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Ecology and Conservation of

Selected Tree Endemics of Kerala

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Summary

Ecology and conservation of five native endemic trees of southern Western Ghats were studied, viz., *Vateria macrocarpa*, *Dipterocarpus bourdillonii*, *Dysoxylum malabaricum*, *Anacolosa densiflora*, and *Gluta travancorica*. Extensive field exploration of the species, stratification of distribution area, phyto-sociological and demographic studies were conducted. Geospatial analysis and density data were utilized for estimating population size. Reproductive phenological studies, germination ecology, and some transplantation experiments were also conducted of the species.

Vateria macrocarpa: In Kerala, the species is found to range between 550 and 1,300 m altitude and the area of occurrence is around 40 km^2. In addition to the natural forests, the species is also found inhabiting coffee and cardamom plantations of the Siruvani Group of plantations. Below 800 m it is largely restricted to streamlets. In the altitudinal regime 900-1300 m, the species has high density (318 trs >= 3 cm dbh/ha), where all the life stages are also well represented; this area (293 ha) is suitable for preservation as a conservation area for the species. The estimate of the tree (>= 30 cm gbh) population is $\pm$ 41,152. Flowering of the species extends during January-April with the peak season of mature fruit availability during February-March. Not all the trees do flower every year and nor all of them bear fruits. A weevil (*Alcidodes* sp.) causes heavy submature fruit fall. Three different fruit-types are observed for the species: (a) Narrow elongate with medium sized beak, (b) obpyriform-ampulliform fruits with long beak, and (c) obpyriform with medium sized beak. We obtained 51.5% germination. Some position of the fruits on the nursery bed results in coiled seedlings. One hundred seedlings of *V. macrocarpa* were planted on the banks of a streamlet south of the Palghat Gap at Upper Moozhiyar so as to evaluate survival. Sixty percent of the seedlings survived 45 days and 44% survived 6 months.

Dipterocarpus bourdillonii is known from Kerala and Karnataka. Malayattur, Attappady, Achenkovil, Moozhiyar, Azhutha and Pamba areas were explored for the species. The population in Kerala is only $\pm$ 200 trees and the total population < 500. In all the places where *D. bourdillonii* is found, the population size was < 30 tr and smaller populations comprising $\pm$ 5 individuals are more frequent. Presumably, the species also suffered from selective logging; the low population size makes the species 'Critically Endangered'. The tree flowers during the second week of January to the end of March. Mature fruits are available by May. By the time the fruits mature, the embryos die and therefore the fruits/seeds fail to germinate. No insect or fungus was found associated with and the causes of seed sterility remain illegible. Apparently seed sterility is inherent in the species, which requires further investigation. Seedlings and pole crops are extremely rare in the wild; seed sterility has contributed to the skewed population structure.

Gluta travancorica inhabits southern W Ghats south of Aryankavu pass in Kerala and Tamilnadu. The area of occurrence in Kerala is *ca.* 178 km^2 and the average density, 30 tr/ha. An estimate of population size, using conservative values for density and area of occurrence, is > 44,500 trees and the species can be considered 'Low Risk, Near Threatened (Lr/Nt). Two-hundred seedlings of the species were transplanted at Upper Moozhiyar and Nilakkal forests (Ranni FD) for evaluating their survival and performance. Because of the failure of NE

monsoon in the planting year, only 20% survival was obtained after 6 months. As in *V. macrocarpa*, coiled seedlings are observed in *G. travancorica* also.

Dysoxylum malabaricum: In Kerala the species is distributed almost in all districts and is preponderant in two locations, Sholayar (Vazhachal FD) and Mooziyar (Ranni FD). Field investigations show that it is very sparse in evergreen forests, but occurs as dense patches in ecotonal semi-evergreen forests. Assuming conservative values for density, the population in Kerala is *ca.* 27,226 trees. Assuming another 20,000 trees together for the W. Ghats of Tamilnadu and Karnataka, the total population would be at least 47,226 trees. The species is extremely rare except the known high density areas of Moozhiyar and Sholayar. The high-density area is only 17 km^2 and therefore, the species may be considered 'Endangered'. A patch of semi-evergreen forest has been identified at Moozhiyar (Pullumed, Ranni FD) where the species grows gregarious and may be preserved as a conservation area for the species. Together with two more species of the same genus, this forest patch is a gene reserve for the genus in Kerala. The tree flowers during January-February and mature fruits are available during June-July. Seeds of *D. malabaricum* have a fleshy seed coat that degenerates quickly and the naked embryos have short viability of about one week. Because of the oil content of the seed, it is highly infested by insects and fungi. Pre-treatment of seeds with bavistin can imporve germination from 50 to 70%. The survival of the seedlings in the nursery bed itself is very low, owing to heavy fungal infection. Two-hundred seedlings of *D. malabaricum* were transplanted in canopy gaps at Nilakkal and Upper Moozhiyar (Ranni FD). Although all the seedlings survived one month, only 20% survived after 6 months, due the failure of NE monsoon.

Anacolosa densiflora, is an extremely rare tree recorded from Anamalai and Travancore. Altogether 15 trees (>= 30 cm dbh) were located in the Periyar Tiger Reserve. The trees are generally found along streamlets slightly away from the watercourse between 800-900 m. The species is capable of colonizing logged over eucalypt plantations; at Pothumkandam (Periyar Tiger Reserve) a large number of seedlings and saplings have colonized the abandoned eucalypt plantations. Geospatial analysis estimates the extent of occurrence at 74 km^2; however, the area of occupancy will be very low, as the species is distributed sporadically. A high estimate of the mature tree population would not exceed 200 trees. The species may be assigned a 'Critically Endangered' status. The trees flower in January and fruits mature in June. The fruits sown in nursery beds failed to germinate; further reproductive biological studies of the species are desirable.

General conclusions: Selective logging has been one of the major causes for reduction of population size in 3/5 species. Intrinsic reproductive barriers are critical in the case of *D. bourdillonii*. All, 5/5, species have heavy fruits leading to mother-centered diaspore distribution and this also contributes to narrow distribution. Across the five RET species, there is much in common. Analysis of the generalities across a large number of species would be required to identify different species groups and frame general strategies for their conservation. Despite the large number of red-listed taxa reported from Kerala, the State does not have a general policy or a consolidated programme for their conservation. As the existing information on RET species is seldom assimilated, repetition of research efforts abound and at the same time many taxa remain unattended and information-deficient. The use-value of existing information for applied conservation efforts is low. Another major impediment for RETP (RET Plants) research stemming from their restricted occurrence in remote inaccessible

wilderness habitats hinder continuous observations. Introducing RET species to near-natural environments in larger live plant conservatories may be considered for facilitating RET research.

1. General Introduction

Background

Many floral and faunal elements are of limited distribution and the population size of many of them is also very small. For the 38,863 km^2 geographic area of Kerala State, nearly 4,465 native flowering plants have been recorded (Sasidharan, 2003). Out of this 1,272 endemic to W. Ghats are found in Kerala (Nayar, 1997) and 497 belong to various threat categories (Sasidharan, 2003). Many species are in the verge of extinction. The red-listed species, also referred to as 'threat categories' often are indicated in many literature sources as RET (Rare, Endangered and Threatened; Kallarackal *et al.*, 2003) species. As the current context pertains to botanical side of biodiversity, the acronym RETP would suffice to indicate RET Plants and is conveniently used in this report.

Apart from the priceless environmental role played by individual species, the real use value of many species is not known that their disappearance can be a loss for the humanity altogether, including the future generations. One half of the conservation philosophy works on this principle. The other half of the philosophy works on the fact that humans can retard and prevent species extinctions through proper interventions, which form the core of conservation programmes.

There are two approaches to biodiversity conservation: (i) Collective approach commonly known as 'ecosystem conservation', and (ii) Conservation targeted on individual species, otherwise termed as 'species conservation' (Soule, 1986). The difference between the two is that in the former, conservation efforts need not definitely embrace: (a) All the species, and (b) Species which badly require conservation attention. This gives the 'species conservation strategy' an edge over ecosystem conservation.

Species conservation programmes do not simply comprise of action programmes for securing sufficient populations of the candidate species. Before the species conservation programmes are implemented, there is always the need for a research component that involves analysis of the various aspects of the candidate species such as population size, reproductive (in)efficiency, existing threats, causal factors, amenability to propagation, possibilities of *in-situ* conservation and species re-introductions, potential ex-situ conservation measures, etc. In other words, species conservation initiatives need precursor outfits answering: (a) Why the species is found only in small numbers? (b) Why the species is found restricted to small areas? (c) In what life stage(s) the threat(s) contribute to mortality? (d) What remedies are feasible to rescue their population?,

and so on. Conservation biological research precisely deals with these issues (Soule, 1986). Of course, how viable populations of the species can be built up is a follow up *posteriori* to this.

Apparently recognizing the importance of species oriented conservation efforts, the Kerala Forest Department (KFD) organized a symposium on *Rare, Endangered and Endemic plants of the Western Ghats* at Trivandrum in August 1991 (Karunakaran, 1991). This served to bring together much information on RET plants of the W. Ghats and also provided a momentum to RETP research in the Kerala State. This project was a logical follow up from the above development. Tree species because of their large form, utilitarian value and familiarity would fetch interest to foresters and funding agencies alike. Up on this redemption, a research proposal was submitted to the Ministry of Environment and Forests (MOEF), Government of India, to undertake conservation biological research on five RET trees of Kerala, which was supported by the Ministry subsequently. The candidate species are: *Vateria macrocarpa* BL Gupta (Fam.: Dipterocarpaceae), *Dipterocarpus bourdillonii* Brandis (Fam.: Dipterocarpaceae), *Dysoxylum malabaricum* Bedd. *ex* Heirn. (Fam.: Meliaceae), *Anacolosa densiflora* (Wt.) Gamble (Fam.: Olacaceae), and *Gluta travancorica* Bedd. (Fam.: Anacardiaceae).

Scope of the study

From existing information sources, all the five tree species were found to be endemic to W. Ghats, restricted to Kerala, restricted to Kerala and Tamilandu, or, restricted to Kerala and Karnataka. Located right within the W. Ghats, Kerala Forest Research Institute (KFRI) was a convenient institutional set up where the study was accomplished. Four of the species were relevant to silviculture and forestry (*V. macrocarpa*, *D. bourdillonii*, *D. malabaricum* and *G. travancorica*), and the last (*A. densiflora*) though not of any utilitarian significance, was a little known tree. Some had very small population size, while a few others had reproductive barriers. Thus the study aimed at generating reliable information useful for the conservation of each of the species. The various aspects of the study embraced field survey of the species and rough estimation of the probable total population, phenological studies, seed biological aspects, propagation trials and limited re-introduction experiments.

Methodology

As the study pertained to five different species, individual species have been treated in separate chapters. Although the methodologies were largely the same, fuller detail of the methods are given for *V. macrocarpa* and limited details given for other species, with thrust on the deviations made.

2. *Vateria macrocarpa* Gupta
(Fam. Dipterocarpaceae)

Introduction

Vateria Linn. (Dipterocarpaceae) is a small genus comprising three species of very restricted distribution. Of these, one species, *V. copallifera* (Retz.) Alston is endemic to Sri Lanka, and the other two, *viz.*, *V. indica* Linn. and *V. macrocarpa* B.L. Gupta., in India. Western Ghats is the natural home of the Indian species. *V. indica* is distributed all along the Western Ghats from North Kanara southwards to Tinnelveli. *V. macrocarpa* is of very restricted distribution, limited to Muthikulam area (Palakkad Dt.) in Kerala and the adjacent areas of the Bolampatty Reserve Forest in Tamilnadu, both falling in the Nilgiri Biosphere Reserve. The area of occurrence of *V. macrocarpa* falls wholly within the area of occurrence of *V. indica* (Fig. 1; FAO, 1985).

Vateria macrocarpa is closely related to *V. indica* and resembles very much the latter. In vegetative state, it is rather difficult to distinguish the two. However, in the generative state *V. macrocarpa* can easily be distinguished from *V. indica*, in the larger flowers, smaller triangular sepals and much larger (9-14 x 5-7 cm) acuminate or beaked fruits (Gupta, 1929).

V. macrocarpa is a large tree of 25-30 m height reaching a diameter of over 100 cm, sometimes reaching 150 cm and even more. The timber is useful for making class I plywood, packing cases, boxes, tea chests and (Nazma *et al.*, 1981). During Second World War the species was used for railway sleepers (Muhammad, 1967). The wood is durable, moderately heavy with a specific gravity of 0.83–0.68 (air dry) and refractory to treatment (Nazma *et al.*, 1981). The species also yields white dammar, used as incense, being the gum oozing out of the tree when wounded. The species is a promising candidate for plantation trials.

The utilization potential and the restricted distribution call for studies on the species. Thus, the objectives of the study were to make an assessment of the population status of *V. macrocarpa*, to identify the intrinsic and extrinsic factors that limit and threat the population and to explore for potential conservation measures for the species.

Though the species was described in 1929, no detailed study has been conducted of it, despite the many potential uses. Botanical differences between *V. indica* and *V. macrocarpa* presumably did not permeate forestry literature and for all practical purposes, the details of the

species were documented under *V. indica*, as both the species held the same trade name.

Materials and Methods

Extensive field explorations were conducted in order to get higher resolution on the distribution of the species in Kerala. Stratification of the distribution area and sampling the strata were done for estimation of population. Phyto-sociological and demographic details were studied in a number of 0.1 ha sample plots in each of the strata. Reproductive phonological studies, seed biology and some transplantation experiments of the species were conducted.

Mapping of the distributional area

From the information available from *Working Plans,* a 1:50,000 distribution map of the species was prepared. Distributional details of specimens accumulated in the Madras Herbarium (MH) have been incorporated into the map. Based on the map, a number of field visits were conducted cutting the distributional area in different directions so as to demarcate the boundaries of distribution of the species in Kerala.

Phytosociology

Different localities in the distributional area in the Kerala part were field visited. Two different ecosystems were found to support *V. macrocarpa*, *viz.,* natural forests and man-modified sylvan ecosystems basically of coffee and cardamom plantations. Based on the field visits, the distributional areas were stratified into a number of strata (eco-units), primarily on the observed differences in the population of *V. macrocarpa*. In each of the strata, a number of 0.1 ha [50 m x 20 m] sample plots were selected and all plants $\geq$10 cm GBH were enumerated, identified, and GBH (at 137 cm) recorded. The locations and samples utilized for studying the structure and composition of the communities in the natural forest ecosystem and the plantation ecosystem are given in Table 1.

The data from these samples were processed for over all dominance and individual parameters of dominance such as density, frequency and basal area (Mueller-Dombois, 1974).

Population studies

A number of 0.1 ha plots were enumerated for sampling the population in different density strata (eco-units) mentioned above. In addition, the data on the species recorded in 0.1 ha plots enumerated for phytosociological studies were also filtered out for individuals of *V.*

macrocarpa and used for analysis of population structure of the species. The locations and samples used for the study are given in Table 2. The data were transformed into life-tables following conventional demographic practices. Mean densities of mature trees (> = 30 cm GBH, ~ 10 cm DBH) were computed from these tables for each of the eco-units.

A GIS of the distribution of *V. macrocarpa* was organized using MAPINFO software Vers. 6.0, relevant topo sheets, and compartment maps of the area obtained from the Kerala Forest Department. The areas of different eco-units (strata) identified on field visit were copied on to the GIS and the extent of each strata computed.

Table 1. Samples studied for phytosociology of *V. macrocarpa.*

Density stratum	*Locations*	*Sample nos.*	*Altitude*	*Total samples*
Natural forest: Low Density Stratum				3
	Koodam	Koo 3-2	675 m	
		Koo 4-3	700 m	
	Poolappara	PPara 14-8	700 m	
Natural forest: Medium Density Stratum				4
	Koodam	Koo 12-1	600 m	
	Above Siruvani Est.	SI 11-13	800 m	
		SI 11-14	850 m	
		SI 11-15	800 m	
Natural forest: High Density Stratum				4
	Muthukanichola	MChola 19-4	900 m	
		MChola 19-5	1,050 m	
	Aduthukkippara	APara 20-6	1,000 m	
	Keralamed	KMed 20-7	1,250 m	
Coffee Estate	Kizhakkambalam	KM 1-cof	900 m	6
		KM 2-cof	900 m	
	Kuruvambady	KY 5-cof	900 m	
		KY 6-cof	900 m	
		KY 7-cof	900 m	
		KY 8-cof	900 m	
Cardamom Est.	Kizhakkambalam	KM 3-cd	900 m	6
		KM 4-cd	900 m	
	Siruvani	SI 9-cd	800 m	
		SI 10-cd	900 m	
		SI 11-cd	900 m	
		SI 12-cd	900 m	

* Size of each sample: 0.1 ha.

Table 2. Samples studied for populations of *V. macrocarpa.*

Density stratum	*Locations*	*Sample no.*	*Altitude*	*Total samples*
Natural forest: Low Density Stratum				6
	Koodam	Koo 4-2	750 m	
		Koo 4-3	700 m	
		Koo 9-5	600 m	
		Koo 9-6	600 m	
	Poolappara	PPara 14-16	700 m	
		PPara 14-17	650 m	
Natural forest: Medium Density Stratum				
	Aduthukkippara	APara 12-23	600 m	9
		Koo 12-1	600 m	
		Koo 12-2	650 m	
	Poolappara	PPara 13-19	650 m	
	Above Siruvani Est.	SI 11-8	800 m	
		SI 11-21	800 m	
		SI 11-22	850 m	
		SI 11-23	800 m	
		SI 11-24	850 m	
Natural forest: High Density Stratum				
	Aduthukkippara	APara 20-21	850 m	11
		APara 20-22	850 m	
	Keralamed	KMed 19-20	900 m	
		KMed 20-11	1,050 m	
		KMed 20-12	1,000 m	
		KMed 20-13	1,200 m	
		KMed 20-14	1,200 m	
		KMed 20-15	1,250 m	
	Muthukanichola	MChola 19-1	1,050 m	
		MChola 19-7	1,050 m	
		MChola 19-11	1,000 m	
Coffee Estate	Kizhakkambalam	KM 1-cof	900 m	7
		KM 2-cof	900 m	
		KM 3-cof	900 m	
	Kuruvambady	KY 9-cof	900 m	
		KY 10-cof	900 m	
		KY 11-cof	900 m	
		KY 12-cof	900 m	
Cardamom Estate	Kizhakkambalam	KM 4-cd	900 m	12
		KM 5-cd	900 m	
		KM 6-cd	900 m	
		KM 7-cd	900 m	
	Siruvani	SI 13-cd	800 m	
		SI 14-cd	900 m	
		SI 15-cd	900 m	
		SI 16-cd	900 m	
		SI 17-cd	900 m	
		SI 18-cd	900 m	
		SI 19-cd	900 m	
		SI 20-cd	900 m	

* Size of each sample: 0.1 ha.

In computing the proximate population size of the species in each of the eco-units, the observed population densities obtained from sampling were transformed to posited lower values and population size computed as the product of extent of land and density. Ecounits (strata) with low densities generally have the species along the river courses restricted to ca. 50 m on either side. The total length of major river/rivulet courses traversing the area was calculated using the GIS environment and the area occupied by the species computed from that.

Observed densities have not been used for computations of the population. Instead, weighted population densities, have been utilized. Trees >= 30 cm dbh alone have been used for computations, this being taken as a provisional criterion for a mature tree.

Phenology

Thirty trees of *V. macrocarpa* were marked for periodic phenological observations in the Muthikulam area (Koodam) on either side of the coupe road (for easy observation). The trees were numbered, GBH measured and documented. Phenological events such as occurrence of resting-bud, flushing, mature leaf, flower bud, mature flower, flower fall, young fruit, maturate fruit, etc, were observed with the help of a binocular, and recorded in data sheets. The phenological observations were continued for a twelve month period from January 2003 roughly at fortnightly interval, so as to characterize the temporal span of each phenophase. Relevant tables and graphs depicting the pheno-behaviours were generated. The flowering and fruiting behaviour of the species across the population of 30 trees were also analyzed.

Seed biology

By rule, the fruits of the species contain but only one seed and hence the diaspore (unit of dispersal) is the fruit itself. The fruits were studied for their characteristics such as size, weigh, etc; morphometric details were used to differentiate kinds of fruits seen in the species. Fruits collected during November, January, February, March and April from Muthikulam area (Kerala) were subjected to various germination experiments in nursery beds, in the vicinity of the Muthikulam Forest Station near to the natural populations of the species. Experiments were conducted to find out: (i) the period of availability of mature fruits, (ii) the longevity of the fruits, (iii) germination percentage, (iv) the temporal spread of the germination across the population, (v) germination behaviour across different seed traits, (vi) preferred soil medium for germination, etc.

Seed longevity studies

Mature fruits of *V. macrocarpa* were collected from Koodam (Muthikulam, Mannarkkad FD) on 24 Feb. 2003 and germination trials conducted in the vicinity of Singampara Forest Station. Repeated germination trials were conducted at an espacement of 5-7 days, so as to understand the longevity of the diaspores.

Germination response across different seed traits

A germination experiment was conducted to see whether the different fruit types display differing germination responses.

Maintenance of seedlings: Seedlings derived from germination trials during November and December 2003, and February, March and April 2004 were maintained in the nursery under shade. Part of the seedling lot was in nursery beds and part in polybags. The seedlings were sprayed with a 3 % solution of NPK as fertilizer during June 2003, in the rainy season to maintain the vigour.

Assessment of initial seedling growth

Twenty-five seedlings derived from Dec. 2002 sowings were selected for growth monitoring; top height, collar diameter and number of leaves were counted at periodic intervals until 23 April 2003 and recorded.

Transplantation experiment

In November 2003, four lots, each containing 25 seedlings of *V. macrocarpa* were field planted in Upper Moozhiyar (near Kakki Reservoir, Pathanamthitta Dt.), on the banks of narrow perennial streamlet in the forest environment. The seedlings at the time of planting belonged to 40-50 cm height class. The survival of the seedlings was monitored subsequently on 25 Dec. 2003 (after 42 days) and 28 May 2004 (after five and a half months).

Results and discussion

V. macrocarpa B.L. Gupta *in* Indian Forester 55: 231. 1920. (Family: Dipterocarpaceae) - Type: *FRI herbarium 43696*! (DD): "Bolampatty Range, Palghat Division", Coimbatore Dt., Tamilnadu, India. – **Figs. 1 & 2.**

It is highly probable that prior to the description of *V. macrocarpa* (in 1920) the species was documented under the name *V. indica.*

Trade name: Vella pine. *Local name:* Vellapine (Malayalam).

Figure 1. *Vateria macrocarpa*. Fig. 1A. The natural vegetation which the species inhabits. Fig. 1B. A tree. Figs. 1C & D. Two sections of the bole showing the size of the tree.

Trees: large, –25 m tall. *Bole*: –120 cm in diam., straight, cylindrical, often with plank *buttress at the base. Bark: dark grey, mottled with white and green, smoothish. Leaves*: alternate, simple, stipules deciduous; petioles 2.5-6 cm long, swollen at the tip, pubescent, black, blade 15-25(-37) x 6-12(-17) cm, oblong or oblong-lanceolate, glabrous, coriaceous; lateral nerves 15-17(-20) pairs, prominent beneath. *Inflorescence*: a panicle, axillary (or terminal), shorter than the leaves, hoary stellate–pubescent. *Flowers*: hypogynous, bisexual, white, ±3.3 cm across. *Calyx*: sepals 5, 3 mm long, imbricate,

triangular, pubescent without, silky within, persistent. *Corolla*: petals 5, 1.5 cm long, elliptic, minutely apiculate, coriaceous, glabrous. *Stamens*: numerous, filaments short, anthers linear, connective produced into a subulate point. *Pistil*: ovary superior, densely tomentose, style subulate, stigma minute. *Fruit*: a capsule, 9-14 x 5-7 cm, cylindric-lanceolate, apex slightly curved, opening by valves; fruiting sepals woody, deflexed: *Seed*: 1, completely filling the seed cavity, seed coat thin, obsolete. *Embryo*: 1, completely filling the seed cavity, radicle superior, peripheral, apparently axial, included between the lobes of the cotyledon, cylindric; plumule rudimentary; cotyledons 2, opposite, thick, isomorphic (difference from *V. indica*), closely appressed, stipitate, faintly ruminate on the inner surface, smooth on the other.

