associated with higher importance values in the CHRs exhibit diverse characteristics, some typical of early seral species, others more typical of mid-late successional species (Tables 3–5). George et al. [1993] observed that species attributes such as shade tolerance, mechanism of dispersal and seed size and vegetative propagation strategies of the native species play an important role in deciding the dominant species groups of secondary forests. Recruitment of additional species may, however, be constrained by continued manipulation/disturbance for cardamom cultivation and, therefore, the sequential recruitment or replacement of species which one might expect in a normal secondary successional situation might not operate in a typical cardamom hill reserve.

Vegetation structure

The tree cover in most of the cardamom areas comprised mostly a monolayer of intermediate (crown class) trees. As much as 52% of all trees at the Pampadumpara site fell in this category, while the dominant and codominant classes accounted for only 19% each and the suppressed individuals were below 10%. Data presented in Fig. 1a–c also corroborate the predominance of a few size classes. It shows that the 10–20 m height classes is predominant in the CHRs, while other height classes were ill-represented.

The height frequency distribution of the evergreen forests (Fig. 1d), however, followed a typical inverse 'J' shaped distribution pattern, characteristic of the uneven aged stand structure. All the three CHRs were, however, characterized by a skewed (+) distribution pattern, similar to that of the homegardens of this tract [Kumar et al., 1994]. Implicit in the lower frequency of the < 10 m size class is perhaps regeneration problems and/or systematic removal of trees and shrubs during the process of cardamom cultivation. Stand structure of CHRs is altered by the removal of lower strata trees and regenerants, resulting in this truncated size-class distribution. Weeding and/or other cultural practices for cardamom also result in the lack of recruitment and preclude understorey establishment. In addition, owing to the 'domino effect' gaps created by the death of the top canopy, trees seldom get covered in the

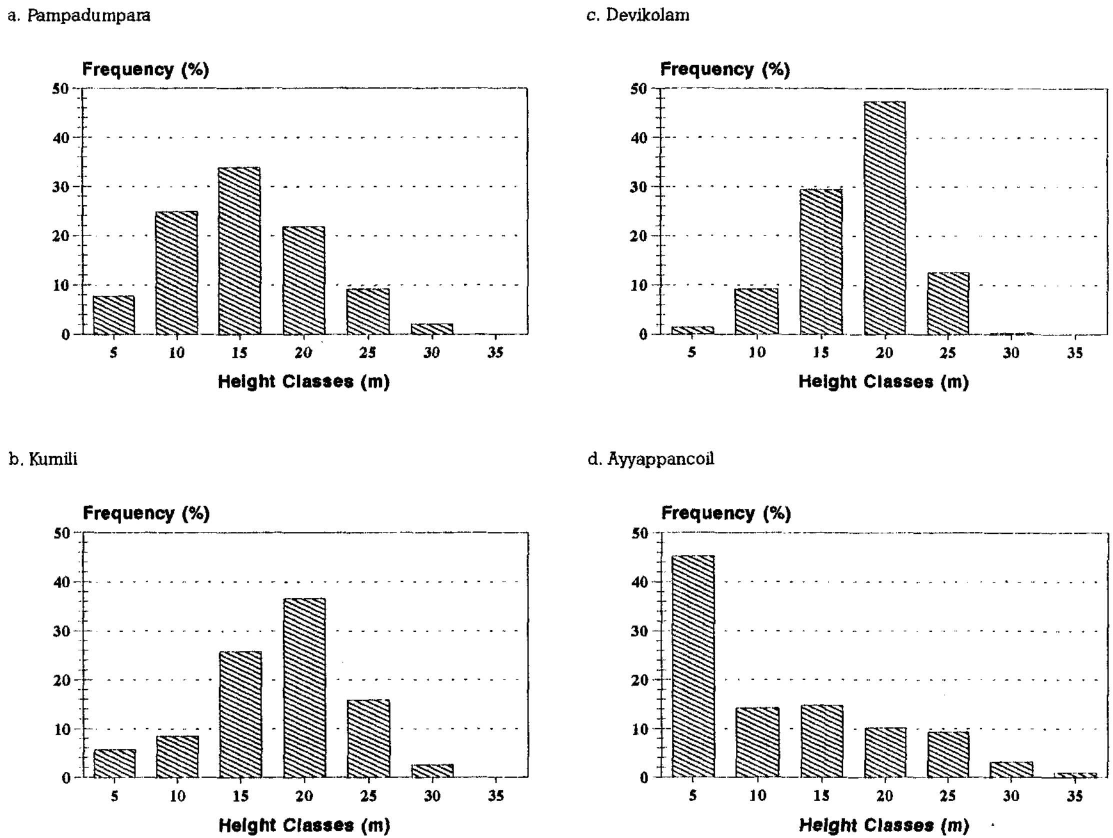

Fig. 1. Height frequency distribution of trees in three cardamom hill reserves (a–c) and an undisturbed evergreen forest stand (b) in the high ranges of Kerala.

absence of a lower stratum. The cumulative effect would be sub-optimal shade levels and a possible drop in cardamom productivity.

Shade trees for cardamom plantations

Being a shade-loving plant, cardamom is traditionally grown as an understorey crop in tropical forest formations. The optimal levels of shade for the crop is estimated to be about 40–60% of the total light intensity in the open. Shade acts as a moisture and temperature regulator and creates the microclimatic conditions favourable to growth and development of cardamom [Abraham et al., 1979; FAO, 1984]. Prominent shade trees in the cardamom plantations of the study areas include: *Vernonia arborea, Artocarpus heterophyllus, Persea macrantha, Actinodaphne malabarica, Cullenia exarillata, Palaquium ellipticum, Mesua nagassarium* and the like. However, it shows considerable variations from site to site depending on the management intensity, length of the cardamom cropping cycle and past stand composition (prior to selective clearing).

Obviously in well-managed plantations more tree species including fast growing exotics are introduced by growers. Species attributes such as tree growth rates, ease of propagation and propagule availability, besides local preferences based on potential uses, hold the key in the choice of species. Ideally shade trees must posses light, compact crowns which allow uniform quantities of filtered light to the understorey. However, since no attempt was made in the present study to quantify the crown and growth characteristics of various shade tree species, it is difficult to generalize on this aspect. Nevertheless, as per the empirical evidences available (author's observations), cardamom plantations, in future, may have more of such planted shade trees than survivors from natural forests. In addition, the traditional system of cardamom cultivation by clearing the middle and lower strata trees in the evergreen/semi-evergreen forests is considered unsustainable owing to its adverse ecological implications.

As regards to the length of cropping cycle, based on empirical observations, we hypothesize a higher density of heliophilic and shade-intolerant tree components in the older CHRs. With age, the 'memory effect' of past stand composition may wear off. Consequently in younger CHRs one can expect greater number of shade-tolerant survivors of the original vegetation.

Conclusions

A deliberate effort by the planters to reduce tree density and/or change species composition is apparent in the cardamom areas. The CHRs are characterized by lower tree density, floristic diversity and a truncated canopy architecture with a unilayer of trees. This is in sharp contrast to the multi-tiered canopy structure of the evergreen forests depicting an inverse 'J' shaped height distribution pattern. The absence of lower size classes in the CHRs clearly suggests regeneration difficulties and the opening up of the canopy when the overstorey trees die. The current suite of species in the CHRs include both evergreen as well as heliophilic and shade-intolerant species. Management intensity forms an important determinant of the CHR floristic spectrum and may take into consideration multiple uses, length of cropping cycle and past stand composition.

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