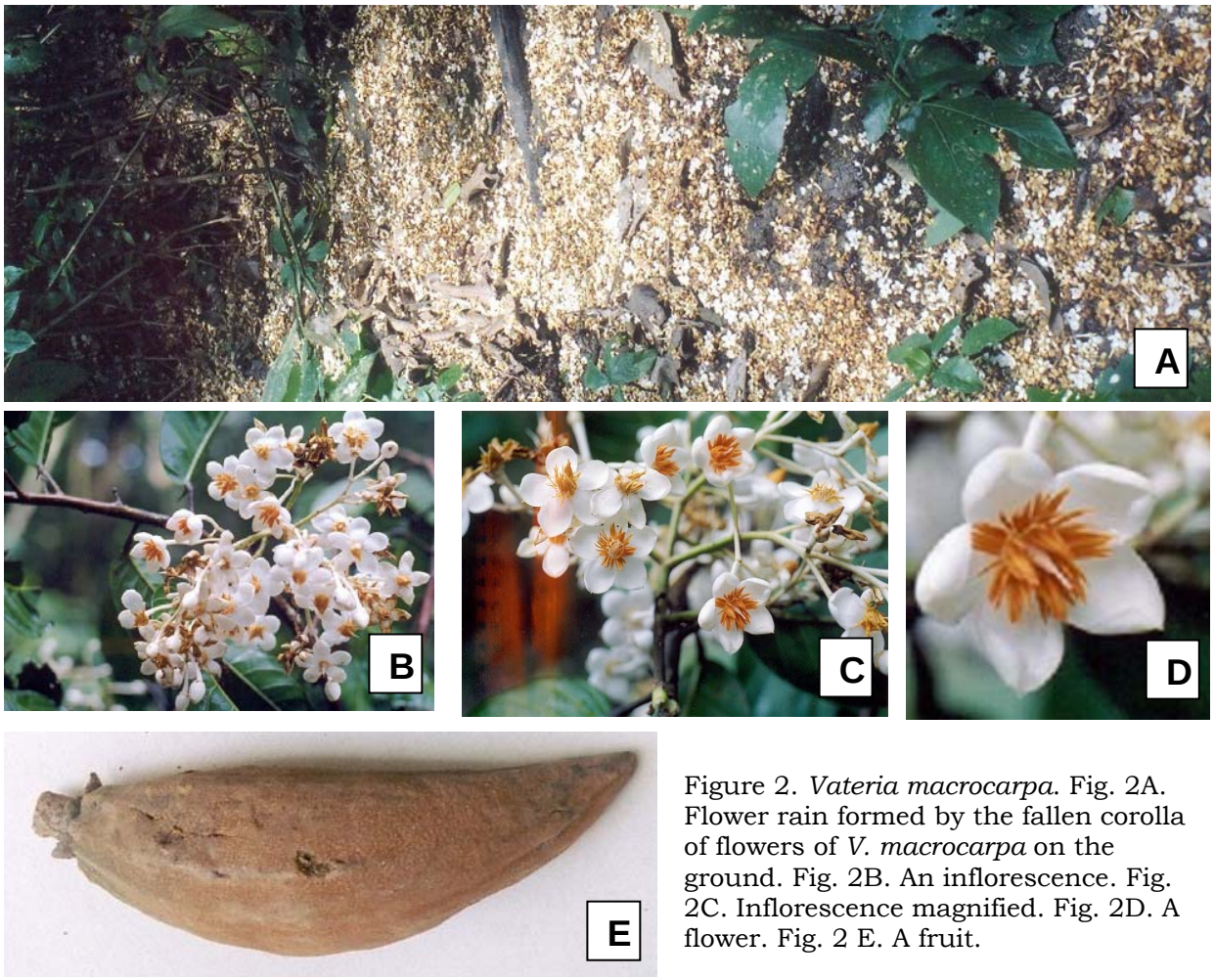


Figure 2. *Vateria macrocarpa*. Fig. 2A. Flower rain formed by the fallen corolla of flowers of *V. macrocarpa* on the ground. Fig. 2B. An inflorescence. Fig. 2C. Inflorescence magnified. Fig. 2D. A flower. Fig. 2 E. A fruit.

Endemic tree restricted to Muthikulam Reserved Forest in Kerala (Gupta, 1929; Muhammad, 1967) and Northern half of the Bolampatty Reserved Forest in Tamilnadu. The species ascends from about 550 to 1,300 m above mean sea level.

Specimens examined: **K E R A L A**: **Palakkad Dt**.: Mannarghat Forest Divis.: Anaikatty Range: Muthikulam, Siruvani, 5-5-1987, *R. Makali 86032* (M H); 25-3-1976, *K.N. Subramanyan 5855* (FRS, MH). *K. Swarupanandan 3682* (KFRI): Muthikulam, 1,300 m. fr., 13-12-1985 (2 sheets). **T A M I L N A D U**: **Coimbatore Dt**.: Bolampatty Range, *FRI 43696* (DD).

Relationships: The species perhaps is related to *V. copallifera* (Retz.) Alston.

Population ecological studies

Distribution of V. macrocarpa:

V. macrocarpa is highly restricted in distribution. In Kerala, it is restricted to the Attappady Reserved Forest Block VI of Palghat Division (Fig. 3) and in Tamilnadu, the northern portion of the Bolampatty Reserved Forest Block II (Basha, 1977; Iyyer, 1935). Henry *et al*. (1979), while enlisting the rare plants of the peninsular India assigned an endangered status to the species.

The Attappady Reserved Forest Block VI extends over an area of *ca*. 37 km^2 falling between the longitudes 76^0 36' and 76^0 42' E and latitudes 10^0 55' and 11^02' N in the Western Ghats. The terrain undulates between 600 to 2,100 m asl and hills and valleys are traversed by a number of rivulets that drain to the Siruvani river (a tributary of Bhavani River), where a dam has been constructed. The characteristic vegetation of the area is of wet evergreen forests, except for small areas of secondary forests, subtropical hill forests and some grasslands. A few cardamom and coffee estates exist in the northern portions of this forest block; in three of these estates, *viz.,* (Kuruvambady and Kizhakkambalam, and Siruvani Estates) *V. macrocarpa* is one of the dominant shade crops, being relictual of the original vegetation.

The species ranges in distribution from 550 to 1300 m in Muthikulam RF (Vellingiri Hills; Fig. 4). The species is found at ca. 550 m in the Chittur-Kuruvambady area, on the lower reaches of the riverine belt of the Muthikulam RF at Puliyara, Thumbappara and Kurukkan Kundu area on the river system. This is the lowest elevational record for the species. In the past, probably the species extended further down on the river courses, and might have been devastated by the expanding villages.

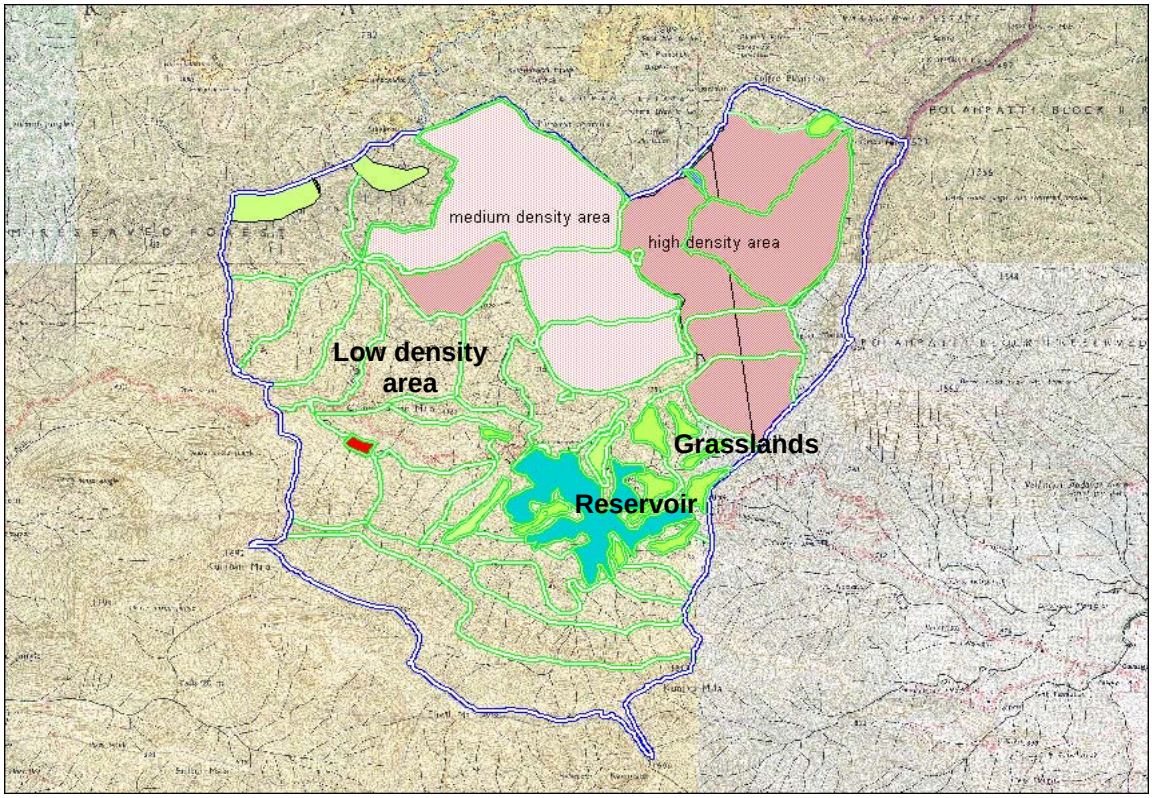


Figure 3. Distribution of Vateria macrocarpa in the Attappady Block VI of Kerala. Toposheet: 58 B9.

Density distribution of V. macrocarpa

V. macrocarpa exists in two populations: 1. *Muthikulam-Bolampatty population* which is the largest population, and 2. *Muthikulam waterfall population,* a small population with ± 20 individuals. It got isolated from the Muthikulam-Bolampatty population due to the construction of the Siruvani reservoir that occupy in between the two. In the reservoir area, before the construction of the dam (Siruvani Dam) there had been many trees of *V. macrocarpa*, as in Koodam, and other low elevational areas. These were felled during the construction of the dam (information from tribal men).

The Muthikulam-Bolampatty population can be stratified into three subpopulations, based on the density distribution in the area (Figs. 3 & 4).

1. *High-density subpopulation*: Where *V. macrocarpa* trees are gregarious and the stands are dominated by *V. macrocarpa.* Large diameter trees are plenty in this area. The area lies between 900→1250 m, and perhaps extends a little further above. The slope of the area is gentle. The compartments 18, 19, 20 and 21 of Muthikulam, falling on the western slopes of the Vellingiri hills and the Sholayur areas are typical locations.

2. *Medium-density subpopulation*: Where the trees are restricted to the river channels, but the population appear to be dense. The area lies between 800-950 m elevation. Because the tributaries are close by, the whole area is composed of streamlets; in other words, the area is a compound tributary system, and hence, the population is dense and continuous there.

3. *Low-density subpopulation*: Where *V. macrocarpa* trees are restricted to the river channels only, but where the density of the trees is extremely low. This area lies between 550-800 m elevation. Eg.: Thumbappara (750 m), Koodam (650 m), Koodam Kunnu (750 m), Thannippara (700 m), Dam site (800 m).

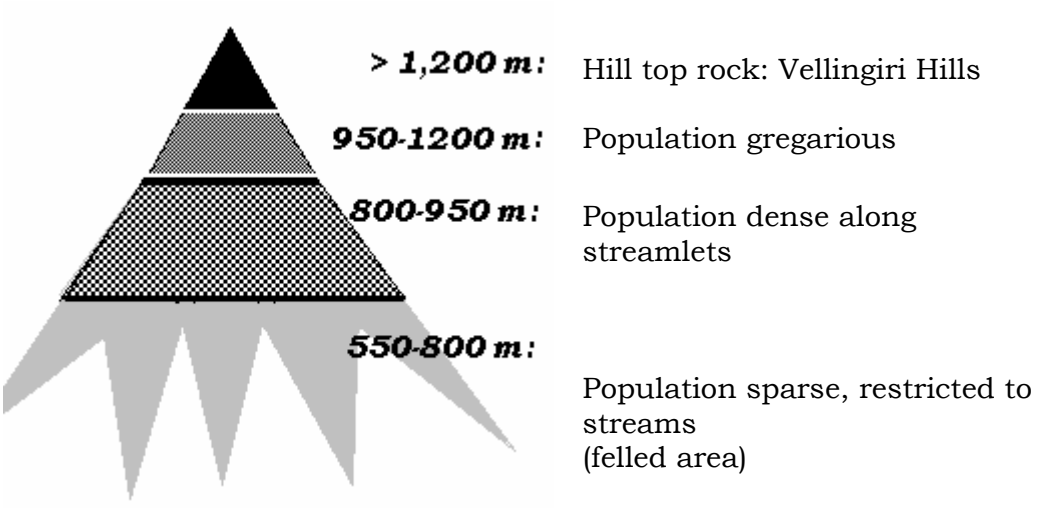


Figure 4. Density distribution of *V. macrocarpa* in the Vellingiri Hills, according to elevation regimes.

Physiography of the three subpopulations of V. macrocarpa:

High-density subpopulation: The ground of the Vellingiri gregarious patch is fully covered by large boulders of 2-4 m size. These boulders seem to be derived from the broken and fallen pieces of the monolith of the Vellingiri hilltop. Soil is not exposed, and several small rivulets flow underneath the broken boulders. In between the closely packed boulders there are many large gaps beneath them, where leaf litter has accumulated. Because of the gaps, it is really difficult to walk along the area. A few case histories of hunter dogs having caught up and taken to death in these gaps exist. Presumably because of the difficult to operate ground situation, the area has not been selection felled.

Medium-density population: Vellpine is available on the western slopes of Keralamed (Medium-density subpopulation), but absent on the eastern slopes belonging to Tamilnad. Apparently Vellappayin has been selectively extracted in the area. *V. macrocarpa* density here is not as much as in Compartment no. 20; on the other hand it is denser than in Compartments 4 and 5.

Low-density population: The Chittur River originates from the Vellingiri hills at around 1800 m and continues down as Pattiayar River and flows into the Siruvani dam wherefrom it flows down to c. 650 m at Koodam. At Koodam, three tributaries of the Chittur River meet together. Along the Koodam-Chittur (Puliyara) tract, the rivulet drops down by a 100 m and the forest tract Singampara-Koodam-Chittur (Puliyara) provides a cross section of the lower reaches of *V. macrocarpa* distribution on the banks adjoining hillocks on either sides; Amantha Mudi ('Ananthamudi' in the toposheet 58 B-9) lies on the West of the rivulet, where *V. macrocarpa* is scarce.

The distribution of the species in the area is rather patchy, density varying drastically with locations. In some areas, the density is poor or the species is totally absent. Where the species is fairly represented, younger size classes such as saplings and poles are also seen. In some of the areas, the slope is very high, often to 75%, especially in Compartment no. 18. Vellpine is available in the Compartments 18 and 19; fairly high density is observed here also, but not as dense as in Compartment no. 20.

Climate

The climate of Muthikulam is typical monsoonal, characteristic of the Western Ghats of Kerala. The details of rainfall across the months are given in Table 3 and Fig. 5. The mean annual rainfall as computed from 10 years' rainfall data (1992-2001) comes to 2,818 mm. Two monsoons, the Southwest and the Northeast, are the major sources of rain. The former contributes about 75 % of the total rainfall and showers between

June to September and the latter about 22% during October and November. Sparse and isolated pre-monsoon showers also received occasionally between February and May.

Table 3. Ten-year (1992-2001) pluvial pattern (mm) at Muthikulam*.

No.	*Pluvial patterns*	*Periods*	*Min*	*Max*	*Mean*	*SE*	*%*
1	South-west monsoon	Jun-Sept.	1352	2803	2117	449	75.1
2	Northeast monsoon	Oct.-Nov.	410	1062	618	238	21.9
3	Pre-monsoon	Feb.-May	15	423	130	128	~ 4.0
	Annual	Rainfall:	1813	3809	2818	585	100.0

* Data from PWD.

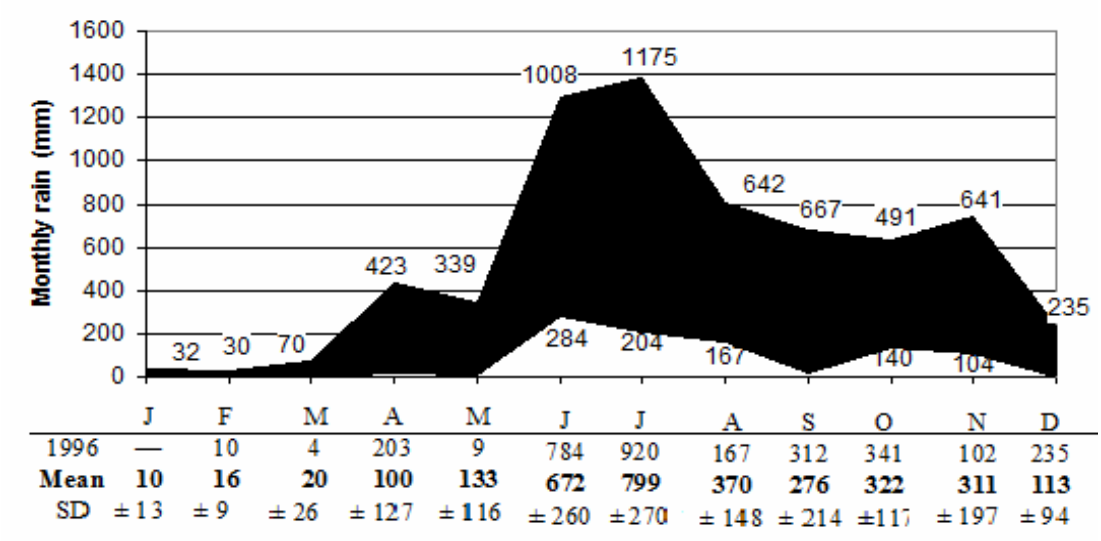


Figure 5. Spread and intensity of rainfall across the months between 1992 and 2001 at Muthikulam, in the natural habitat of *V. macrocarpa*. The table below the graph provides the values for 1996, an average year.

Edaphic conditions:

V. macrocarpa is basically a riverine species with affinity to water and watercourses. Apparently, continuous supply of water could be the reason for the dense gregarious growth of *V. macrocarpa*. In sites where the species is gregarious, water logging and semi-swampy situation are observed. In this it resembles *Myristica magnifica*, another endemic swamp-tree (South Kerala) restricted to low-level freshwater swamps. From the base of the Vellingiri hills (Kerala Part, High density subpopulation) we have found that the gregarious patch of *V. macrocarpa* is receiving waterfalls from the top of the monolith.

Communities supporting V. macrocarpa:

Natural forests: The samples studied for phytosociology are spread across two ecosystems: (i) Natural Wet Evergreen forests, selection felled during the sixties, and (ii) Coffee and Cardamom plantations, established by transforming natural Wet Evergreen forests, where *V. macrocarpa* is one of the dominant constituents of the shade trees. There were 11 samples belonging to each of the ecosystems. The samples of the natural forests ranged between 650→1,250 m.

Pascal (1988) classified the evergreen forest communities along the Western Ghats across the latitudinal and altitudinal gradients and recognized 13 communities, based on species composition. The latitude of the distributional area of *V. macrocarpa* is around 11° 1-2' N and north of the Palghat Gap, and the altitudinal range of its occurrence is 550→1350 m. Pascal (l.c.) documents two forest communities in this geodesic realm: (i). *Dipterocarpus indicus* –

Kingiodenderon pinnatum – Humboldtia brunonis community across the altitudinal gradient 100-700 m, and (ii) *Cullenia exarillata – Mesua ferrea – Palaquium ellicpticum* comm. between 600→1,400 m. Most of the area of occurrence of *V. macrocarpa* falls in the latter type. According to Pascal (*l.c.*), the community in the order of importance was *Cullenia exarillata – Palaquium ellipticum – Mesua ferrea,* with other associates like *Cassine glauca, Hydnocarpus alpina, Agrostistachys meeboldii, Myristica* sp., *Gomphandra tetrandra*, and *Calophyllum apetalum*, together constituting the relative importance value to 64.8 percent.

Basha's (1977) enumerations in the Kerala part of the occurrence of *V. macrocarpa* and Jayaram's (1973) in the Bolampatty region (Tamilnadu) on the other hand documented the following dominance pattern: *V. macrocarpa – Cullenia exarillata – Palaquium ellipticum – Artocarpus heterophyllus*. Our results also showed similar stand structure (See Tables A1-A22: Appendix-1). This community may be a local facies of the *Cullenia exarillata – Mesua ferrea – Palaquium ellipticum* comm., where, *V. macrocarpa* has attained dominance over all other species. In all the samples, *V. macrocarpa* recorded highest dominance, ranging between 18.6 and 57.5%. *Palaquium ellipticum* was absent in all these samples above 900 m asl (4 out of 11) and was found replaced by *Mesua ferrea*. Within the area of occurrence of the species, *V. macrocarpa* also showed higher density with increasing altitude (900-1250 m). Strong positive correlation with *Mesua ferrea* was also apparent in these plots.

Table 4 describes the statistic of density (D) and relative density (RD) for *V. macrocarpa* from phytosociological analyses. In terms of D and RD, across the three strata, the results showed that there is not much difference between low and medium density strata. On the other hand Mean-D and Mean-RD values from the high-density stratum stood distinctly high (D: 318; RD: 42.2) than that obtained for low and medium strata (D: 160 tr/ha, 115 tr/ha; RD: 24.2, 16.3). The range of values and their variability were also much higher for the high-density stratum.

Table 4. Density and relative density of trees (>= 10 cm gbh) of *V. macrocarpa* across different strata of natural forests.

No.	*Parameters*	*Stratum*	Range	Mean + SE
1	Density (D)	Low	90-320	213 ± 116
		Medium	170-180	143 ± 41
		High	150-470	318 ± 161
2	Relative density (RD)	Low	9.6-34.4	24.0 ±12.9
		Medium	12.6-20.9	16.3 ± 3.8
		High	23.1-64.4	42.2 ± 18.0

V. macrocarpa also recorded the higher values of relative frequency (RF; Table 5); it is evident that the high-density stratum stood distinct from the other two strata with a high Mean-RF of 23.7%. The range of the values (15.2→30.3) also did not overlap with the range recorded for the low- and medium- density strata (9.2→15.1%).

Table 5. Relative frequency (%) of trees (>=10 cm gbh) of *V. macrocarpa* across different strata of natural forests.

No.	*Density stratum*	*Range*	*Mean ± SE*
1	Low	9.2-15.1	11.1 ± 3.0
2	Medium	12.3-13.7	13.1 ± 0.6
3	High	15.2-30.3	23.7 ± 6.3

The range of basal area (BA) of the species was 18.8→79.7 m^2 (Table 6), being the highest recorded for any of the tree high-BA species. However, the values of BA and its percentile (RBA, relative basal area) always displayed overlap across the three strata. The species is so gregarious in its area of occurrence that it occupied 37→79.7% of the BA. The three stratal identities were not discernible in terms of BA and RBA.

Table 6. Basal area and relative basal area of trees (>= 10 cm gbh) of *V. macrocarpa* across different strata of natural forests.

No.	*Parameters*	*Density Stratum*	Range	Mean ± SE
1	Basal area (BA, m^2)	Low	23.8-34.6	29.2 ± 5.8
		Medium	18.8-49.3	35.6 ± 13.1
		High	30.5-70.4	44.9 ± 17.8
2	Relative basal area	Low Medium	37.1-54.4	43.6 ± 9.0
	(RBA, %)	High	35.6-67.1	53.1 ± 13.6
			49.3-79.7	66.5 ± 14.7

The values of the composite index of dominance, Importance Value (IVI), was transformed to its percentile (= IVI/3) and are given in Table 7. The overall dominance of *V. macrocarpa* in the stands ranged between 24.51 to 57.45%, which is very high for any given stand and again depicts the gregarious nature of the species. Here again, the high-density stratum maintained a high mean value (44.13%) compared to 24.51% and 27.67% shared by the two other strata.

Table 7. Importance value (in %) of trees (>= 10 cm gbh) of *V. macrocarpa* in the different strata of natural forests.

No.	*Density stratum*	*Range*	*Mean ± SE*
1	Low	18.6-34.6	24.5 ± 8.3
2	Medium	20.8-34.7	27.7 ± 5.7
3	High	29.2-57.5	44.1 ± 11.6

Plantations containing V. macrocarpa: The three plantations (Kizhakkambalam, Kuruvambady and Siruvani) are under private ownership and belonged to the 800-900 m altitudinal belt. The plantations are of coffee or cardamom (Table 1). In all these estates, trees are maintained to provide shade to the cash crops and are the reminiscences of the original evergreen forest vegetation.

In all the 11 samples, values of density (D) and relative density (RD) obtained for coffee and cardamom plantations were more or less comparable without much appreciable difference of mean values and ranges across the two eco-units (Table 8).

Table 8. Density and relative density of trees (>= 10 cm gbh) of *V. macrocarpa* in the coffee and cardamom plantations.

No.	*Parameters*	*Ecounits*	Range	Mean ± SE
1	Density (D)	Coffee plantations	50-140	95.0 ± 35.1
		Cardamom plantations	40-120	86.6 ± 32.0
2	Relative density(RD)	Coffee plantations	13.5-29.6	23.8 ± 7.7
		Cardamom plantations	9.8-36.7	20.9 ± 9.5

In coffee and cardamom plantations tall trees are maintained only for shade above the crops, but are maintained in low density so as to meet the light requirement of the crops. Thus, compared to the evergreen forest samples, density (D) and relative density (RD) of *V. macrocarpa* is quite low in these plantations. While the range of D of *V. macrocarpa* in natural forest stands was 90→470, the same was found to be 50→140 in plantations. The low values of D are a result of thinning of trees in natural forests during their transformation into plantations, so as to facilitate growth of the crops. The mean-RDs in plantations (20.9→23.8) also were at par with the mean values obtained for natural forests (16.3→24.0) in low- and medium- density strata. This shows that the estate owners do not target *V. macrocarpa*, while thinning out the shade trees for re-planting; nevertheless, the values of mean-RDs (23.8, 20.9) were quite low compared to the mean-RD from the high-density stratum of natural forests (42.2; *cf.* Tables 5 & 9). This is mainly because the high-density stratum occupies a higher altitudinal belt, where the species grows much more gregariously. The samples from the estates were largely from the 800→900 m altitudinal belt.

The values of relative frequency (RF) of *V. macrocarpa* in the plantations however showed improved values (19.2 and 21.5; cf. Table 8) as against the values from forest samples from low and medium strata coming from 800→900 m elevation (Table 11). This again confirms that the species is not target for any logging specifically targeted at the species. Table 12 describes the BA and RBA of *V. macrocarpa* in coffee and cardamom plantations.

Table 9. Relative frequency (%) of trees (>= 10 cm gbh) of *V. macrocarpa* in the Siruvani Group of Plantations *.

No.	*Eco-units*	*Range*	*Mean ± SE*
1	Coffee plantations	14.3-29.0	21.5± 5.3
2	Cardamom plantations	4.2-22.0	19.2± 6.3

Table 10. Basal area (m^2) and relative basal area (%) in the coffee and cardamom plantations (Siruvani Group).

No.	*Parameters*	*Eco-units/Strata*	Range	Mean ± SE
1	Basal area (BA, m^2)	Coffee Est.	6.7-54.4	26.2 ± 16.7
		Cardamom Est.	12.5-33.1	20.1 ± 8.8
2	Relative BA (RBA, %)	Coffee Est.	28.0-78.1	49.8 ± 18.2
		Cardamom Est.	30.0-87.3	35.4 ± 17.3

The BA of *V. macrocarpa* in plantations is too low compared to that in natural forest stands; being transformed stands, this is expectable. This difference however is less reflected in RD. Apparently the estate owners are refrained to extract more timber from the stands, which is a desirable state as far as *V. macrocarpa* is concerned. The high variability of D and RD across plantations points to the fact that the above cannot be generalized for all plantations. Some of these plantations show very low values for BA and RBA; this is particularly true for some of the coffee plantations.

The overall dominance of *V. macrocarpa* in the plantations remained comparable to that in natural stands, and which is desirable (Table 11).

Table 11. Relative Importance value (RIVI, %) of *V. macrocarpa* in the coffee and cardamom plantations (Siruvani Group).

No.	*Ecounits*	*Range*	*Mean± SE*
1	Coffee plantations	22.0-47.4	31.7 ± 9.8
2	Cardamom plantations	16.7-34.5	24.0 ± 6.1

RIVI= Relative importance Value = IVI/3.

Population size of V. macrocarpa in the Kerala part:

As already mentioned, in Kerala *V. macrocarpa* is found only in the Attappady region. Here, the area of its natural occurrence comprises four eco-units. The details of the population across the different eco-units are given in Table 12.

Table 12. Population size of *V. macrocarpa* across different ecounits in Kerala*.

No	*Ecounits*	*Compart-ments*	*Density*	*Weighted Density*	*Area*	*Weighted area*	*Popul. size*
			tr/ha	*tr/ha*	*ha*	*ha*	*trees*
1	Low	3,4,5, 7, 9, 10, 14, 15	135	45	1274	424	19,080
2	Medium	11,12, 16	120	40	917	305	12,200
3	High	18, 19, 20, 21	147	49	293	98	4,802
4	Plantations	Estates	90	30	508	169	5,070
				Total:	**29.92**	**1,870**	**41,152**

* Note: The populations of Bolampatty area (adjoining Muthikulam and falling in Tamilnadu), has not been included in this study. Strata with very low and low densities generally have *V. macrocarpa* restricted along the river courses approximately for a width of about 100 m. The total length of major river courses traversing the area has been calculated using GIS and the area of occupancy computed from that. In order to obtain a conservative estimate of the population size, instead of observed densities, weighted densities have been used for computations. Trees >=30 cm dbh alone have been used for this computation.

The approximate total population of mature trees (>= 30 cm dbh) has been found to be 41,152 individuals. This population is distributed in two major ecological habitats: (i) natural forests, an (ii) Private coffee and cardamom plantations established in transformed natural forest areas. Out of the 41,152 individuals, 36,073 are found in the natural forests and 5,079 in the plantations. Although the low-density areas contain *V. macrocarpa* largely along the river/rivulet courses, the population in this area is also sizable (46.4%).

Population structure of V. Macrocarpa *in natural stands*

Silvigenesis is the process of tree/stand building and indicates transition across size classes over time. As size classes correspond to different cohorts size class structure informs about past sylvigenesis. Figure 16 provides graphs of size class structure of the total sampled populations, and of the various density strata mentioned earlier. In order to describe the sylvigenesis, 10 size classes are recognized based on DBH classes (Table 13).

Table 13. DBH classes recognized.

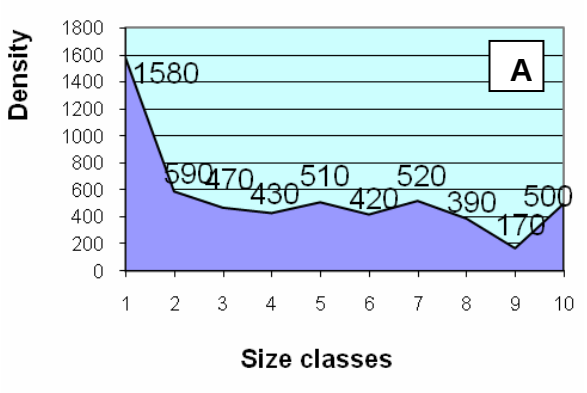
No	DBH Class	No.	DBH Class
1.	3-10 cm - Saplings	6.	50-60 cm - Medium trees
2.	10-20 cm - Poles	7.	60-70 cm - Large trees
3.	20-30 cm - Small trees	8.	70-80 cm - Large trees
4.	30-40 cm - Small trees	9.	80-90 cm - Very large trees
5.	40-50 cm - Medium trees	10.	> 90 cm - Very large trees

The total population structure (Fig. 6 A) shows an inverse-J curve characteristic of a stable population with more frequencies in the lower size classes; this is indicative of a satisfactory sylvigenesis. In low-density areas however (Figs. 6 B & C), regeneration are fewer compared to other classes. In medium- and high- density stand (Figs. 6 D-F), the inverse-J shaped curve characteristic of the total-population is explicit; nevertheless, in some of these (Figs. 6 D & F), the number of trees in the 30- and 60- cm dbh classes were low compared to that of the lower and higher classes. The causes of the low frequencies can be local, linked to the site factors.

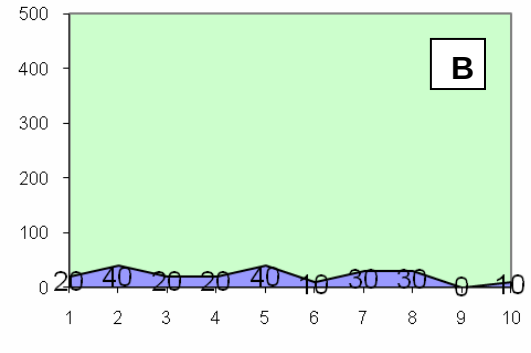
Population structure of V. Macrocarpa *in Coffee and Cardamom plantations*

The size class structure of *V. macrocarpa* in Coffee and Cardamom plantations are different (Fig. 7 A; Tables A-23 to A-26). In coffee plantations, the graph more or less acquires the characteristics of a normal curve making it different from the inverse-J curve characteristic of tropical forests. The curve infers poor representation in lower size classes. Compared to this situation, in the case of Cardamom plantations, lower size classes are also more or less well represented though not to the extent as in natural forest stands.

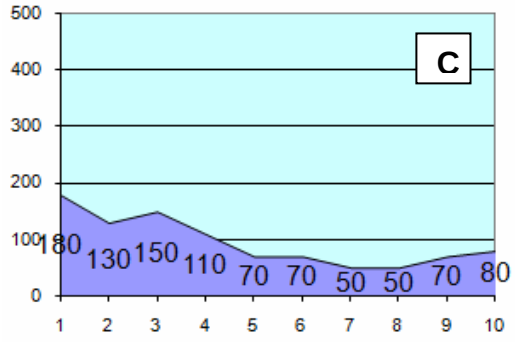
This difference of size class structure of *V. macrocarpa* in Coffee and Cardamom plantations tells of the eco-physiological preferences of the crops and the cultural practices across Cardamom and Coffee plantations. Despite the fact that Coffee plants are pruned and kept low in plantations, it is a tree and requires more sunlight than Cardamom – which is a herb and an undergrowth. The intensity of shade crops in coffee plantations therefore is less compared to that in Cardamom plantations. In coffee plantations, new recruits are continuously removed. Across the plantations of different ownership, both in Coffee and Cardamom plantations, there are slight differences in the size class structure of *V. macrocarpa*.



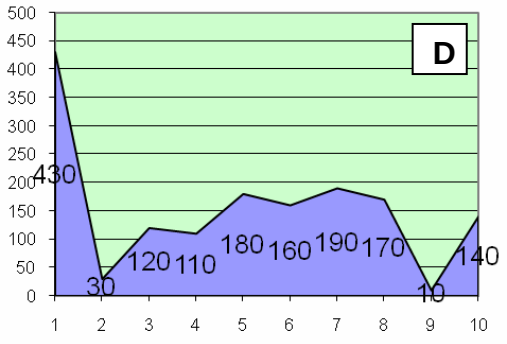
Total population structure
(Trees measured: 5490;
n=26 samples; Size: >1 cm dbh)



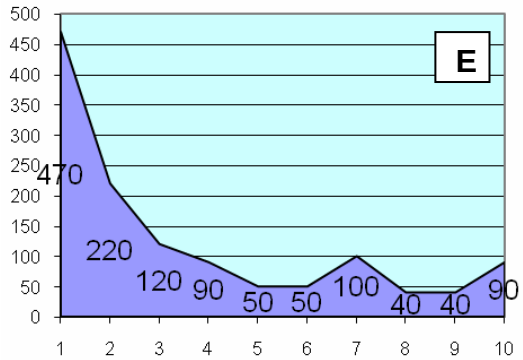
(Very) Low density stands
(n = 2 samples)



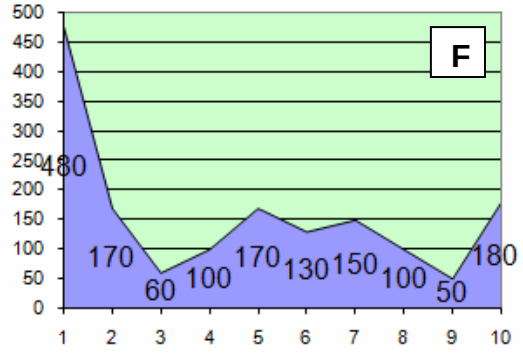
Low density stands
(n = 4 samples)



Medium density stands
(n = 9 samples)



High density stands, < 900 m asl
(n = 4 samples)



High density sands, > 900 m asl
(n = 7 samples)

Fig. 6. Size class structure of *V. macrocarpa* stands across varied density strata. *Size classes*: 3-10 cm dbh (Saplings); 2. 10-20 cm dbh (Poles); 3. 20-30 cm dbh (Small trees); 4. 30-40 cm dbh (Small trees); 5. 40-50 cm dbh (Medium sized trees); 6. 50-60 cm dbh (Medium sized trees); 7. 60-70 cm dbh (Large trees); 8. 70-80 cm dbh (Large trees); 9. 80-90 cm dbh (Very large trees); 10. > 90 cm dbh (Very large trees).

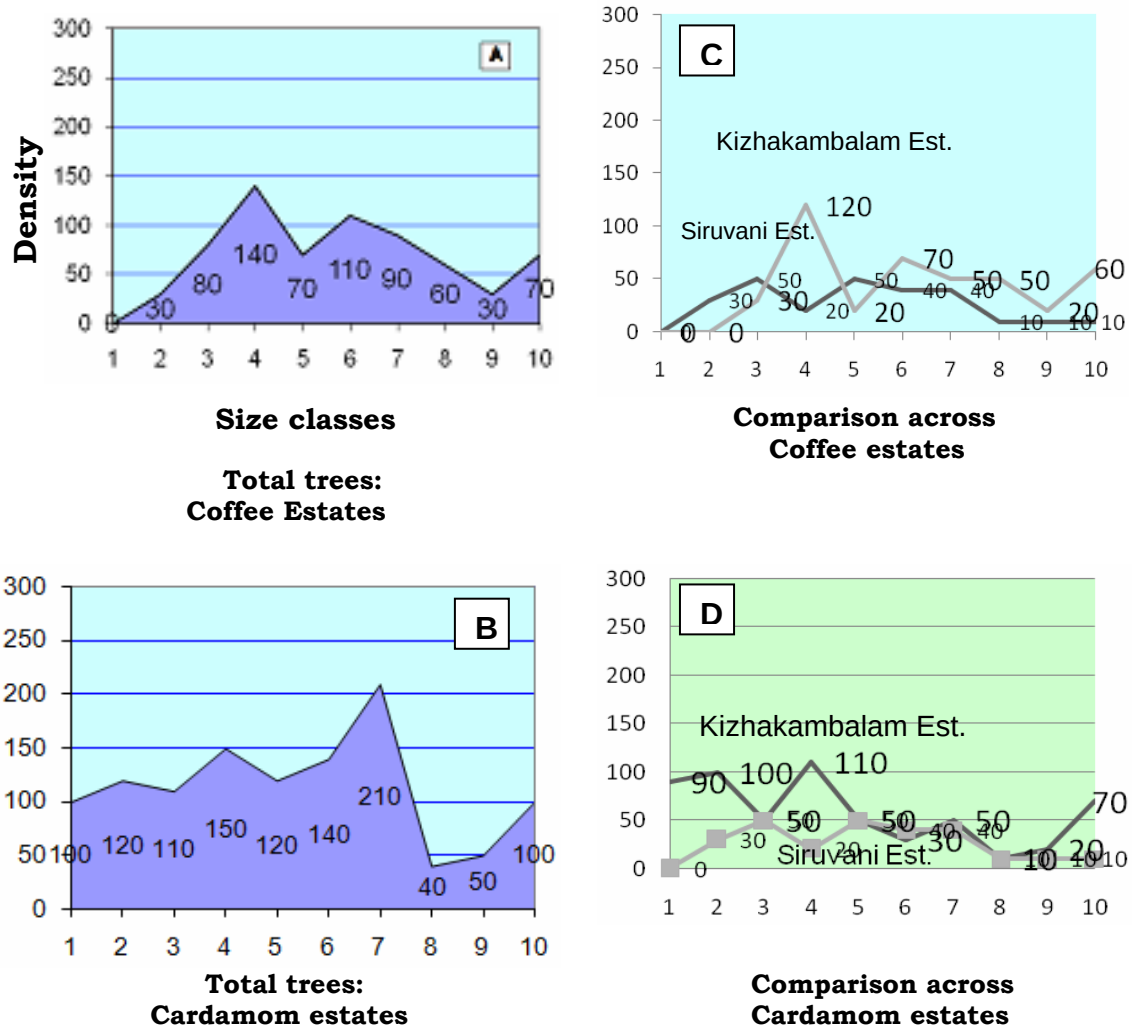


Figure 7. Size class structure of *V. macrocarpa* in Coffee and Cardamom estates. *Size classes*: 3-10 cm dbh (Saplings); 2. 10-20 cm dbh (Poles); 3. 20-30 cm dbh (Small trees); 4. 30-40 cm dbh (Small trees); 5. 40-50 cm dbh (Medium sized trees); 6. 50-60 cm dbh (Medium sized trees); 7. 60-70 cm dbh (Large trees); 8. 70-80 cm dbh (Large trees); 9. 80-90 cm dbh (Very large trees); 10. > 90 cm dbh (Very large trees).

Reproductive biological studies

Reproductive phenology of V. macrocarpa

Local people note that *V. macrocarpa* flowers once in two years and when they are in flower, honey yield from forests is higher (information from Mr. Mathew: Kizhakkambalam Estate). Not all the populations flower every year; it is probable that different populations flower and fruit in different years. Thus we found that while the population at Koodam was in flower, the population at Sholayur estate was in vegetative phase. Although fruit set is found in over 50% of the trees, fruits mature only in a very low percent, insect attack and immature fruit fall being the causes. In November 2002, at Koodam,

98% of the trees had no fruits and only a few trees along the riverbank were found to bear fruits. However, the insect infested fruits are also found to germinate and establish, although they produced week seedlings.

Fig. 8 depicts the reproductive phenophases of *V. macrocarpa*. Flowering in the sense of emergence of inflorescence has been observed in trees from January to April, but mature flowers were found only in March and April. However, on some of the trees, semi-mature fruits were seen in January-February, indicating that occasionally there is an early flowering during September-October, through November and December. Young fruits were obtained from January till June, and mature fruits also likewise.

Figure 8. Reproductive phenogram for *Vateria macrocarpa*

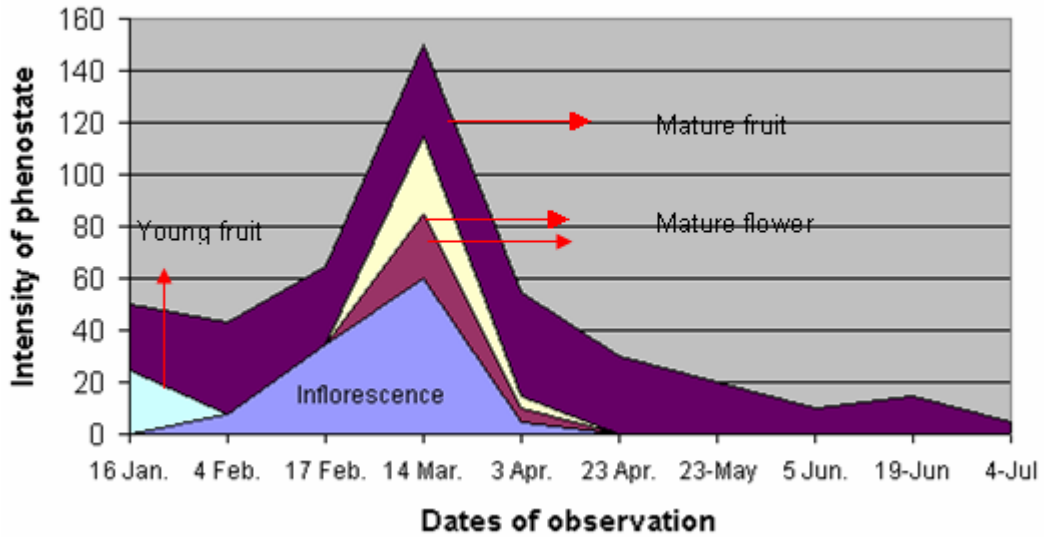


Figure 9. Intensity of different reproductive phenophases of *V. macrocarpa*.

In Fig. 9, intensity of the reproductive phenophases, based on recorded visual ratings, is given for a representative tree. The peak

availability of mature fruits is from February→March (Fig. 9). However, the intra-population variation in flowering and fruiting is pronounced (Fig. 9).

Figure 10 depicts the intra-population variability of flowering and fruiting in a lot of 30 trees continuously monitored for a period of 12 months at fortnight interval. 14/30 trees flowered in 2003 and only 11/30 produced mature fruits and 3/30 trees lost all the fruits before maturity. Based on the presence of previous year's (2002) fruits, we could also see that 8/30 trees flowered during 2002 and 2003 successively.

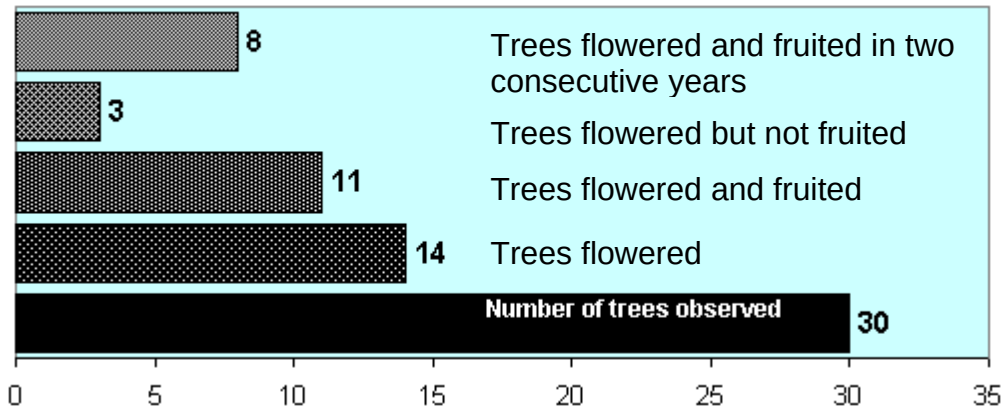


Fig. 10. Statistic of flowering behaviour of Vat*eria macrocarpa*

Fruits of V. macrocarpa

The fruit is a capsule with thick stalk and a persistent calyx that is slightly excrescent in the fruit. The capsule is solid with a single large embryo filling the entire cavity of the seed. Very rarely pseudo-polyembryony, *i.e.*, two embryos derived from two ovules, is also met with. A detailed description of the fruit is given below, as the internal morphology of the fruit is of silvicultural importance.

Fruit stalk 2.2-1.2 cm long, 8-10 mm thick; fruiting calyx connate at base and companulate to flat, -3.5 cm across, sepals 5, 5-15 x 5-15 mm, narrowly to broadly triangular, reflexed, capsule proper 10.5-13.6 x 5.3-3.7 cm, broadest above the middle, slightly ventricose, base narrow, tip beaked, beak 2.5-6.9 cm long, curved towards one side; pericarp 2.5 mm thick, smooth, brown without. Embryo 1.

Fruit polymorphism in V. macrocarpa

The species exhibits three different types of fruits (Fig. 11): (i) *Obpyriform-ampulliform* fruits with long beak (Fig.11 A), (ii) *Ellipsoid*

fruits with medium sized beak (Fig. 11 B), and (iii) *Narrow-fusiform* fruits. Ellipsoid fruit with medium sized beak (Fig.11 C) is the common type, but some of the trees characteristically produce ob-pyriform and fusiform fruits.

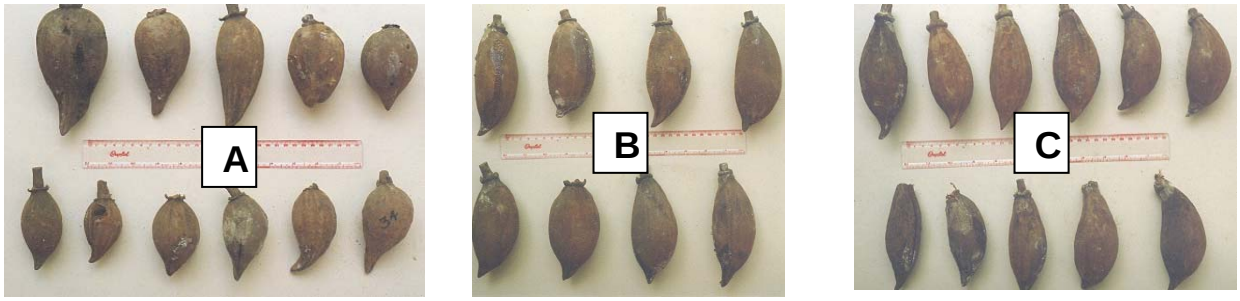


Figure 11. Polymorphism of fruits in *V. macrocarpa*. Fig.119 A. Obpyriform fruit. Fig. 11 B. Ellipsoid fruit. Fig. 11 C. Narrow-fusiform fruit.

The differences in the size of the different morphotypes of fruits are given in Table 14. One kilogram of the fruits contains 8-12 number and embryos weigh from 30-140 grams. A standard nursery bed accommodates 130-150 fruits. Weight of different morphotypes of fruits is given in Table 17.

Table 14. Fruit size across the different morphotypes of *Vateria macrocarpa*.

No.	*Fruit type*	*Length of fruit (cm)*		*Length of beak (cm)*		*Diameter (cm)*	
		Range	*Mean ± SE*	*Range*	*Mean ± SE*	*Range*	*Mean ± SE*
1	Obpyriform-ampulliform	13.0-17.0	15.4 ± 1.5	3.5-6.5	4.6 ± 1.1	6.1-7.5	6.9 ± 0.5
2	Ellipsoid	9.5-17.5	12.4 ± 2.2	2.0-4.5	3.3 ± 0.9	3.2-6.2	5.0 ± 0.9
3	Narrow-fusiform	11.5-18.5	14.3 ± 2.7	2.0-4.5	2.8 ± 1.0	5.1-5.7	5.5 ± 0.3

Table 15. Weight of different morphotypes of fruits of *Vateria macrocarpa*.

No.	Fruit type	Range (gm)	Mean ± SE (gm)	n
1	Obpyriform-apulliform	158.9-298.4	230.7 ± 36.1	10
2	Ellipsoid	69.4-152.7	108.3 ± 22.3	10
3	Narrow-fusiform	61.7-174.9	136.9 ± 43.1	10

Embryo of V. macrocarpa

A description of the embryo is given below and the embryos are illustrated in Fig. 12.

Embryo 1, axial, completely filling the seed cavity, globose to narrowly ellipsoid, 9-11 x 4.5-5 cm, ellipsoid, reddish or cream, or intermediate, bilaterally symmetric. Radicle central, supra-median, vertical, completely enclosed between the cotyledonary lobes of the distal cotyledon, pointed towards the distal end of the capsule. Plumule rudimentary. Cotyledons 2, large, massive, thick, empile in longisection, couvrant (covering) in transection, unequal, sometimes subequal, the distal cotyledon (with respect to the fruit) usually smaller, semicircular, lalongate, stalked, blades juxtaposed one over the other, conduplicate, 1-2 cm thick, outer surface smooth.

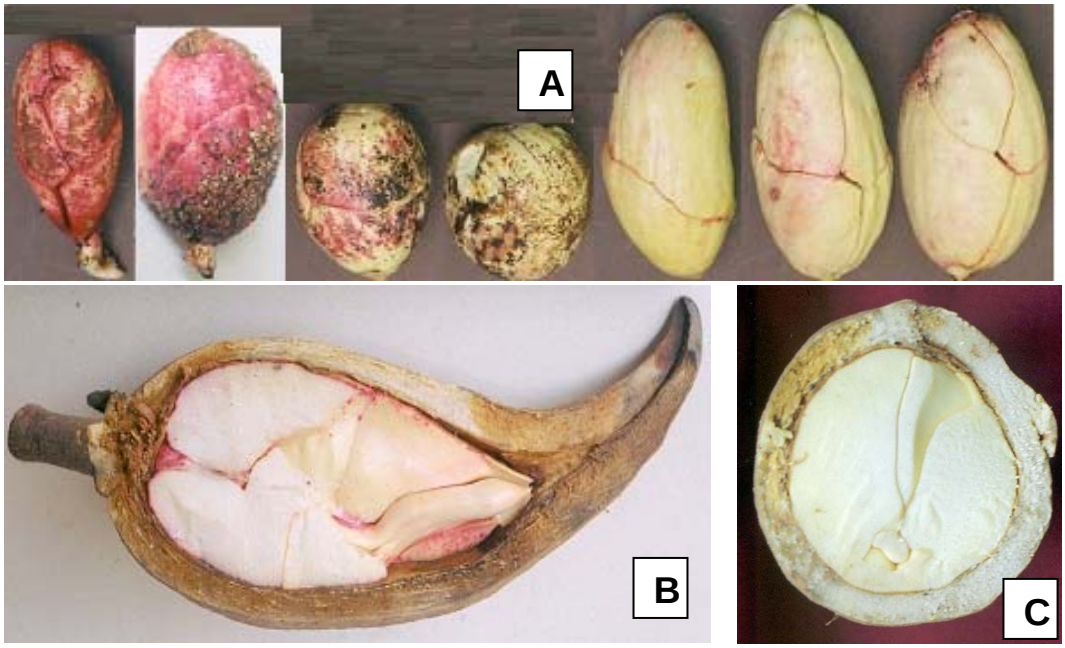


Figure 12. Embryo of *V. macrocarpa*. Fig. 12 A. Different types of embryos derived from different types of fruits. Fig. 12 B. A median longisection of the fruit, showing the position of the radicle. Fig. 12 C. Cross section of the fruit showing the conduplicate fold of cotyledons and the axial position of the radicle.

The 3D-shape of the cotyledons is better discernible in the young seedling and is illustrated in Fig. 13.

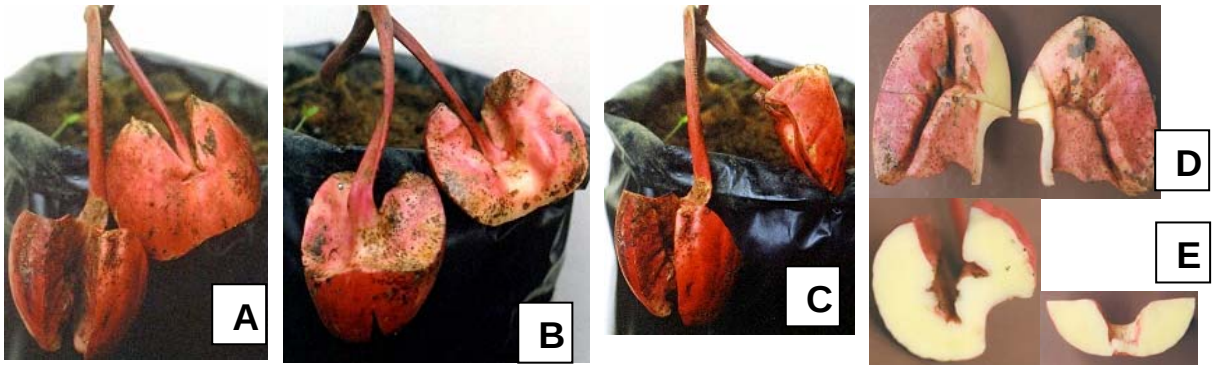


Figure 13. *Vateria macrocarpa*. Fig. 13 A-C. Different postures of the seedling-cotyledons showing shape and conduplication. Fig. 13 D. The ventral surface of the seedling-cotyledon showing the areolate surface. Fig. 13 E. Median cross sections of the seedling-cotyledons showing conduplicate fold.

Pseudo-polyembryony in V. macrocarpa

Very rarely, pseudo-polyembryony is met with, when the fruits are slightly larger in size. Pseudo-polyembryony results in the formation of more than one embryo in a fruit, which generally produces only one embryo. The two or three embryos thus produced are actually derived from 2(-3) ovules/seeds. When pseudo-polyembryonic embryos are formed, the embryos get compressed due to space limitations (Fig. 14).

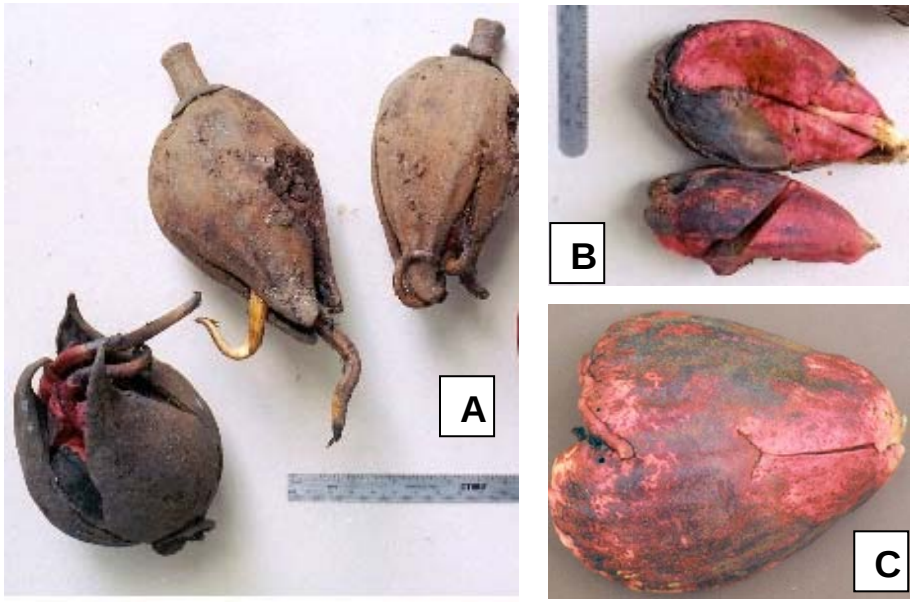


Figure 14. Pseudo-poly-embryony in *Vateria macro-carpa*. Fig. 14 A. Pseudo-polyemb-ryonic fruits with more than one radical emerging from the fruits. Fig. 14 B. A compressed, flat embryo derived from a pseudo-polyembryonic fruit.

Diaspore (fruit) dispersal:

The fruit, as it contains only one seed, is the dispersal unit (diaspore). As the fruits are heavy, they seldom reach far away from the mother trees, except when they fall into the river/rivulet. In many locations

we have seen semicircular seedling populations around the mother tree.

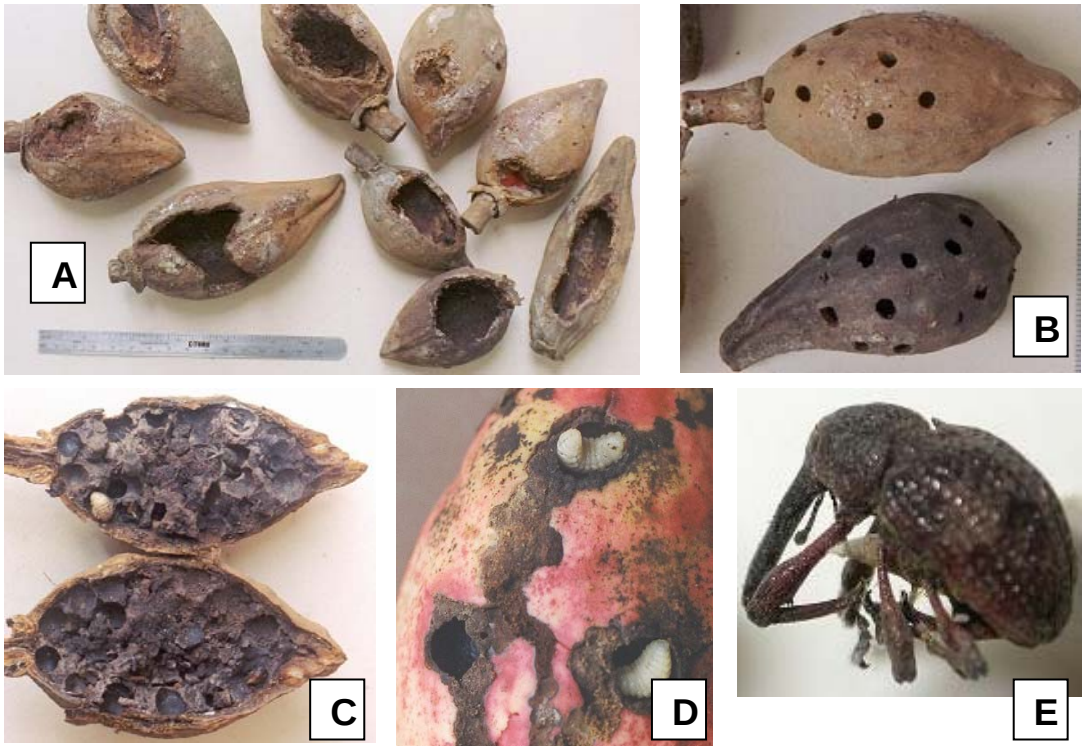


Figure 15. Fruit damage in *Vateria macrocarpa*. Fig.15 A. Fruits damaged by squirrels. Figs. 15 B-D. Fruits infested by insects. Fig. 15 E. Insect infesting the fruits.

Fruit infestation

Fruits of *V. macrocarpa* are infested by vertebrate and insect pests. Giant squirrels devour the fruit (Fig. 15 A) when they are young or maturing. Insect pests probably enter into the ovary early in development by ovipositioing, the larvae feed on the growing embryo and the adults liberate when the fruits are submature (Fig. 15 B-E). In both the cases, high infestation results in dead fruits.

Propagation studies

Fruit/ seed longevity:

Results of seed longevity studies are given in Table 16. The longevity of the fruits was found to extend for 15-16 days since the collection of fruits, with the optimum viable period being up to 12 days.

Table 16. Results of seed germination trials to evaluate longevity of fruits *.

Sl. No.	*Dates of sowing*	*n*	*Days after sowing*	*Number germinated*
1	3-3-2003	10	7	9
2	7-3-2003	10	11	9
3	12-3-2003	10	16	4
4	17-3-2003	10	21	..
5	21-3-2003	10	25	..

n – No. of fruits/seeds in sample. Seeds collected on 24-2-2003.

Population behaviour of germination:

Seed germination trials were conducted to determine the germination percentage, span of germination event, variability across different fruit types and variability across different soil types (Tables 16-18).

Germination experiments conducted in December 2002 and February 2003 are given in Table 19. The range of germination percentage obtained varied from 12→65 percent. The Mean-Germination % obtained in the 2003 trail was 43.6.

Normally the fruit/seed populations were found to germinate in 10-21 days and the event spans out for a period of three months. The observed germination percentages in the 2003-trial ranged between 30 and 63, with an average value of 43.6%. Germination started with 14 days after sowing, and more than 50% of the total germination was completed in 36-43 days (Table 17), and the germination was completed in 60-92 days time.

Table 17. Result of germination experiments of *V. macrocarpa* conducted in 2002 and 2003.

Year	Date of sowing	Repli-cates	n	Germination %				
				17 Jan.	5 Feb.	17 Feb.	23 Apr.	3 Jun.
2002	28 Dec	R1	100	13	20	30	50	50
	.. ..	R2	100	2	5	11	16	16
	.. ..	R3	100	4	4	6	12	12

Year	Date of sowing	Repli-cates	n	Germination %			
				14 Mar.	4 Apr.	23 Apr.	23 May
2003	19 Feb	R1	100	15	17	23	30
	.. ..	R2	100	26	36	54	63
	.. ..	R3	100	10	15	24	38

n – No. of fruits sown.

The results of germination experiment conducted with two different soil types and three fruit-types are given in Table 18.

Table 18. Germination behaviour of different fruit types under two soil conditions.

No.	Soil treatment	Fruit type	Replicates	n	Germination	
					%	Mean + SE
1		Ob-pyriform	R1	30	13	20.0 ± 10
			R2		27	
	Forest soil	Ob-pyriform	R1	30	43	51.5 ± 12
			R2		60	
		Ellipsoid or globose	R1	30	30	31.5 ± 2.1
			R2		33	
2		Ob-pyriform	R1	30	20	21.1 ± 2.1
			R2		23	
	Forest soil + sand	Ob-pyriform	R1	30	33	28.0 ± 7.1
			R2		23	
		Ellipsoid or globose	R1	30	17	17.0 ± 0
			R2		17	

n – No. of fruits sown. Date of sowing: 4 April 2003.

Apparently the different fruit-types do not have any effect on the germination percentage. Forest soil when mixed with sand resulted in poor germination percentage (17→23%); on the other hand, fruits sown in forest soil provided an average germination percentage of 34.3 ranging between 13→60%. The low germination percentages with forest soil mixed with sand shows that the species prefers forest soil than garden soil.

Seedlings:

Seedlings of *V. macrocarpa* (*V. macrocarpa*) have not been described by Swarupanandan (1987); they are described below briefly.

Seedlings (22 days old; Fig. 16): 25-28 cm tall. Hypocotyl: 5.5-8.5 cm long, 6-7 mm thick, cylindric, reddish. Cotyledons, 2, cream coloured or intermediate, pendent, petioles 6-8 cm long, 5-6 mm broad, 2 mm thick, shallowly channelled; cotyledon-1: attachment basal, blade reddish, convolute, tip 2-fid to ½, bilobed, base oblique, outer surface smooth, inner surface weakly areolate (not to the level as in *V. indica*), 6 x 5.3 cm wide, 2 cm thick, deeply convolute; cotyledon-2: blade 5.3 cm long, 4.6 cm broad, 2.8 cm thick, reniform, base agitate, basal lobes 3.3 cm long, 3.8 cm wide, smooth within and without. Epicotyl 18.5-20.6 cm long, 2-2.5 mm thick, cylindric. 1st node: leaves 3, whorled, stipulate, stipules 2, lateral, petioles 3.5-4 cm long, cylindric, distally pulvinate, leaf blade hanging obliquely from the pulvinus, blade 11.5-13.5 cm x 6-6.5 cm, tip acuminate, base obtuse, light

copper-red at first, turning to green by age, lateral nerves112-18 pairs, intercostae parallel.

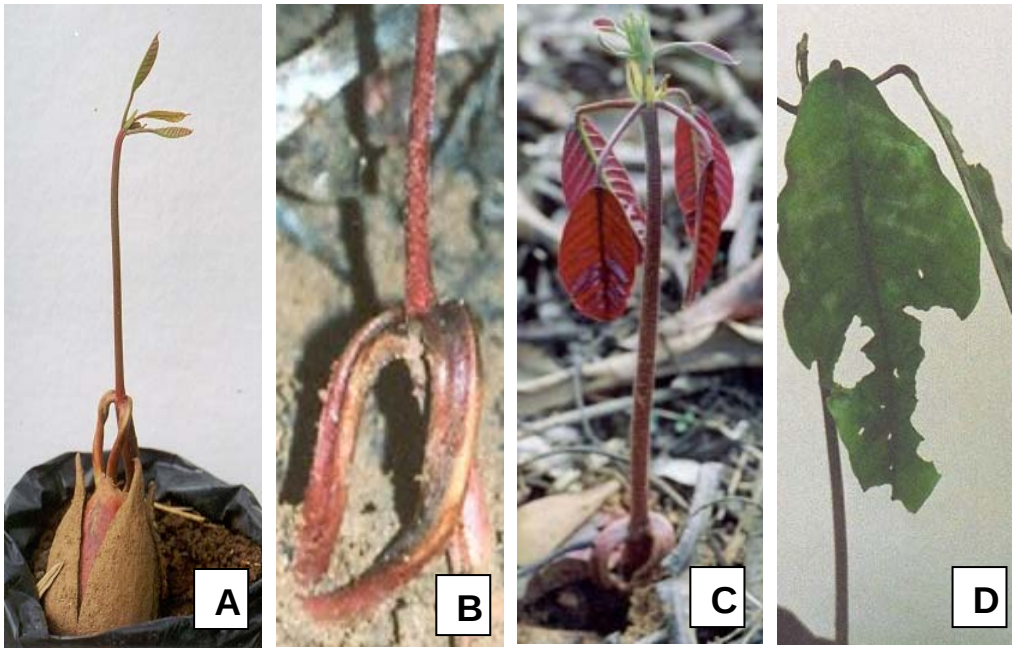


Figure 16. Seedlings of *Vateria macrocarpa*. Fig. 16 A. A young seedling showing the epigeal cotyledons. Fig. 16 B. The long flat cotyledonary petioles. Fig. 16 C. Seedling showing the first node with a whorl of four leaves. Fig. 16 D. Seedling with insect devoured leaves.

Coiled seedlings in V. macrocarpa: position effect of fruits on seedlings

Occasionally coiled seedlings are produced in *V. macrocarpa* (Fig. 17 A & B). This is a result of position effect of fruit on the seedling (Fig. 17 C & D). The cotyledonary petioles in *V. macrocarpa* are relatively broad and are closely appressed in the embryo. The plumule which lies in the split between the two cotyledonary petioles, can grow out smoothly, when the split is vertical with respect to the ground surface (Fig. 17 C). When the split is positioned in a horizontal plane, in the first instance, the plumule has to grow horizontal and then to take a vertical turn so that coiling of the seedling axis takes place (Fig.17 A, B and D). This information has silvicultural implications.

Nursery diseases and pests:

The leaves of the seedlings derived from Deember-2002 trial were found affected by powdery mildew and insects that cut the leaf blade in February 2003 trial. Spraying 2% Bavistin was successful in controlling the infestation. Ekalux 25 EC, 0.05% [2 ml/l; insecticide] + Fesovit [2 ml\li; a glue] were applied to control the insect pest and pathogen and was found effective.

Figure 17. Coiling of seedlings in *Vateria macrocarpa*. Figs. 17 A & B. Coiled seedlings. Fig. 17 C & D. Diagrammatic sketches showing relative position of plumule and cotyledonary petioles in normal and coiled seedlings (For details see text).

Assessment of initial seedling growth:

Statistic of seedling growth at the elapse of c. 4 months duration is given in Table 19. Seedlings attained a height of 15-40 cm with a mean value of 24.7 cm. The collar diameter ranged between 0.4-0.7 cm. There were 2-6 leaves per seedling by this time with a mean of 3.8 leaves.

Natural regeneration

In natural stands, regeneration is fairly good, particularly in the high density stratum. At Vellingiri, sapling populations are plenty (Fig. 18 A). Here, the ground is composed of large boulders rock pieces which practically made extending the coupe roads to this area impossible and therefore the area escaped felling (Fig. 18 B).

Table 19. Size of c. 4 months old seedlings of *V. macrocarpa**.

No.	*Parameters*	*Min (cm)*	*Max (cm)*	*Mean ± SE (cm)*
1	Height	15.5	40.0	24.7 ± 6.7
2	Collar diameter	0.4	0.7	0.54 ± 0.1
3	No. of leaves	2.0	6.0	3.8 ± 0.9

SE – Standard error. N – No. of seedlings studied: 25.

Survival on transplantation:

A small transplantation experiment was conducted in order to understand: (a) Amenability to cultivation, and (b) Whether the species would grow in forest areas outside its area of occurrence. Nursery grown seedlings were used for the purpose (Fig. 19). The results of this experiment are given in Table 20. The results show that 60% of the seedlings survived one and a

half months and 44 % survived 5 months. The planting sites were rivulet courses in the Upper Moozhiyar (Pathanamthitta Dt.) south of the Palghat gap. The observed results are optimistic and points to the fact the restricted distribution of the species primarily is due to the incapability of the species to disperse the fruits to far and wide places as they are large and heavy.

Table 20. Survival of seedlings of *V. macrocarpa* on transplanting at Upper Moozhiyar, on the banks of a nala.

Replicates	Seedlings Planted	Seedling survival		Seedling survival (%)	
	12 Nov 2003	25 Dec. 2003	28 May 2004	25 Dec. 2003	28 May 2004
R1	25	15	15	60	60
R2	25	13	4	52	16
R3	25	12	10	48	40
R4	25	20	15	80	60
			Mean ± SD:	60 ± 14*	44 ± 21*

* Figures rounded off.

Synthesis

Status of the species:

The area of occurrence of *V. macrocarpa* in Kerala is roughly 29.92 km^2. In addition, a sister population of the species exists in the Bolampatty Reserve Forests of Tamilnadu, which is in continuum with the Muthikulam RF. Despite the fact that no estimate of the area of occurrence of species is available for this segment, provisional assessment form the relevant topo sheets adds another 12 km^2 to the area of occurrence, making a total of 39.92 km^2. According to the IUCN norms for assessing the status of rare taxa, a species qualifies designation as 'Endangered (EN)' when the area of occurrence of the species is < 100 km^2. According to this ranking *V. macrocarpa* may be considered endangered.

Table 12. Population size of *V. macrocarpa* across different ecounits in Kerala*.

No	*Ecounits*	*Compart-ments*	*Density*	*Weighted Density*	*Area*	*Weighted area*	*Popul. size*
			tr/ha	*tr/ha*	*ha*	*ha*	*trees*
1	Low	3,4,5, 7, 9, 10, 14, 15	135	45	1274	424	19,080
2	Medium	11,12, 16	120	40	917	305	12,200
3	High	18, 19, 20, 21	147	49	293	98	4,802
4	Plantations	Estates	90	30	508	169	5,070
				Total:	**29.92**	**1,870**	**41,152**

Fig. 18. Regeneration of *V. macrocarpa* in the high-density stratum. Fig. 18 A. Copious saplings of *V. macrocarpa* in the Vellingiri area. Fig. 18 B. The bouldry ground of the Vellingiri area (for details see the text).

Figure 19. *Vateria macrocarpa*. Fig. 19 A. Nursery grown seedlings. Fig. 19 B. A planted seedling.

Risk evaluation of V. macrocarpa:

A conservative estimate of the population in Kerala is roughly 41,152 trees. If we add a minimum of ± 5,000 trees from the Bolampatty block (Tamilnadu), the total population will be ± 46,152 mature trees. The population with roughly 46,152 mature individuals is not very low for a magnificent tree like *V. Macrocarpa*; but the fact that the species does not have a viable population in any other parts of the country makes it endangered. Eighty-nine percent (41,082/46,152) of the tree population belong to natural reserve forests under the control of the Forest Departments of Kerala and Tamilnadu.

As already explained previously, in the Kerala part there is significant difference in the density of mature trees (>= 30 cm dbh) across the high-density stratum and the rest of the area. Interaction with the forest staff and other local tribe men suggests that the low and medium density strata were also equally high-density areas, prior to selective logging. Logging therefore has to be considered one of the major threats that contributed to an appreciable reduction of the population in the past. Selective logging as a strategy for management of our natural forests has been abandoned since 1984 and therefore, there is no immediate risk of loss of a sizable percentage of the mature population of the species inhabiting the natural forests. Chances of return to the abandoned management strategy is remote; nevertheless, the area is the last foot hold of the species and future management plans of the area should take this into consideration.

Prior to the construction of the Muthikulam dam there had been some population of *V. macrocarpa* in the Muthikulam Water falls area, which was in continuum with the population of Compartment no. 18, along the lower elevations. After the construction of the dam, because of the reservoir, the tree population got disjunct and isolated from the rest. Dangers from such activities are not there in the immediate future. However it would be worth exploring whether the inundation area of the temporarily abandoned check dam at Chittoor (Attappady) would touch up on the lower reaches of the distributional area of the species.

Coffee being a light demander than cardamom, conversion from cardamom to coffee causes to the removal of a good number trees of *V. macrocarpa* retained as shade trees. The low densities of mature trees in some of the coffee plantations, as already indicated depict this fact.

V. macrocarpa is also subject to another threat. In order to collect the dammar, the tribal people often make slashes on the bole and the method is too crude causing gradual decay and finally casualty to trees (Fig. 20 A). The number of trees affected this way is not small, although a statistical account of it is not available. Growing *V. macrocarpa* in plantations, or in homesteads for extraction of dammar

is a possibility, when healthy methods of extraction of dammar such as making bore holes on the bark can be adopted. However, this requires experimental feasibility studies.

Occasionally the tribal people fell large trees for extracting white dammar, which is used as an incense (Fig. 20 B-D). The percentage of casualty in terms of number of trees felled although is not very high, the impact is very high, as it affects the larger trees. The impact increases every year, and there is no effective check on it.

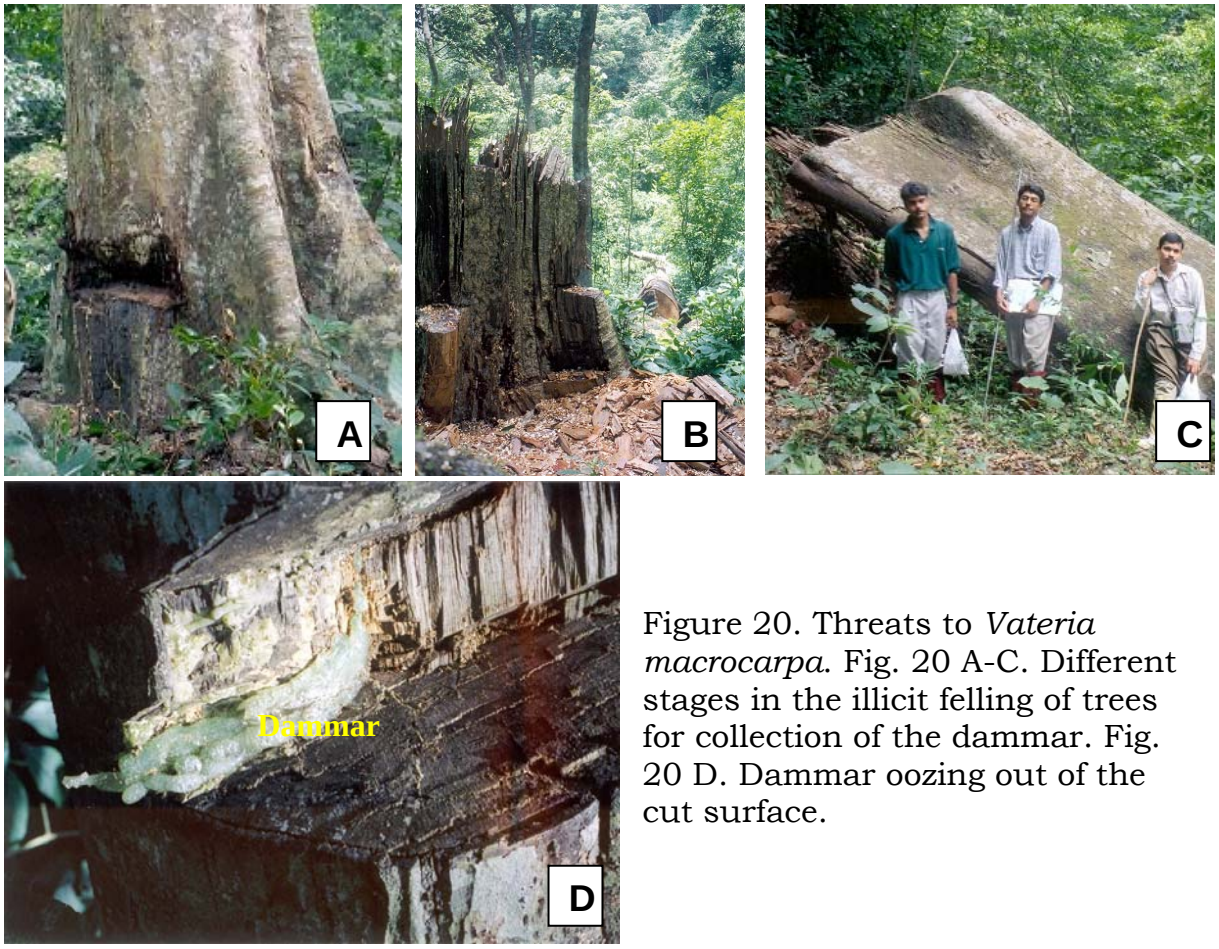


Figure 20. Threats to *Vateria macrocarpa*. Fig. 20 A-C. Different stages in the illicit felling of trees for collection of the dammar. Fig. 20 D. Dammar oozing out of the cut surface.

In-situ conservation strategies for V. macrocarpa:

In the existing scenario, the following *in-situ* conservation measures are feasible for the species.

1. The high elevational high-density belt of Attappady Reserve Forest may be declared as the last foothold of *Vateria macrocarapa*. All future management plans in the area need to take care of this fact and derive management strategies in tune with this. The area of occurrence of *V. macrocarpa* in the Bolampatty Reserved Forests and its population may be assessed and feasible segment added to this.

2. Transformation of cardamom plantations to coffee plantations in the area, and culling out of the shade crops may be discouraged.
3. Augment planting of the Muthikulam forests with seedlings of *V. macrocarpa* might improve the population further.
4. A scientific method of extraction of white dammar may have to be devised and the practice of crude extraction of the dammar by the tribes men may be controlled.

Potential areas for augment planting:

On the look out for areas for augment planting seedlings of *V. macrocarpa*, many options are available.

a. The Muthikulam waterfalls area where the ganja cultivators burnt a significant portion of the population is ideal. The area is now overgrown with early successional species such as *Macaranga indica, Mallotus albus/ tetracoccus* and *Clerondrum viscosum* and some mid successional species such as *Aporusa lindleyana*. So, enough shade to sustain the seedlings of *V. macrocarpa* is already there. Here, some reminiscence of the once extended population of *V. macrocarpa* is still available.
b. Along the Koodam and adjacent areas, below 800 m elevation (Compartments 4, 5, 12, etc) 90% of the *Vateria* population had been extracted in the past and now the species is largely restricted to the river courses. These areas were the natural habitats of the species, and the area can be augment-planted.
c. Because *V. macrocarpa* prefers swampy, hydric edaphic environments, banks of reservoirs might also be suitable. However, this requires preliminary experimental studies.

Conclusions

1. According to the IUCN criteria, *Vateria macrocarpa* is an endangered species, as its area of occurrence is under 5,000 km^2 and area of occupancy under 500 km^2. Muthikulam Reserve Forest (RF) in Kerala is the largest abode of the species with a sister population in the Bolampatty RF of Tamilnadu. In the Muthikulam RF, the elevational belt 1000-1350 m, is a high-density area of the species. All life stages of the species are copiously represented in this area and may be declared the 'last survival site' of the species. The last instance of selective logging and the construction of the Siruvani Dam heavily thinned out the populations of the species in the lower reaches of the distributional area in the Muthikulam RF.

2. An approximate population size of the species is $\pm$ 70,000 mature trees. A good percentage of the population inhabits the Siruvani Group of Plantations, where the tree is part of the original

reminiscent vegetation. Transformation of cardamom plantations to coffee plantations involves further culling of shade tree populations and therefore should not be allowed in the above plantations lest it should affect a major portion of the living population of *V. macrocarpa*.

3. Although there is no immediate threat of appreciable loss of a significant percentage of the population of *V. macrocarpa* in the natural forests, conservation measures are desirable for the sustenance of the population. The conservation measure may include two activities:

    i. The low and medium density strata identified within the Muthikulam RF, which were impoverished of *V. macrocarpa* may be augment planted with seedlings of the species.
    ii. All future management plans for the Muthikulam RF may include strategies that will not hamper with the populations of *V. macrocarpa*.

4. Flowering and fruiting events display considerable intra-population variation. Not all the trees flower every year, and not all the flowering trees succeed in producing mature fruits. The loss of mature fruits is basically due to immature fruit fall, which is caused by a weevil and apparently it affects the germination percentage.

5. The fruits of *V. macrocarpa* do readily germinate and there are no difficulties in raising seedlings. The fruits reflect certain undesirable position effects on the emerging seedlings and produces coiled seedlings, which are not suitable for planting. Coiled seedlings are not produced when the plane of the curvature of the fruit's beak and the plane of the ground coincide.

6. Transplantation of seedlings to the Kakki Reservoir area, south of the Palghat gap, proved that 44% of the seedlings survived 5 months; it is likely that the species survive afterwards also. This shows that the restricted distribution of the species is basically due to its inefficiency in dispersing the fruits far and wide, because of the heavy fruits.

3. *Dipterocarpus bourdillonii* Brandis (Fam.: Dipterocarpaceae)

Introduction

Within the tree family Dipterocarpaceae the genus *Dipterocarpus* is well known for the timber value of several of its species. *D. bourdillonii* and *D. indicus* are two species endemic to the Western Ghats. Both are lofty evergreen trees of primary wet evergreen forests growing to a height of 45 m. Compared to its related species *D. indicus, D. bourdillonii* generally grows larger (1-1.5 m dbh).

While *D. indicus* is distributed all through the Western Ghats, *D. bourdillonii* is of limited distribution. Presumably because of its restricted distribution, there are only a few specimens in herbaria. It is an element of the low level evergreen forests, earlier reported from Malayattur, Pooyamkutty, Attappady and Wayanad. Ramesh and Pascal (1997) assigned a threatened status to the species.

The timber of the species was long been exploited for softwood. Tall straight and unbranched bole makes *D. bourdillonii* attractive both from the point of view of its use value. Apparently with the intention of raising plantations of the species, there were sporadic but unsuccessful attempts at propagating the species, particularly in the Kerala Forest Department.

The small population size of the species is further complicated by its reproductive inefficiency. Each mature tree produces several thousand fruits/seeds, but, dead embryo is the rule and therefore germination trials fail. *D. bourdillonii* being a timber species of potential plantation value, developing successful propagation techniques is also desirable.

D. bourdillonii is also a flagship species contributing to the forest composition and architecture of the low elevational forest type: *Dipterocarpus bourdillonii – D. indicus – Anacolosa densiflora* type, described by Pascal (1988). The future genetic value, the flagship nature, endemic and patchy distribution, and the threatened status of the species underline the need for its conservation.

Materials and methods

Herbarium specimens of *D. bourdillonii* were examined at Madras Herbarium (MH), Coimbatore, and Tropical Botanical Garden and

Research Institute (TBGRI), Trivandrum, and Kerala Forest Research Institute (KFRI), Peechi, in order to locate the distributional areas of individual species. This was followed by extensive exploration of the distributional area for getting higher resolution for the distributional data. Malayattur, Attappady, Achenkovil, Moozhiyar, Azhutha and Pamba areas were explored for finding out the extent of distribution. Six 0.1 ha plots were enumerated for estimation of the population of at Moozhiyar. Complete enumeration of the population of the species was done at Malayattur (Urulanthanni & Pinavoorkudi) and Munnumukku (Mooziyar), where the population is extremely small. Phyto-sociological and demographic details were studied in sample plots (0.1 ha) in each of the strata. Reproductive phenological studies were conducted of twenty-five trees distributed along the Moozhiyar-Pamba transect; the trees were marked and phenological observations made at fortnightly interval. Twenty fortnightly phenological observations were made of the trees. Germination ecology and some transplantation experiments of the species were also conducted.

Karanjali, the Malayalam vernacular is applicable to both *Dipterocarpus indicus* and *D. bourdillonii*. In the following sections Karanjali has been used in place of *D. bourdillonii*.

Results and discussion

Dipterocarpus bourdillonii Brandis in Hooker, Ic. Pl., ser. 4, t. 2403. 1986; Bourdillon, For. Trs. Travancore 32. 1908; Gamble, fl. Pres. Madras 1: 58. 1957; KFRI, Dipterocarps of South Asia, 68. 1985; Balasubramanyan *et al.*, *Field key to arborescent trees of Kerala*, 73. 1985. – **Figs. 21-23.**

Mal.: Karanjali, Karutha anjali.

Large trees, 40-45 m tall (Fig. 21 A), 1-1.2 m diam (Fig. 21 C), with a spreading crown (Fig. 21 B) and a clean straight bole of 30-35 m, bark pale, thick, exfoliating in thick irregular flakes;. Herbage covered with dense rufous tomentum (Fig. 22 A). Leaves alternate, simple, stipulate, stipules large, stipular scars annular, petioles 3.8-5 cm long, swollen at the tip, stellate-pubescent; blade 25-40 x 12.5-25 cm, elliptic-oblong (Fig. 22 B), base subcordate or rounded, tip acuminate, margin wavy and ciliate when young, glabrous except the ribs above, stellate-pubescent along the veins beneath, lateral nerves 15-25 pairs, oblique, intercostae sub-scalariform (Fig. 22 B); coriaceaous. Racemes axillary (Fig. 23 B), pendent, 4-6 flowered, peduncle tomentose. Flowers short-stalked 1.5-2 cm wide (Fig. 23 C). Calyx tube 5-lobed, campanulate, outer surface 5-ribbed (Fig. 23 E & F), ribs antipetalous. Petals 5, 5 cm long, oblong (Fig.

23 C), pubescent, twisted in bud, contorted, base coherent while falling, apex obtuse; creamy with slight purple tinge. Stamens many, anther yellow, connective produced into a bristle (Fig. 23 D). Ovary ovoid, tomentose, enclosed within the calyx tube, style cylindrical, stigma 1, slightly enlarged than the style. Fruit a nut, encased within the calyx cup, calyx cup 5-ribed; fruiting sepals 5, accrescent, 2 sepals large, 10-13 x 1.5-2.5 cm, oblong (Fig. 23 G), base cuneate, apex obtuse or rounded, 3-nerved to the middle, reticulate, assisting in short-distance dispersal, smaller sepals 3, -1.5 cm long, ovate. Nut ovate-ovoid (Fig. 32 A), embryo 1 (Fig. 32 C), mostly dead (Fig.32 B).

Wood: The wood is diffuse–porous with moderately large vessels and resin ducts traversing vertically. Sap wood and heartwood are fairly well demarcated and the latter pale red to reddish–brown, moderately hard and moderately heavy (Chowdhury and Ghosh, 1958; Gottwald and Parameswaran, 1966; FAO, 1985), but difficult to wax and polish (Sekhar, 1955). Because of its restricted occurrence, in trade, it was not distinguished from other species of *Dipterocarpus* and the timber was used in plywood industry.

Specimens: KERALA: **Palakkad Dt.:** Behind bridge, Mukkali, 380 m, fl., 4-4-1983, *Nair, N.C. 78309* !(MH). Mandampotty Forests, Mukkali, 550 m, fl., 22-1-1980, *Nair, N.C. 65660* ! (MH). **Ernakulam Dt**.: Malayattoor, fl., 10-2-1898, flowering January to February, fr. May to June, *Bourdillon T.F. 3039* ! (FRS). Angamoozhi, Ranni Forest Div., 25-2-1984, *Mahadevan, N.P., Venkatasubramanyan N., and Sasidharan, K.R. 9217*! (FRS). Kandamkayam, Azhutha River Bank, Ranni Reserve, 14-9-1982, *Subramanyan K.N. 8626* ! (FRS).

Population ecology of *D. bourdillonii*

Distribution

The species is endemic to Southern Western Ghats extending from Shimoga (Coorg) southwards. There are reports from Coorg (Pascal, 1988; Ramesh and Pascal, 1997), Sholayar, Edamalayar (Pooyamkutty forests), Kallar Valley, Ranni and Kulathupuzha (FAO, 1985). Though the species extends from Shimoga (Karnataka) southwards, its distribution is broken into a few disjunct patches (Ramesh and Pascal, 1997; Fig. 24 A).

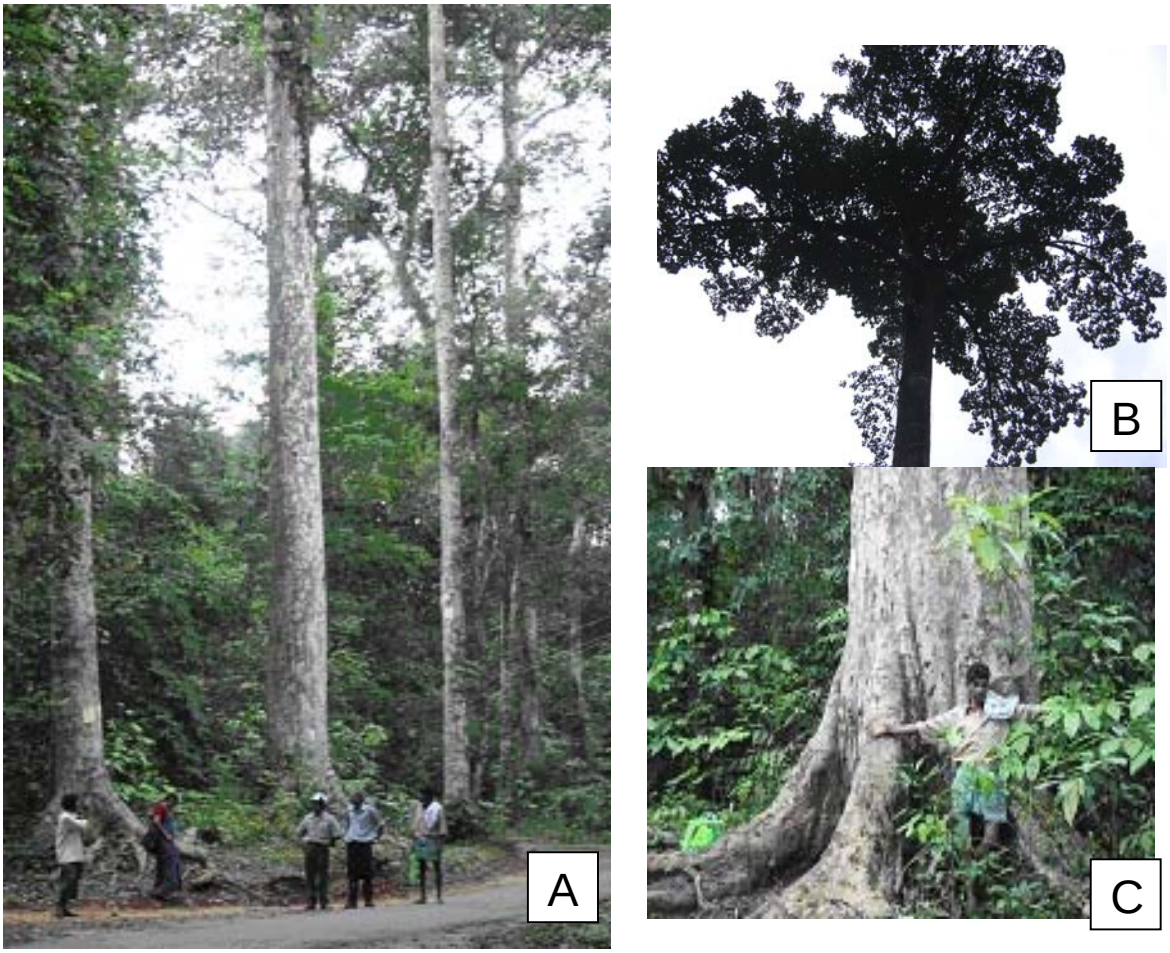


Figure 21. *Dipterocarpus bourdillonii.* Fig. 21 A. A stand showing the gigantic trees of *D. bourdillonii.* Fig. 21 B. A picture showing the large size of the bole. Fig. 21 C. The crown.

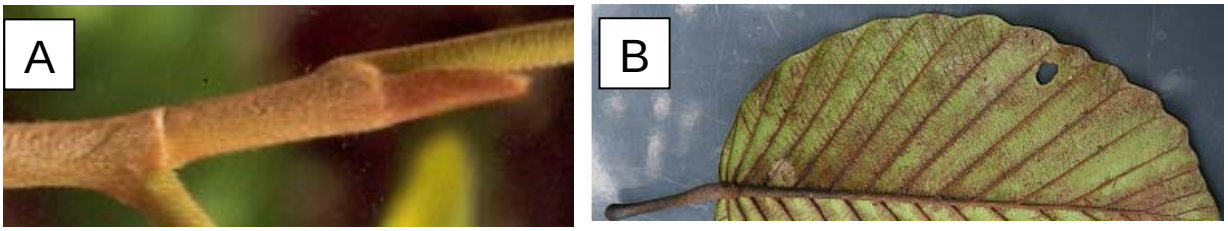


Figure 22. *Dipterocarpus bourdillonii.* Fig. 22 A. The bud and young plant parts are covered with rufous tomentum. Fig. 22 B. A mature leaf showing the wavy margin, oblique nerves and sub-scalariform intercostae.

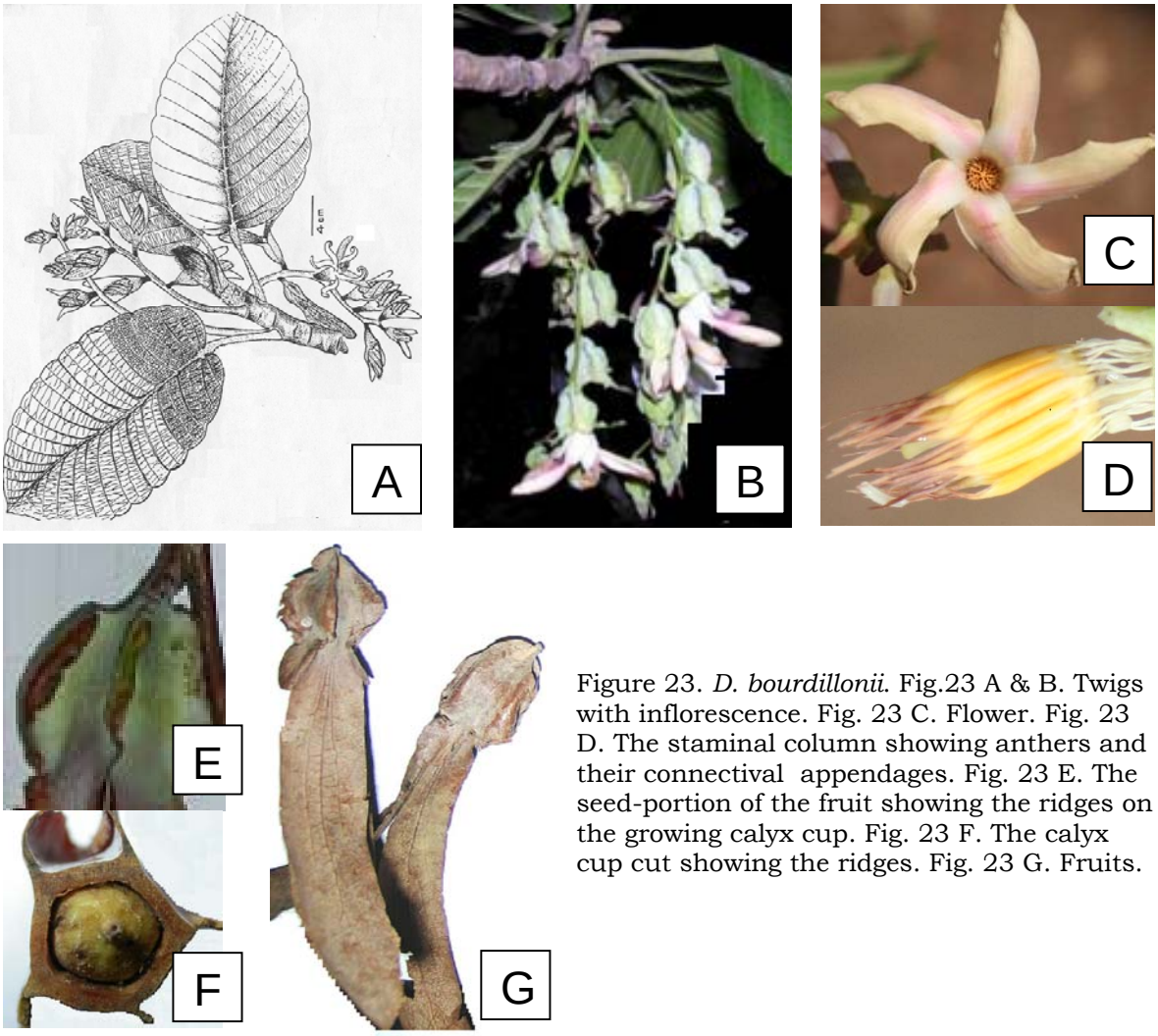


Figure 23. *D. bourdillonii.* Fig.23 A & B. Twigs with inflorescence. Fig. 23 C. Flower. Fig. 23 D. The staminal column showing anthers and their connectival appendages. Fig. 23 E. The seed-portion of the fruit showing the ridges on the growing calyx cup. Fig. 23 F. The calyx cup cut showing the ridges. Fig. 23 G. Fruits.

Ramesh and Pascal (1997) also assigned a '*threatened*' status to the species. The species is mostly confined to river banks at low elevations up to 400 m asl (Fig. 24 B & C); in this it resembles *Vateria macrocarpa.* Champion and Seth (1968) observed that the rock formation beneath the species is of gneiss, quarts and felspar. The soil is loamy, alluvial in Ranni, of chocolate-coloured loam at Sholayar and alluvial at Kallar.

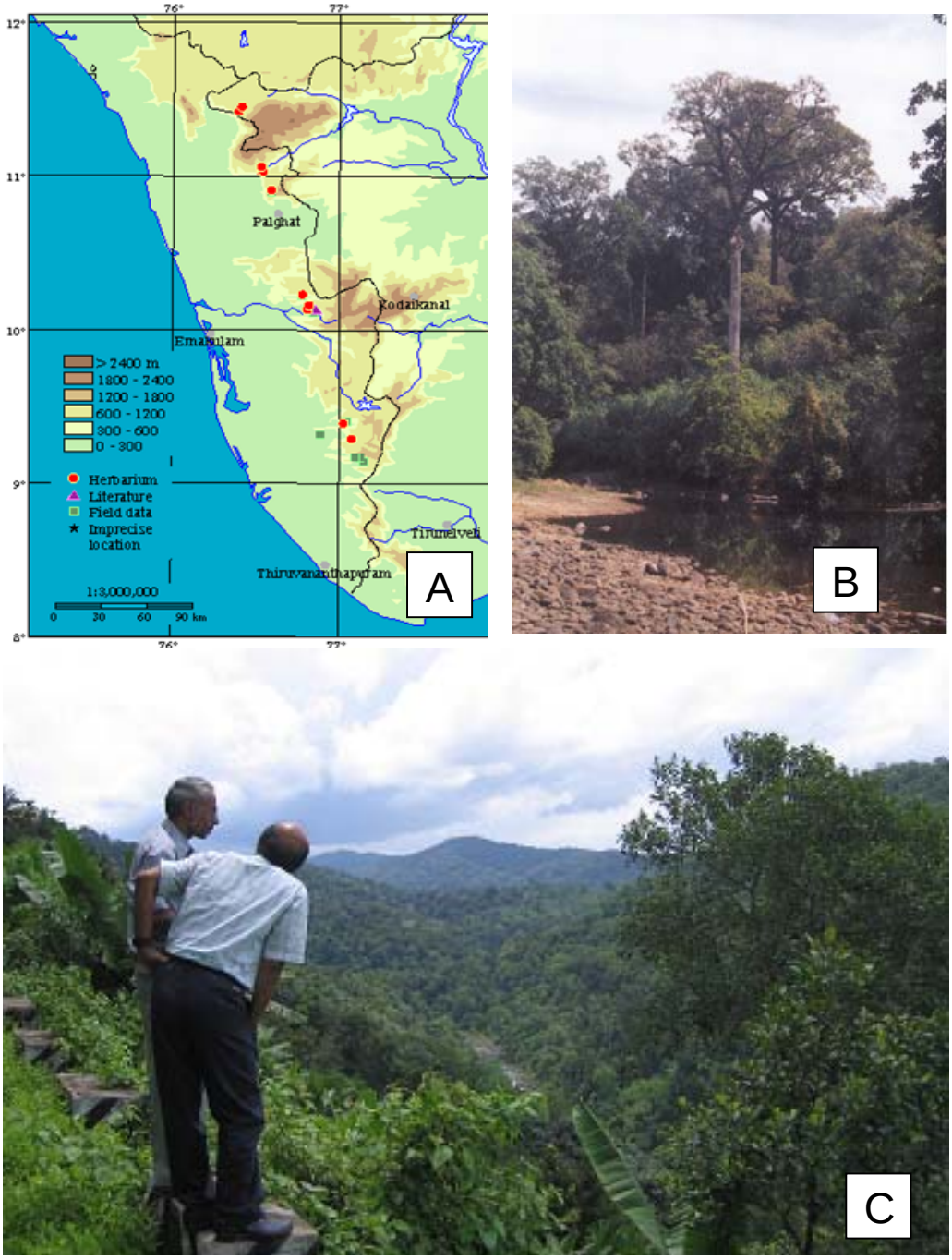


Figure 24. *D. bourdillonii*. Fig. 24 A. Distribution. Fig. 24 B. A riparian habitat where the species inhabits. Fig. 24 C. Another view of the riparian habitat.

South of the Palghat Gap, we have located the species from the following locations.

- **MALAYATTUR FOREST DIVISION**: Urulamthanni area (Near Pooyamkutty forests), and Pooyamkutty forests (rare)
- **GOODRICKAL FOREST DIVISION**: Angamoozhi Jn, Moozhiyar mukku, Moozhiyar
- **PERIYAR TIGER RESERVE:** Thriveni Samgamam at Pamba
- **KONNI FOREST DIVISION:** From Attathodu to Pamba, especially from Chalakkayam to Pamba, along t he banks of Manian Ar, Kakki Ar and Pamba Ar.
- **ACHANCOIL FOREST DIVISION:** Vazhaperiyar area (30 km E of Achankovil in the Kallar Valley).

Distribution of *Dipterocarpus bourdillonii* in the Periyar Tiger Reserve and the adjacent Konni Reserved Forest based on actual field investigations are depicted in Fig. 25.

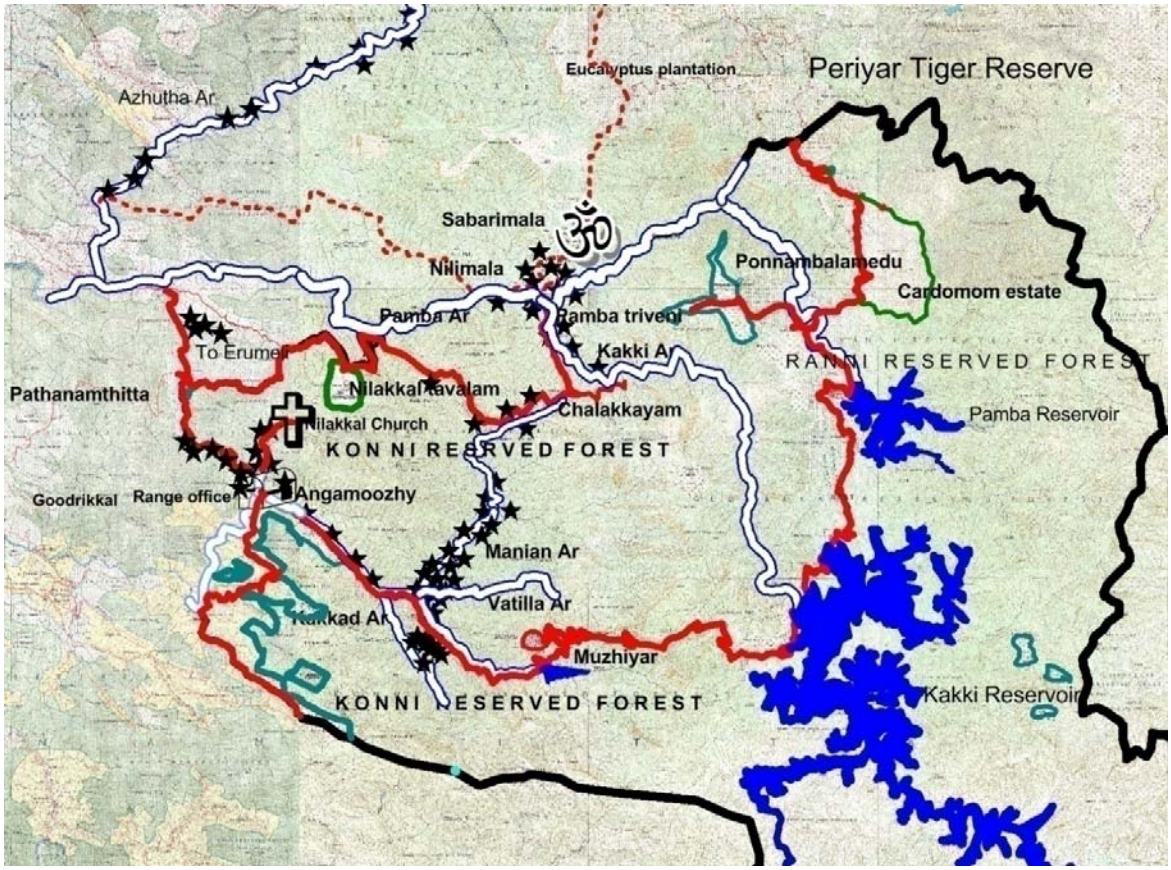


Figure 25. Map of Periyar Tiger Reserve and adjacent areas showing the distribution of *Dipterocarpus bourdillonii*. The asterisk marks indicate geopositions of trees of *D. bourdillonii*. The species is distributed along the river courses of tributaries of Pamba Ar.

Communities supporting D. bourdillonii

Structure of the stands containing *D. bourdillonii* is found to differ. At Ranni and Sholayar, *D. bourdillonii* coexists along with *D. indicus*

(Karunakaran, 1975; Viswanathan, 1958). At Kallar however, it is not associated with *D. indicus.* Community structure of stands where *D. bourdillonii* is found, in terms of species importance values are:

Composition of the stand at Goodrikkal (south of Palghat gap) is given in Table 21. The community according to the dominance structure is *Dipterocarpus bourdillonii - Turpinia malabarica - Cinnamomum malabatrum - Drypetes oblongifolia - Baccaurea courtallensis - Strombosia ceylanica community*. Here, though the density and frequency of *D. bourdillonii* are low, it has gained dominance by way of its large basal area.

Table 21. Structure of the stand in the decreasing order of dominance at Pannikunnu in the Goodrikkal Forest Range (South of Palghat Gap).

Species	**D**	**BA**	**RD**	**RF**	**RBA**	**IVI**	**RIVI**
Dipterocarpus bourdillonii	28	36.87	5.5	6.1	47.6	59.1	19.7
Turpinia malabarica	65	1.66	12.9	9.1	2.1	24.1	8.0
Cinnamom.malabatrum	50	3.78	9.9	8.1	4.9	22.9	7.6
Drypetes oblongifolia	55	1.40	10.9	7.1	1.8	19.8	6.6
Baccaur. courtallensis	48	0.60	9.4	7.1	0.8	17.3	5.8
Strombosia ceylanica	33	2.37	6.4	6.1	3.1	15.6	5.2
Knema attenuata	30	2.75	5.9	5.2	3.6	14.5	4.9
Tetrameles nudiflora	3	10.03	0.5	1.0	12.9	14.4	4.8
Polyalthia fragrans	28	0.80	5.5	6.1	1.0	12.6	4.2
Dysoxyl. malabaricum	15	3.99	3.0	4.0	5.2	12.2	4.1
Hopea parviflora	15	3.83	3.0	4.0	5.0	12.0	4.0
Elaeocarpus serratus	25	0.94	5.0	4.0	1.2	10.2	3.4
Macaranga peltata	15	1.52	3.0	5.1	2.0	10.0	3.3
Hydnocarp.macrocarpa	18	0.37	3.5	4.0	0.5	8.0	2.7
Vateria indica	10	1.03	2.0	4.0	1.3	7.4	2.5
Dillenia pentagyna	8	3.27	1.5	1.0	4.2	6.7	2.2
Artocarp.heterophyllus	13	0.21	2.5	3.0	0.3	5.8	1.9
Persea macrantha	8	0.64	1.5	2.0	0.8	4.3	1.4
Actinodaph. malabarica	10	0.11	2.0	2.0	0.1	4.1	1.4
Xanthophy.arnottianum	8	0.11	1.5	2.0	0.1	3.7	1.2
Litsea floribunda	5	0.27	1.0	2.0	0.4	3.4	1.1
Drypetes venusta	5	0.06	1.0	2.0	0.1	3.1	1.0
Myristica beddomei	5	0.27	1.0	1.0	0.4	2.4	0.8
Sterculia guttata	3	0.36	0.5	1.0	0.5	2.0	0.7
Holigarna beddomei	3	0.22	0.5	1.0	0.3	1.8	0.6
Dimocarpus longan	3	0.02	0.5	1.0	0.1	1.5	0.5
Garcinia wightii	3	0.02	0.5	1.0	0.1	1.5	0.5
Total:	**505**	**77.51**	**100.1**	**100.0**	**100.0**	**300.0**	**100.0**

Compositions recorded in a few other locations are given below.

Sholayar: *Anacolosa densiflora, Antiaris toxicaria, Calophyllum elatum, Toona ciliata, Cullenia exarilata, Dipterocarpus indicus, D. bourdillonii, Diospyros assimilis, Dysoxylum malabaricum, Elaeocarpus tuberculatus, Holigarna arnottiana, Hopea parviflora, Persea macrantha, Knema attenuata, Palaquium ellipticum, Polyalthia fragrans, Vateria indica* (Viswanathan, 1958).

Ranni: *Dipterocarpus indicus, D. bourdillonii, Cullenia exarillata, Hopea parviflora, Calophyllum elatum, Mesua ferrea, Persea macrantha, Palaquium elllipticum, Canarium strictum, Artrocarpus heterophyllus, Syzygium cumini, Dysoxylum malabaricum, Vitex altissima, Gluta travancorica, Lophopetalum wightianum, Alstonia scholaris, Acrocarpus fraxinifolius, Semecarpus anacardium, Polyalthia fragrans* (Karunakaran,1975).

Kallar: *Dipterocarpus bourdillonii, Vateria indica, Bischofia javanica, Knema attenuata, Hopea parviflora, Hydnocarpus pentandra, Mesua ferrea, Tetrameles nudiflora, Trema orientalis, Humboldtia vahliana, Myristica magnifica, Gluta travancorica.*

Population size of D. bourdillonii

Outside the conventional floristic documentations, no population details of the species were available.

The areas explored and the trees encountered are summarized in Table 22. The species has been found restricted to areas adjoining river courses only in interior forests. Major outcomes are also summarized subsequently.

Table 22. Number of trees of *Dipterocarpus bourdillonii* (>= 30 cm gbh) recorded during field visits.

No.	Locations	Trees
1	Urulamthanni, Pinavurkudi	51
2.	Manikandanchal, Pooyamkutty	19
3.	Moonnumukku, Muzhiyar	28
4.	Pampa, Periyar Tiger Reserve	49
5.	Vazhaperiyar, Kallar valley, Achankovil	25
	Total:	**174**

The populations of the species north of the Palghat Gap were not explored in this study. The species in Karnataka (in the Coorg area) has

also not been explored in the present study. As a result, the current estimate of the population size of the species south of Palghat gap is only 174 trees ≥ 30cm gbh. The largest population encountered was composed of 51 trees at Pinavurkudi (Urulamthanni) and 49 trees at Pampa. In other places, the species is very sparse with few individuals. Apparently, the situation has arisen due to devastation of once extensive low level evergreen forests and the past logging activities. The species now is 'Critically Endangered' status as per the IUCN criteria.

Population structure of D. bourdillonii

Structure of a major section of the population of the species occupying was analyzed. Of the 179 trees (≥30cm gbh), 78 were Very-Large-trees (Girth Class, GC: >270 cm), 37 Large-trees (GC: 180-270 cm), 48 Medium-trees (GC: 90-180cm). There were only 9 Small-trees (GC: 60-90 cm) and 7 Poles (GC: 30-60 cm) recorded. Against this there were only 20 Saplings (GC 10-30cm), which is a very low figure. The largest tree so far encountered was with a circumference of 775.2 cm gbh (= 246.8 cm dbh) from Moonnumukku, Goodrikkal. Trees in the range of 400-600 cm gbh are also frequent.

Life stage structure of four larger populations is given in Fig. 26. Individual populations of the species differed in their life stage structure. Two out of the four populations at Moonnumukku and Pamba had only larger girth classes, ≥ 60cm gbh, *i.e.*, they did not have young ones to replace their older trees (Fig. 6 A & B). The structure at Manikandanchal (Pooyamkutty) also approached a similar pattern, with limited representation in lower classes (Fig. 26 C). The Pinavurkudi-population had all the life stages including Established seedlings, Saplings, Poles and Mature trees. Against the population of 179 mature trees (>= 10cm dbh) we have come across with only 70 seedlings.

At Moonnumukku and Pamba seedlings were almost wanting and at Pamba, both seedling and young tree-populations were also wanting. The skewed population structure at Pamba can be due to the impact of intense pilgrimage (to Sabarimala) on the local vegetation. At Pinavurkudi, there are a few scattered seedlings and advanced seedlings. Low frequencies in smaller size classes speak of reproductive barriers and the non-viable embryo in the mature fruits precisely indicates this.

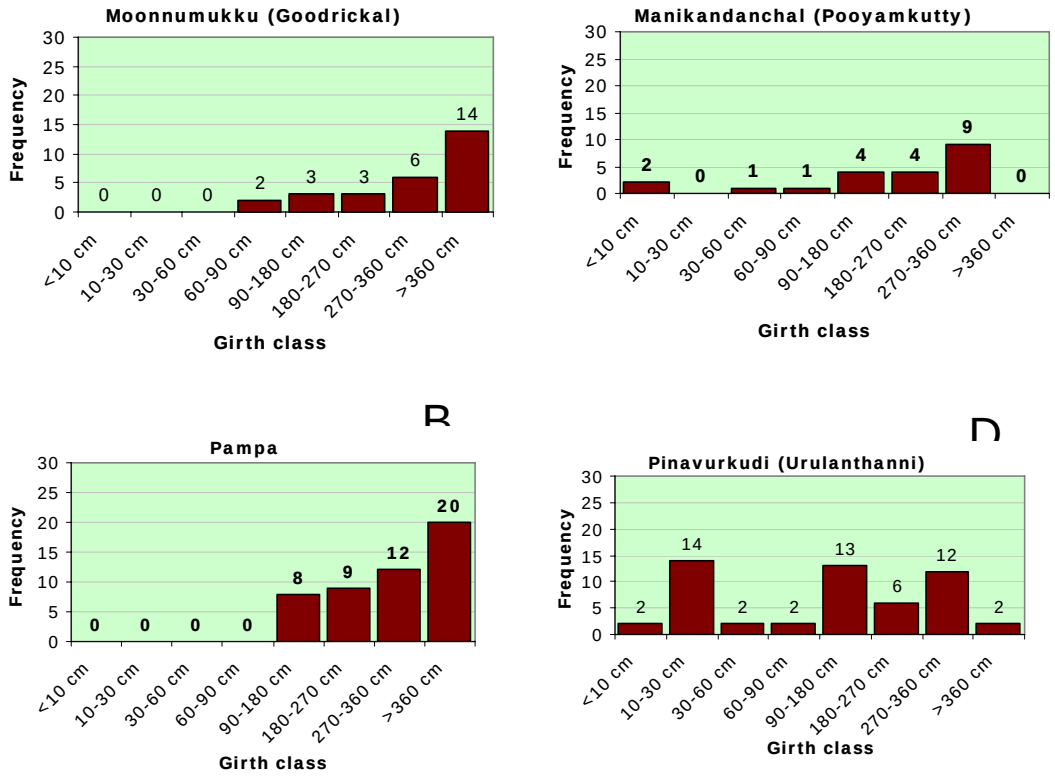


Figure 26. Population structure of *Dipterocarpus bourdillonii*.

Reproductive biology of *D. bourdillonii*

Reproductive biological studies of the species was conducted in order to: (a) identify prevailing reproductive constraints if any, (b) identify the life stages at which the reproductive anomalies operate, and (c) to generate knowledge useful for the effective propagation of the species. The findings from the above studies are discussed below.

Reproductive phenology of D. bourdillonii

Most of the results discussed are based on 20 fort-nightly observations on 25 marked trees of the species in the Pamba-Moozhiyar transect. Phenogram of the species is presented in Fig. 27.

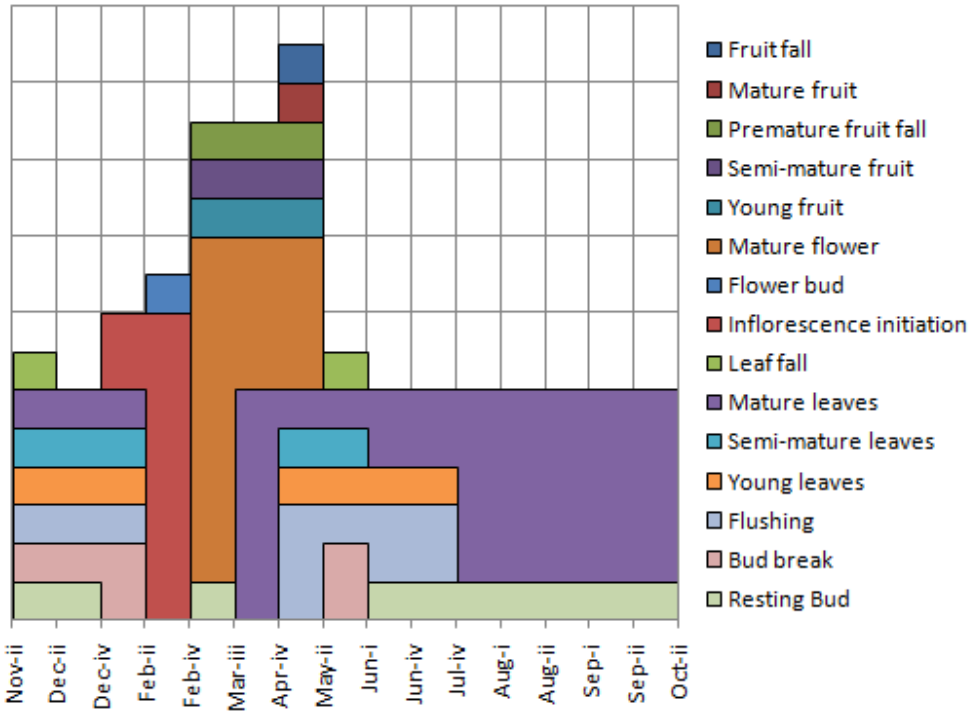


Figure 27. Phenogram of a tree of *Dipterocarpus bourdillonii* during 2003-2004 at Pamba. The graph indicates only the temporal span of different phenophases and does not provide details of intensity of each pheno-expression. It also does not provide any details about the intra-population variations in pheno-behaviour.

Though *D. bourdillonii* is essentially evergreen, most of the old leaves are shed during March. Leaf fall takes place immediately before initiation of flowering and new flush appears soon after leaf fall. A second episode of leaf production (leaf fall and flushing) is also observed during April to July (Fig. 27). Normally flowering spans between January and February and the fruits mature during April-May (FAO, 1985). Trees at Muzhiyar and Pamba flowered from mid-January → March; sporadic flowering from mid-November → late-December was also observed (Fig. 28). Mature fruits are available by May. By June there is a rich fruit/seed carpet on the ground. Flowering, fruit development and dispersal were found synchronous, *ie*, without much time lag across the individuals of the population.

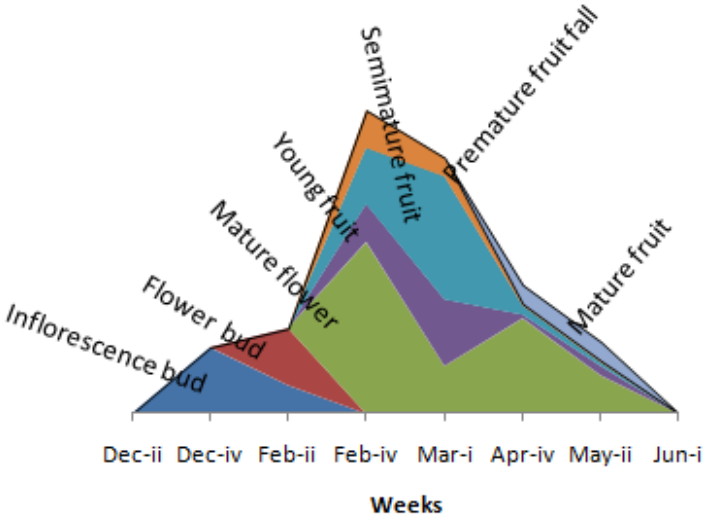


Figure 28. Intensity and temporal span of reproductive phenophases of *Dipterocarpus bourdillonii*.

Fruit development and seed set

One seed per fruit is the rule as only one out of six ovules mature into the seed. The rest of the ovules degenerate. Apparently this is part of a parent-offspring resource conflict or more appropriately a resource economization mechanism. Flowering to mature fruit spans for 75-80 days. Sixty to 65 days after flower opening the fruits undergo browning. Drying of fruits takes place thereafter. Each tree bears thousands of fruits (Fig. 29) but the fecundity of the fruits is low.

Figure 29. A fruiting tree of *Dipterocarpus bourdillonii*. Despite the low fecundity, *D. bourdillonii* flowers and fruits copiously. For details see the text.

Factors affecting fruit/ seed populations in D. bourdillonii

Insects interfere the reproductive cycle of *D. bourdillonii* in two stages, flower buds and fruits. Two groups of insects, the Dipteran and the Lepidopteran, attack the growing flower buds. Larvae of an unidentified Dipteran grow inside the flower buds and cause immature flower fall (Fig. 30 A). Larvae of another unidentified Lepidopteran were also found in the flower buds eating up the floral parts inside the corolla (Fig. 30 B). Often, the buds fall off and metamorphosis of the insect takes place there and adult emerges out.

Figure 30. *Dipterocarpus bourdillonii*. Fig. 30 A. Flower buds abscised due to Dipteran attack. Fig. 30 B. Insect larvae emerging from the flower bud. Fig. 30 C. Weevil.

Insects attacking the fruits are weevils (Fig. 30 C); weevils ovipose inside the ovary near the base of the style. The larvae grow inside at the expense of the embryo (Fig. 31) but fruit development and dispersal go routine. The mature insects emerge out of the fruits before or after dispersal.

Flower damage by insects is roughly 10-12%; the flower and fruit damage together causes ca. 40-45% reduction in overall fecundity.

Pre-mature degeneration of embryos

Dissections conducted 10-20 days prior to dispersal in open pollinated fruits have shown that around 61% of fruits have decayed embryo but without any trace of insect infestation. The decay of embryo was complete and transforms to a dead, brown amorphous mass within the seed (Fig. 32 B).

Figure 31. Longitudinal sections of the nut of submature fruits of *Dipterocarpus bourdillonii* showing the insect larvae.

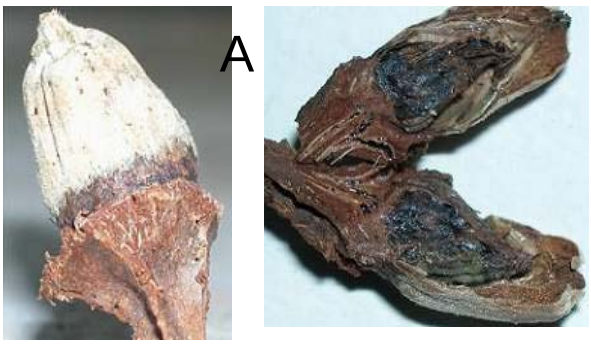


Figure 32. *Diptero-carpus bourdillonii*. Fig. 32 A. A nut excised from the calyx cup. Fig. 32 B. A mature fruit split open to show the decaying embryo. Fig. 32 C. A viable embryo inside the fruit.

Fruit dispersal: Supported by the two alar calycine wings, *D. bourdillonii* is basically anemophilous. Low wind currents take the winged fruits to shorter distances from the mother tree. In the case of Dipterocarps devoid of alar wings for the fruit (eg., *Vateria, Vatica,* etc.), most of the fruits fall around the mother tree, as there are no special mechanisms assisting dispersal. The result is mother-centered populations. In species with winged fruits, short-distance dispersal to a distance of 20-40m from the mother trees is achieved (Tamari and Jacalne, 1984). This dispersal syndrome though is capable of impacting the mother-centered population build-up, the impact is low (Fig. 33 A & B).

Figure 33. Two views of a clustered population of *Dipterocarpus bourdilloni* at Urulamthanni. Clustered populations generally are due to the lack of efficient seed dispersal mechanisms. For details see text.

Propagation studies in *D. bourdillonii*

The percentage of germination obtained from different experiments varied. In a trial containing 513 seeds collected from five trees, 15 seeds germinated thus providing 2.9 % germination. The un-germinated 140 fruits (27 %) were found infested by insects. Thus, out of the healthy 373 seeds, the actual germination percentage obtained was only 4%. In two other trials containing 600 and 500 seeds each, 1.5 and 2.4 % germinations were obtained respectively (Fig. 34). A few seed germination trials conducted at Pamba and Konni resulted in total failure (Information from the Kerala Forest Department).

Figure 34. *Dipterocarpus bourdillonii*. Fig. 34 A. Germination trial. Fig. 34 B. A geminating seed.

Fruit dissection studies showed that the percentage of fruits with viable embryo at maturity was only 7.4 percent. The extremely low fecundity of fruits/seeds, low germination turn over and the general failure of germination trials are strong indications of abnormal reproductive behaviour. A resolution of these issues requires further reproductive biological studies.

D. bourdillonii is native to and natural in the low elevational evergreen forests of Kerala, particularly along the riverine vegetation. This forest type was much more widespread in the past along the lowlands and the midlands, where the rivers are wider. Expansion of settlements and transformation of many riverine habitats for agriculture in both the lowlands and midlands had a serious impact on the species. As a result of this, the natural habitat of the species shrunk drastically. In southern Kerala, the selective logging which was operative during the first half of the 20th century included *D. bourdillonii*. The timber of trade 'Karanjaly' included both *D. indicus* and *D. bourdillonii* in the past. Practically this helped devastating the larger seed bearing populations of *D. bourdillonii*

at locations such as Achankovil and Kulathupuzha. As narrow river tributaries join together to become mainstreams, denudation of vegetation along the main streams results in fragmentation of the riparian vegetation along the tributaries. All these activities apparently transformed *D. bourdillonii* to relictual populations restricted to remote narrow riverine habitats away from broader sections of the rivers. The small, patchy and disjunct populations comprising 19-51 individuals of *D. bourdillonii* precisely represent this situation. In some locations, the population is made up of just five individuals. The natural consequences of small and fragmented populations are: (a) Diminished chances for cross pollination and cross fertilization, (b) Constrained gene-flow, and (c) Inbreeding depression. Inbreeding depression leads to incompatibilities which in turn are expressed as reproductive abnormalities. The unviable embryos of *D. bourdillonii* could be an example of this situation. This also reinforces the need for further reproductive biological studies.

Seed propagation in D. bourdillonii

Natural regeneration: As the species is of restricted distribution, no serious attempt has been made for its propagation. Seedlings collected from the wild were transplanted in degraded evergreen forest at Kulathupuzha on an experimental basis and was found to be successful (FAO, 1985).

Conservation biology *of D. bourdillonii*

Threats to D. bourdillonii

Past selective logging and opening up of low-level riparian evergreen forests had a definitive role in reducing the populations of *D. bourdillonii*. The extent of the impact of selective logging on the species is obliterated by the application of the same trade name 'Karanjali' for both *Dipterocarpus indicus* and *D. bourdillonii*.

At least in a few instances, the populations of the species inhabit areas adjoining settlements. The Urulamthanni population is a typical example. The natural habitat of the species there is a small patch of evergreen forest enclosed and surrounded by settlements and agricultural landscapes. Some of large trees have actually been located in encroached private holdings containing crops such as rubber, coconut, pineapple, etc. (Fig.35).

Figure 35. A huge tree of *D. bourdil-lonii* located in a private holding at Urulam-thanni (Pinavoorkudi) in cropland compri-sing of rubber, coconut, pine apple, etc. See the leaves of coconut and branches of rubber over-arching the canopy of *D. bourdillonii*.

At Pamba, where a good number of trees of *D. bourdillonii* is found, the pressure of pilgrimage is high. Hundreds of thousands of pilgrims visiting the Sabarimala Ayyappa shrine in November-December use Pamba as a halting place for camping and resting. The pressure of the pilgrimage is so high that no seedlings of *D. bourdillonii* can grow.

The inherently unviable embryo is a big threat to the sustenance of the species, as there are no cohorts to replace the large trees. The larger trees by virtue of their age are on their way to extinction. Nevertheless, in some places such as Urulamthanni (Pinavurkudi) and Moozhiyar, some seedling and sapling populations were observed (Fig. 36 A).

Past conservation efforts on D. Bourdillonii

As already mentioned, the Kerala Forest Department made some isolated trials to germinate the seeds, which however did not succeed. Subsequently, with the intention of raising plantations of *D. bourdillonii*, which is otherwise a good plywood yielding timber, seedlings were collected from the wild and transplanted in degraded evergreen forest at Kulathupuzha on an experimental basis and was found to be successful (FAO, 1985).

In the present study, we collected 250 wildlings of *D. bourdillonii* and transplanted in the KFRI Campus (Fig. 36 B) as well as along the river course at Upper Moozhiyar. In the KFRI campus, where the seedlings were underneath the moist deciduous forest, all the seedlings survived.

For a total of 250 seedlings planted in 2003 at Upper Moozhiyar, by May 2004, we received only a very a very low rate of survival (7%). This low survival was due to the failure of north-east monsoon in 2003.

Fig. 36. *Dipterocarpus bourdillonii*. Fig. 36 A. A sapling in the field. Fig. 36 B. A seedling planted beneath the moist deciduous forest stand in the KFRI campus.

Suggestions for conservation of D. bourdillonii

1. The larger populations of *D. bourdillonii* at Urulamthanni (Pinavurkudi) and Moozhiyar may be given status as 'last foot hold sites' of the species. These sites may be given location-specific conservation oriented management.

2. Techniques for artificial propagation of *D. bourdillonii* may be evolved through vegetative propagation and tissue culture and the natural sites augment planted with these stocks. Protection to the seedlings during the initial few years may be given to the planted seedlings. A census of the planted site once in six-months is recommended so as to make necessary corrective measures as and when required.

3. Reproductive biology of the species may be subjected to detailed study so as to understand the actual causes leading to unviable embryo. The findings from reproductive biological studies may be utilized for evolving appropriate conservation strategies.

4. *Gluta travancorica* Bedd.
(Fam.: Anacardiaceae)

Introduction

Gluta travancorica was described by Beddome in his *Flora sylvatica* (1870) and was reported from Travancore and Tinnevelly. Dr. Sasidharan (2003) assigned a Low Risk/Near Threatened status for the species. The species is found to inhabit shola forests south of Aryankavu pass in Kerala and Tamilnadu. The timber is of good quality, used for furniture, ship building, turnery and carving industries. In Tamilnadu (Thinnelvely), it is known to be raised in plantations.

Trivedi Babu (1991) provided a brief note on the status of the species then in Kerala. A series of publications on the species emerged subsequently, mainly by Jose (2001), Jose and Pandurangan (2003a, 2003b), and Jose *et al.*, (2000, 2011). These studies included population ecology, reproductive biology, propagation studies, and conservation biology. As a matter of fact, the present study was restricted to limited aspects of the species.

Methodology

Herbarium specimens were examined at Madras Herbarium (MH), and FRS, Coimbatore. Exploration of the distributional area south of the Aryankavu pass was conducted. The areas of distribution of *Gluta travancorica* were explored at Ponmudi in Palode Range Pandimottai area in Kulathupuzha Range (Trivandrum FD), Rosemalai and Rockwood area in Chendurney Wildlife Sanctuary. A GIS has been organized for the distributional area of the species in Kerala.

Twenty-two 0.1 ha plots were enumerated for estimation of the population of *G. travancorica* (Ponmudi, Rockwood). Twelve 0.1 ha plots were enumerated for community ecology.

Fruits of *G. travancorica* were collected from Chendurney WLS (± 300 m) and from populations near the Braimore Estate. Germination experiments were conducted in nurseries at Muthikulam and Moozhiyar.

Internal morphology of the seed, particularly the position of the radicle in the seed/diaspore is very important for the production of the seedling stock. Unfortunately there are no serious studies on the fruit and seed morphology of evergreen trees in the country. Thus efforts were also

made to understand the internal morphology of the fruit/seed of *G. travancorica*.

Two hundred seedlings of *Gluta travancorica* were transplanted at Upper Moozhiyar and Nilakkal forests (Ranni FD) for evaluating their performance.

Detailed reproductive biological aspects have been studied of the species by Pandurangan and Jose (2003a, 2003 b) and therefore only the population aspects have been given thrust in this study.

In the subsequent sections of the text, the Malayalam vernacular 'Chemkurinji' has been used in lieu of *Gluta travancorica*.

Results

Gluta travancorica Beddome, Fl. Sylv. 1: t. 60. 1870; Bourdillon, For. Trs. Travancore 294. 1908; Gamble, Fl. Pres. Madras 1: 186. 1957; Balasubramanyan et al., Field key to arborescent trees of Kerala, 89. 1985 – **Figs. 37-40**.

Malayalam: Chemkurinji

Large trees; height 30-36 m, diameter 1-1.5 m; bark 6-8 mm thick, pinkish-grey, smooth. Leaves simple, alternate, crowded at the tips of the branchlets, petiole short, blade 7.6-15.2 x 2.5-5 cm, elliptic-oblong, base narrow, apex obtuse to acute; coriaceous, lateral nerves 13-16 pairs. Flowers in terminal panicles, small c. 8 mm across, cream-coloured. Calyx syn-sepalous, spathaceous, splitting irregularly, deciduous. Corolla of 4-6 petals, imbricate, spreading, inserted on the elongate-cylindric disk. Stamens 4-6, alternating with the petals, filaments capillary. Ovary 1-celled, oblique, style lateral, filiform, stigma simple, ovule 1. Fruit a drupe, 3.5-3.8 cm across, globose, seed 1, embryo filling the entire seed cavity.

Herbarium specimens:

KERALA: KOLLAM Dt.: Thenmala, 13-7-1978 and 3-4-1964 - *KN Subramanyan (FRS) 7319, 1559*. TRIVANDRUM Dt.: Belamore Estate Tamilnadu 500-3500ft, 21-3-1896 – *TF Bourdillon 3616* (FRS); Kottaram vacha para, way to Agastyar kudam 450Alt 5-3-1980 – *M Mohan 66062* (M H); Uthapanchi, way to Agastyar kudam from Boneecard 1000 ft (M H 59316); Merchiston 900ft (MH 66623); Ponmudi Guest House, Shola forest, Moist forest; Way to Lower Sanatorium to Ponmudi, 850ft -

Vivekanathan 66132 (MH). PALAKKAD Dt.: Muthikulam Forest Office Compound, 1,100 m (Cultivated)., fr. 2-5-1993 – *Sasidharan N 3697* (KFRI). KANNUR Dt.: Vattaparayil , Peria, 825 ft, VS Ramachandran *66856 (MH) – Species originally introduced there as part of silvicultural* experiments.

TAMILNADU: Balamore to Muthukuzhivayal – MH 60791, 77107,77113,52412 (M H); Vallachithodue 70655(M H).

Figure 37. A shola forest stand on the western slopes of Ponmudi showing a tree of *G. travancorica* in the foreground.

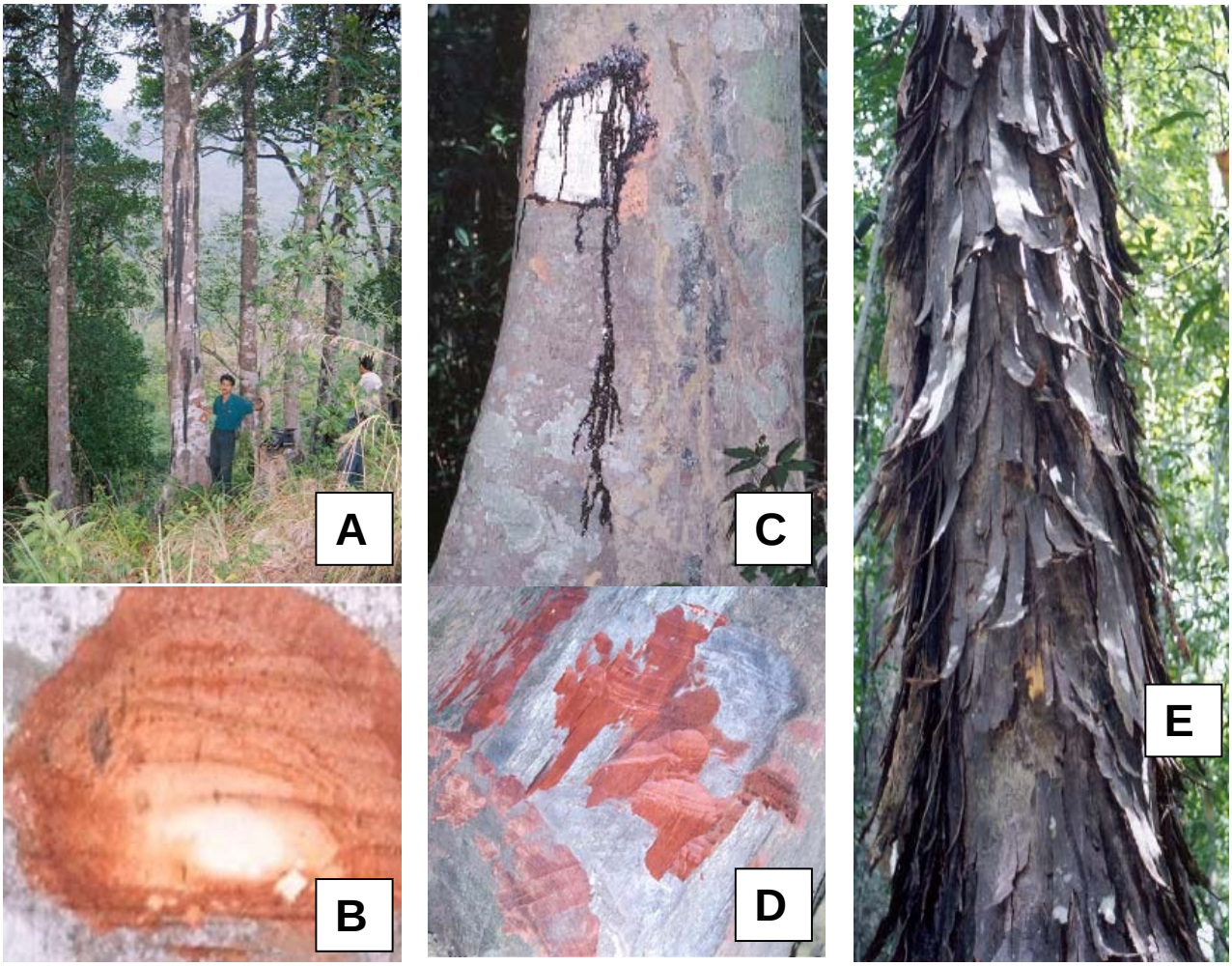


Figure 38. *Gluta travancorica*. Fig. 38 A. Trees of *G. travancorica* in the Breymore Estate. Fig. 38 B. Blaze. Fig. 38 C. A slash on the tree and the dark exudation from it. Fig. 38 D. The rose coloured wood of *G. travancorica.* Fig. 38 E. The characteristic exfoliating bark of *Hopea racophloe*a, an associate of *G. travancorica*.

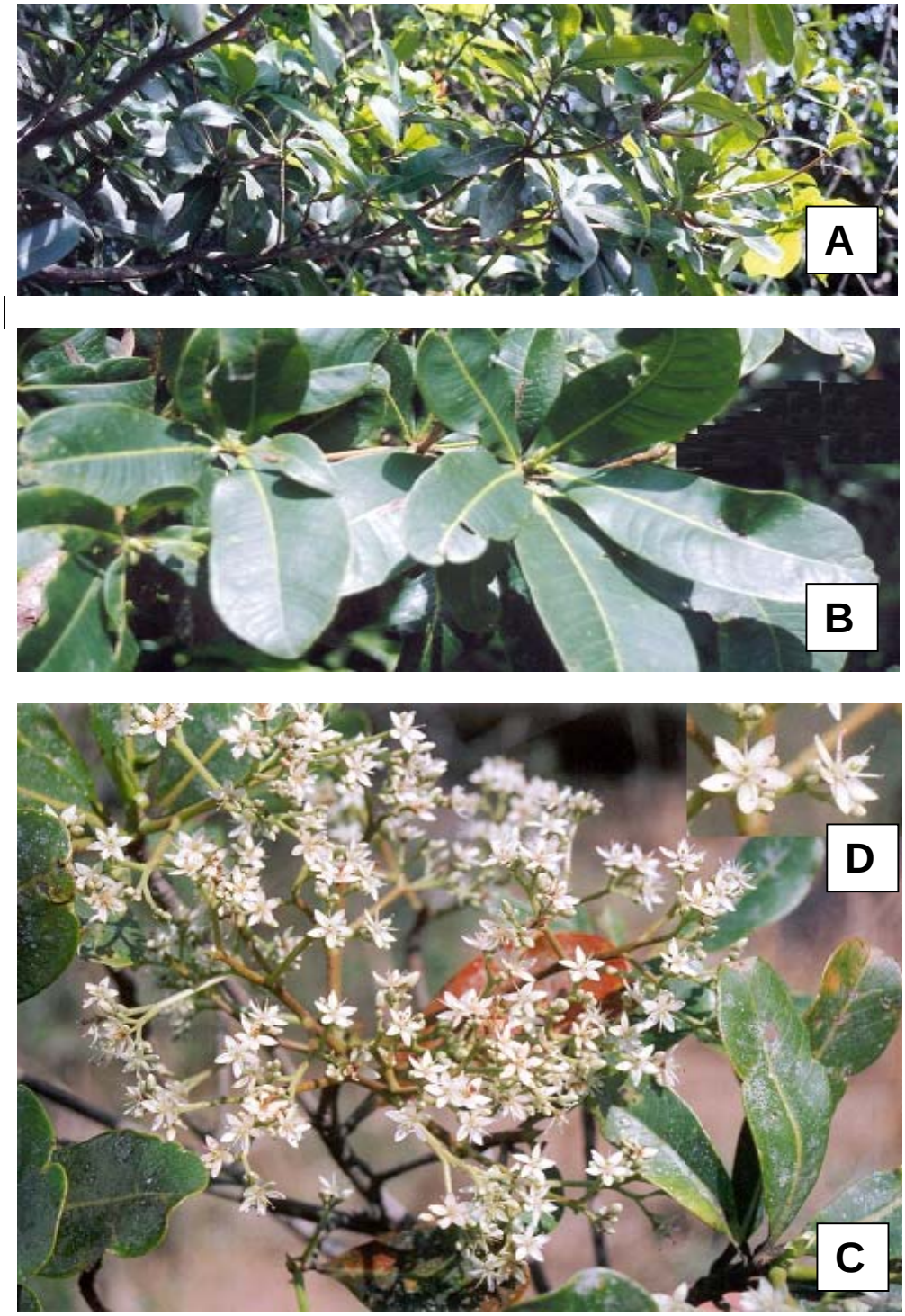


Figure 39. *Gluta travancorica*. Fig. 39 A. The sympodial branching pattern. Fig. 39 B. Leaves. Fig. 39 C. An inflorescence. Fig. 39 D. A magnified view of two flowers.

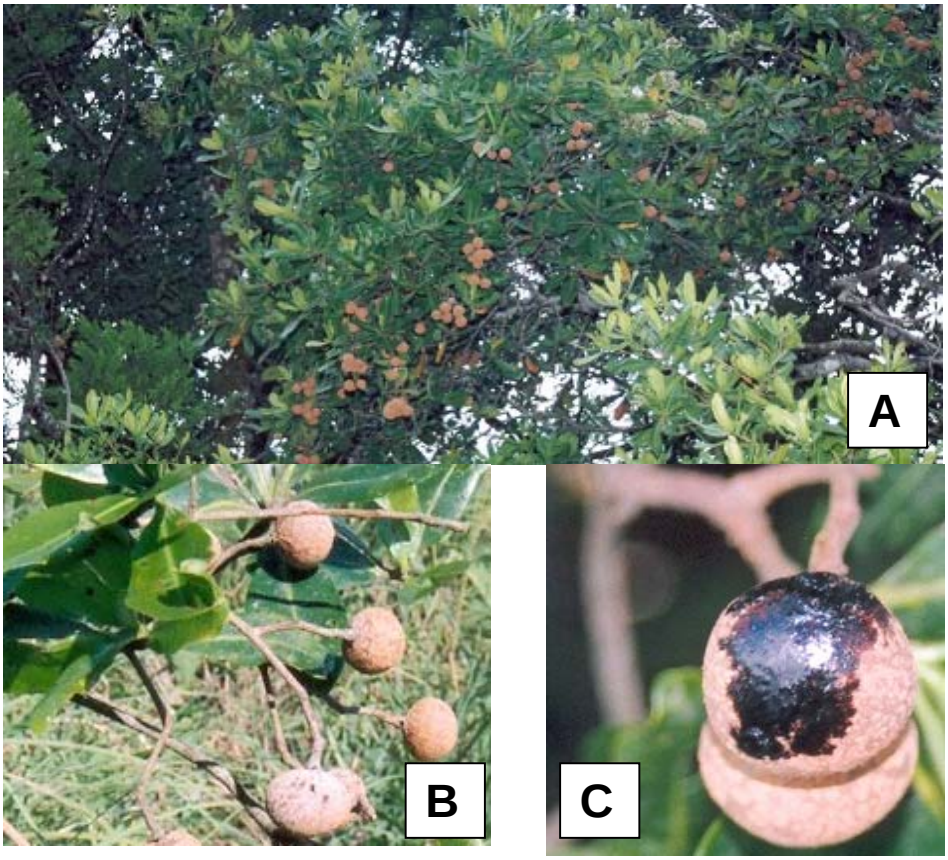


Figure 40. *Gluta travancorica*. Fig. 40 A. Fruiting canopy of a tree. Fig. 40 B. An infructescence showing the fruits. Fig. 40 C. A fruit showing the dark exudation.

Population ecology

Distribution of G. travancorica

The species is reported from the Western Ghats of Kerala (Windward side) and Tamilnadu (Leeward side). It is confined to evergreen and shola forests between 700 and 1200 m in southern Kerala (Fig. 41 A).

In Kerala, specimens are available from Thenmala, Kottaram vacha para → Agastyar kudam; Uthapanchi (Bonecaud → Agastyar kudam), Merchiston Estate and Ponmudi. We have located the species at the following locations: (i) Ponmudi: Sholas of Seetha Kulicha Kulam and Upper Sanatorium (Chanipara shola), (ii) Transect between Ponmudi and Varayaadu Motta: Ponmudi → Kuthirathadam → Breimore Estate, (iii) Transect between Venkolla → Pandimottai: Sastham nada → 30 feet bridge → 20 feet bridge → Shankili → Apooppankutti → Choondippara. *Gluta* is more or less gregarious in the rather flat-tops at the base of the Pandimottai peak (>1000 m).

A small population of the species is found at ca. 400 m near the Check station of Breimore Est. (Shavakkad area). Apparently the population is an introduction. The species was introduced to Muthikulam (Palakkad Dt.) and Chandanathodu (Wayanad Dt.) as part of silvicultural experiments.

Herbarium specimens are also known from Tamilnadu along the Balamore → Muthukuzhivayal transect and Vallachithod. Owing to its good quality timber, the species is grown in plantations.

In many areas of distribution of the species, exposed white parent rock materials are visible particularly on the way to Pandimottai; presumably these are rocks with lime content (Fig. 41 B). *G. travancorica* is usually found associated with a species of *Hopea racophloea.*

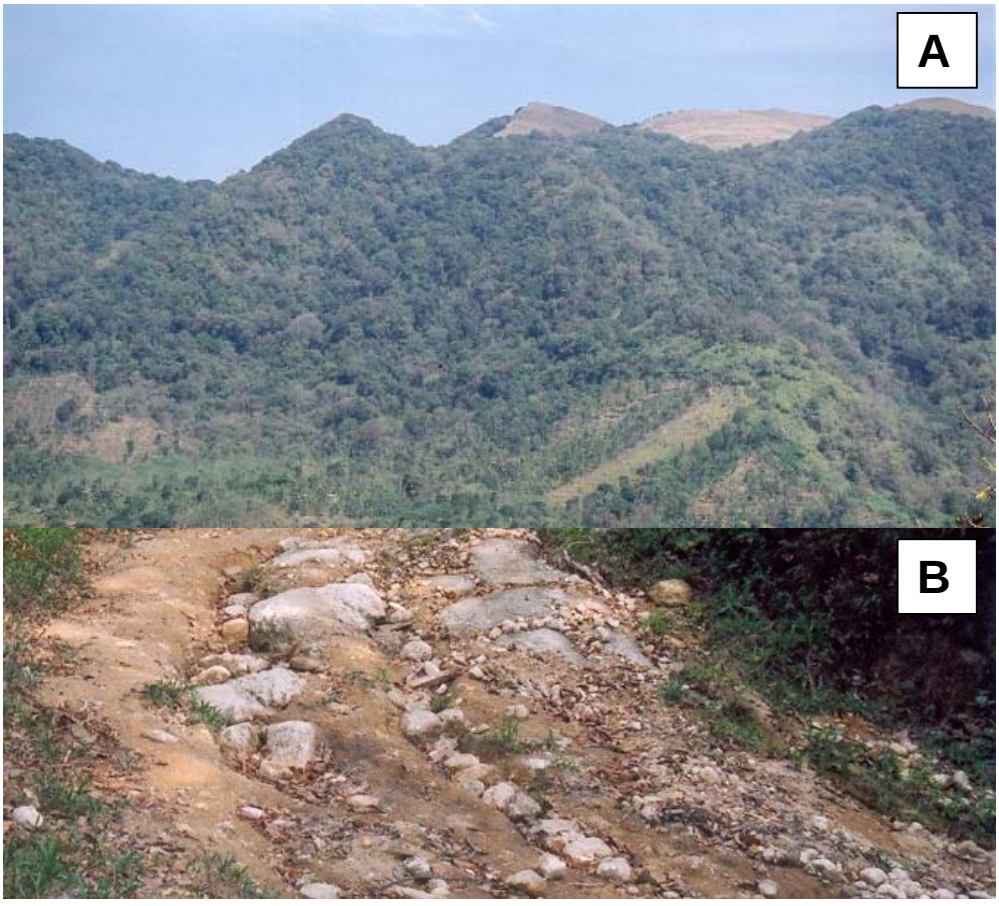


Figure 41. *Gluta travancorica.* Fig. 41 A. A bird's eye view of the shola forest at Rosemala, where *G. travancorica* is found. Fig. 41 B. The white rocky parent material on the way to Pandimotta; the white colour of the rock is perhaps due to lime content.

A distribution map of the species generated from GIS studies is given in Fig. 42. The extent of occurrence encompasses the ghat sections of Shendurny Reserved Forests (RF), Yerur RF, Peppara Wildlife Sanctuary (WLS) and Neyyar WLS. Nearly 178 km^2 area has been found to be probable area of occurrence of the species in Kerala.

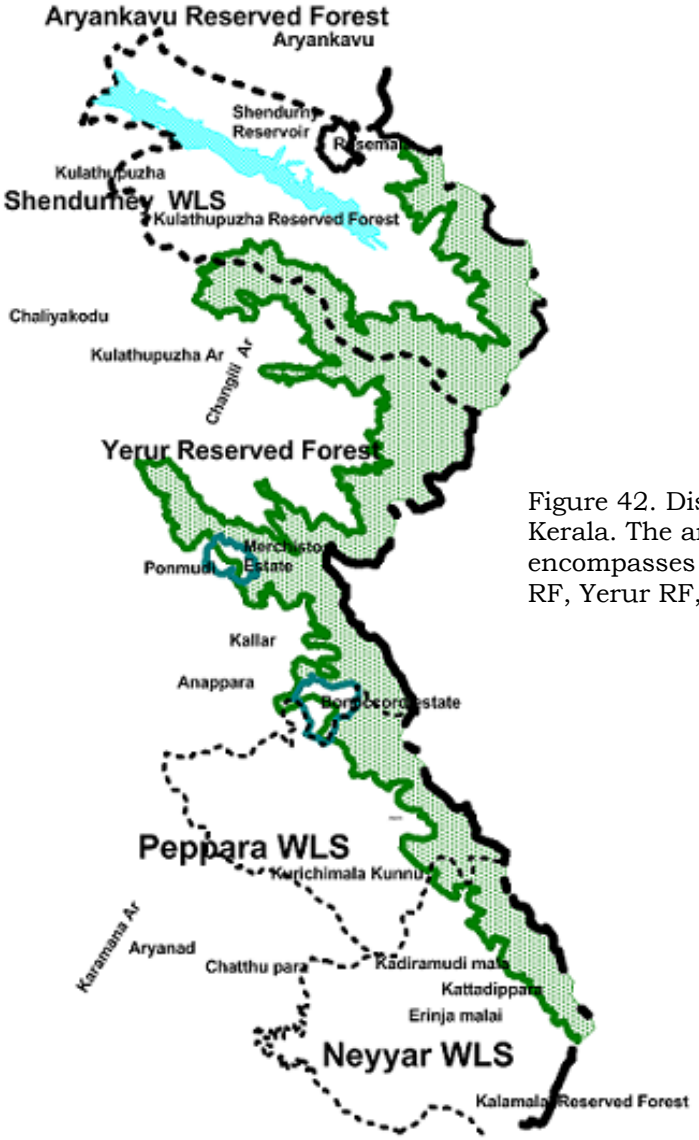


Figure 42. Distribution of *G. travancorica* in Kerala. The area of occurrence (178 km^2) encompasses the ghat sections of Shendurny RF, Yerur RF, Peppara WLS and Neyyar WLS.

Communities supporting G. travancorica

In many locations where *G. travancorica* is present, it dominates the stand in terms of relative importance of the species (RIVI). Stand structure of the forest stand inhabited by *G. travancorica* at Ponmudi (950 m asl) and Rockwood (650 m asl) are given below. The forest is of *Vateria indica - Cullenia exariallata – Mesua ferrea* type, but where the

dominance of these species is not seen. Invariably *G. travancorica* is a dominant component, but the associated dominant species differ from location to location. A*porusa lindleyana*, different species of the genus *Syzygium, Polyalthia coffeoides* or *P. fragrans, Strombosia ceylanica* are generally sure associates with *G. travancorica.*

Based on the dominant species the communities at Ponmudi and Rockwood are:

Ponmudi: *Gluta travancorica - Cullenia exarillata - Aporusa lindleyana - Holigarna arnottiana - Cinnamomum malabtrum* Comm. (Table 23).

Rockwood: *Gluta travancorica - Xanthophyllum flavescens - Aporusa lindleyana - Strombosia ceylanica - Canarium strictum* Comm. (Table 26).

Table 23. Stand structure of evergreen forest at Ponmudi (950 m asl), a natural habitat of *G. travancorica.*

Species	D	BA	RD	RF	RBA	RIVI
Gluta travancorica	50	8.37	10.4	8.7	30.9	16.7
Cullenia exarillata	30	4.78	6.3	6.5	17.6	10.1
Aporusa lindleyana	50	0.54	10.4	8.7	2.0	7.0
Holigarna arnottiana	20	2.82	4.2	4.4	10.4	6.3
Cinnamomum malabtrum	40	0.29	8.3	8.7	1.1	6.0
Syzygium sp.	30	0.74	6.3	6.5	2.7	5.2
Persea macrantha	20	1.78	4.2	4.4	6.6	5.0
Dimocarpus longan	20	1.02	4.2	4.4	3.8	4.1
Litsea floribunda	20	0.99	4.2	4.4	3.7	4.1
Agrostistachys meeboldii	20	0.85	4.2	4.4	3.1	3.9
Canthium umbellatum	20	0.78	4.2	4.4	2.9	3.8
Elaeocarpus munronii	20	0.79	4.2	4.4	2.8	3.8
Garcinia sp.	20	0.48	4.2	4.4	1.8	3.4
Poeciloneuron sp.	10	1.36	2.1	2.2	5.0	3.1
Calophyllum polyanthum	20	0.05	4.2	4.4	0.2	2.9
Chionanthus leprocarpa	10	0.58	2.1	2.2	2.1	2.1
Artocarpus heterophyllus	10	0.46	2.1	2.2	1.7	2.0
Vateria indica	10	0.17	2.1	2.2	0.6	1.6
Ficus hirta	10	0.13	2.1	2.2	0.5	1.6
Aphanomyxis polystachya	10	0.06	2.1	2.2	0.2	1.5
Sterculia guttata	10	0.04	2.1	2.2	0.2	1.5
Garcinia morella	10	0.03	2.1	2.2	0.1	1.5
Syzygium cumini	10	0.03	2.1	2.2	0.1	1.5
Syzygium munronii	10	0.03	2.1	2.2	0.1	1.5
Total	480	27.11	100.0	100.0	100.0	100.0

Table 24. Stand structure of evergreen forest at Rockwood (650 m asl), a natural habitat of *G. travancorica*.

Species	D	BA	RD	RF	RBA	RIVI
Gluta travancorica	40	8.77	5.9	10.0	27.1	14.3
Xanthophyll.flavescens	80	0.93	11.8	7.5	2.9	7.4
Aporusa lindleyana	80	0.37	11.8	7.5	1.2	6.8
Strombosia ceylanica	30	2.84	4.4	5.0	8.8	6.1
Canarium strictum	30	2.22	4.4	5.0	6.9	5.4
Syzygium sp.	50	1.32	7.4	2.5	4.1	4.6
Vateria indica	20	1.64	2.9	5.0	5.1	4.3
Agrostistachys meboldii	40	0.53	5.9	5.0	1.6	4.2
Cullenia exarillata	30	1.52	4.4	2.5	4.7	3.9
Humboldtia decurrens	30	0.50	4.4	5.0	1.5	3.7
Macaranga peltata	20	0.96	2.9	5.0	3.0	3.6
Otonephel. stipulaceum	30	0.37	4.4	5.0	1.1	3.5
Fahrenheitia zeylanica	30	1.11	4.4	2.5	3.4	3.4
Elaeocarp. tuberculatus	20	1.48	2.9	2.5	4.6	3.3
Dimocarpus longan	20	1.17	2.9	2.5	3.6	3.0
Mesua ferrea	20	0.90	2.9	2.5	2.8	2.7
Vepris bilocularis	10	1.25	1.5	2.5	3.8	2.6
Dysoxylum malabaricum	10	1.15	1.5	2.5	3.5	2.5
Litsea sp.	20	0.54	2.9	2.5	1.7	2.4
Prunus ceylanica	10	0.88	1.5	2.5	2.7	2.2
Artocarpus heterophyllus	10	0.51	1.5	2.5	1.6	1.9
Polyalthia fragrans	10	0.51	1.5	2.5	1.6	1.9
Hydnocarpus alpina	10	0.45	1.5	2.5	1.4	1.8
Calophyllum polyanthum	10	0.34	1.5	2.5	1.0	1.7
Actinodaph. malabarica	10	0.10	1.5	2.5	0.3	1.4
Cinnamomum sp.	10	0.07	1.5	2.5	0.2	1.4
Total	680	32.41	100.0	100.0	100.0	100.0

The populations of *G. travancorica* studied by Jose and his associates from the Tropical Botanical Garden and Research Institute (TBGRI) are from the Ponmudi area. A Relative Importance Value (RIVI) of 33% was reported by them. Our samples, again from Ponmudi and Aryankavu showed only 14-17 percent, indicating site-to-site variations.

Population size of G. travancorica

Findings on the population size of the species are derived from twenty-two 0.1 ha plots distributed at Ponmudi and Rockwood.

The species showed an average density of 30 tr/ha. Taking a conservative figure for the area of occurrence of the species (178 km^2 *1/4) as 90 km^2 (= 4,450 ha) in Kerala, and giving a conservative mean density (30 tr * 1/3) of 10 tr/ha, the population estimate would be around 44,500 trees. The

gregarious nature of the tree suggests that this figure would be an under-estimate. This is a fairly good population size and as the area of occurrence is over 100 km^2, it does not qualify any rare category. In Tamilnadu, the species is also being grown in plantations.

Population structure at Ponmudi and Rockwood are given in Fig. 43. The species is represented in all size classes. At Rockwood, the larger size classes are better represented than at Ponmudi (Figs. 43 A & 43 B). In both the cases however, the frequency in the size class d20 (dbh 10-20 class) is low.

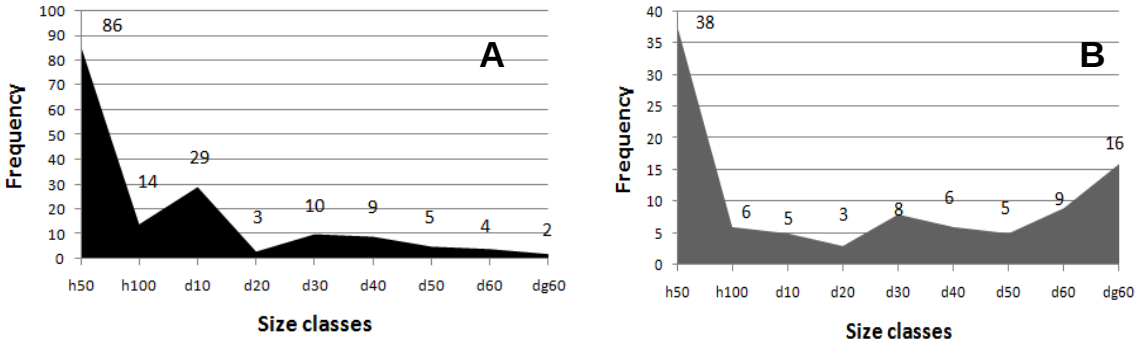


Fig. 43. Population structure of *G. travancorica.* Fig. 43 A. Population structure at Ponmudi. Fig. 43 B. Population structure at Rockwood.

Reproductive phenology of G. travancorica

An abstract of reproductive phenology of the species from earlier published works is as follows. The peak flowering is observed during February-March; an occasional second flowering is observed during September-October. The flowers open during night (8 pm-8 am) and are mildly fragrant. Mature fruits are available only after 11-12 months, ie, in April-May. About 25-30% fruits are damaged by weevils. Seeds do not possess any effective dispersal mechanism.

Propagation studies of *G. travancorica*

In dicotyledons, where the two cotyledons remain compact without separating from each other, knowledge of the internal morphology of the seed/diaspore is very important for raising the planting stock. Thus, a detailed study of the fruit/seed of *G. travancorica* was conducted.

The globose fruit contains a single seed and therefore functions virtually as a seed (Fig. 44 A). The embryo completely fills the seed; the two cotyledons are thick (sarcocotylous) and they do not separate off and

remain inside the seed. The radicle is rudimentary and peripheral (Fig. 44 B). The plumule being situated between the two cotyledons (as also in

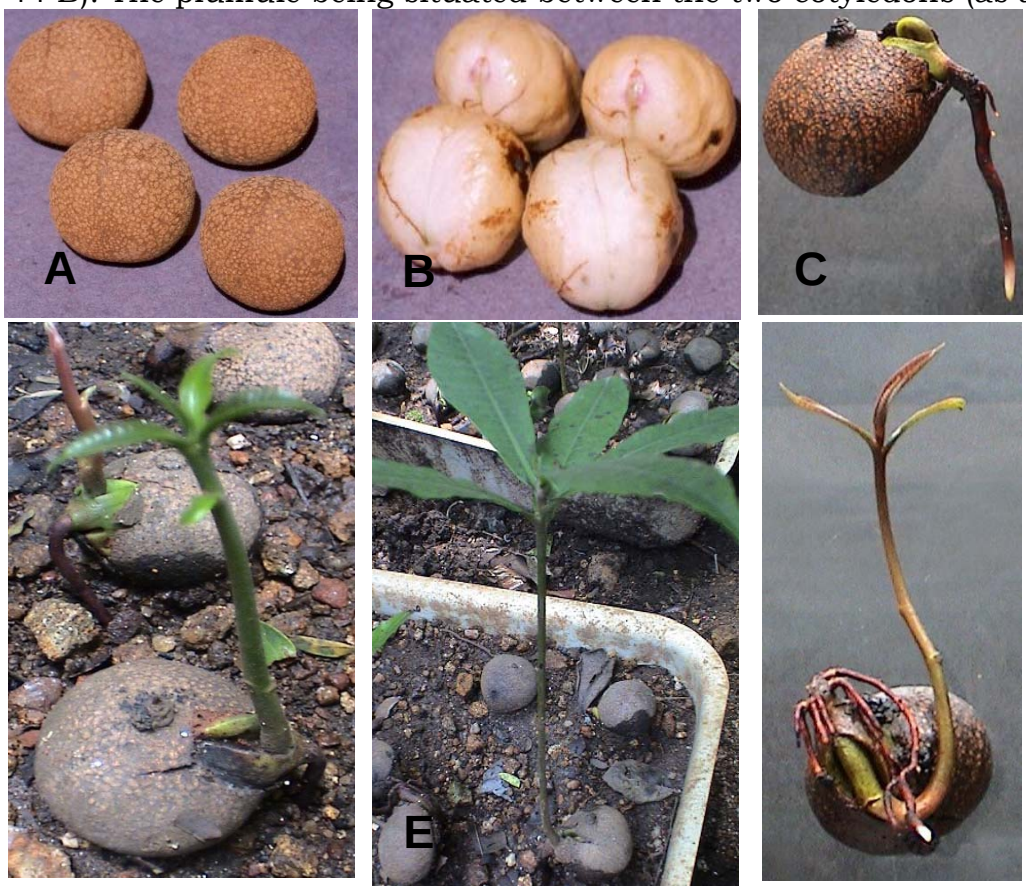


Figure 44. *Gluta travancorica*.. Fig. 44 A. Fruits showing a linear mark on the surface, presumably representing the raphe. Fig. 44 B. Excised embryos showing the peripheral acumbent radicle. Fig. 44 C. A germinating seed; while the radicle and plumule emerge out of the seed, the cotyledons remain inside the fruit/seed. Fig. 44 D & E. Normal seedlings with the indehiscent seed and leaves; the plumule has emerged through the split between the cotyledonary stalks. Normal seedlings are produced when the stalk of the fruit points upward on the ground. Fig. 44 F. A coiled seedling – this results when the split between the cotyledonary stalks is horizontal on the ground and obstructs the emergence of the plumule. – For details see the description of coiled seedlings of *Vateria macrocarpa*. Apparently the ovule is anatropous and the micropyle is situated closer to the fruit stalk, through which the radicle emerges out.

Vateria *macrocarpa*), the only way for its emergence is the split between the two short cotyledonary stalks (Fig. 44 C-E). This is the normal course of germination when the split between the cotyledonary arms is vertical with respect to the g round. If the split happens to be horizontal with respect to the ground, the plumule has to toil to first grow laterally and turn upwards, when coiled seedlings emerge, which are not suitable for planting (Fig. 44 F).

It has been observed that always the seedling emerges out by breaking the fruit-wall closer to the fruit-stalk. This means that the micropyle is situated closer to the fruit-stalk and that the ovule (and seed) is anatropous. All fruits invariably bear a linear streak on their outer surface. Through dissection studies it has been verified that the radicle of the embryo is located along this line, at the end of the streak nearer to the fruit-stalk. Thus, if the fruits are sown on the nursery bed with the fruit-stalk kept upwards as in Fig. 44 C, the split between the cotyledonary stalks would be erect and would produce normal healthy seedlings. In the silviculture of the species this knowledge is useful.

Seeds of *G. travancorica* are recalcitrant having a viability period of almost one month. Over 75 % germination has been obtained for current years seeds. Seed longevity can be extended up to 17 months by keeping the critical moisture content at 40-42 percent (Jose and Pandurangan, 2003 a, 2003 b).

Natural regeneration

Regeneration, ie, the lower size classes which include the seedlings (h50 = ht -50 cm) and established seedlings (h100 = ht 50-100 cm) of the species in natural stands is not poor. Nevertheless, the transition from seedlings to advanced seedlings is found slightly constrained (Figs. 43 A & B).

Vegetative propagation

The species is amenable for vegetative propagation. Tender stem cuttings pre-treated with IBA (1000 ppm) provides 91% rooting; with higher concentrations of the hormone rooting response reduced (Jose and Pandurangan, 2003 b).

Transplantation studies of G. travancorica

Two-hundred seedlings of *Gluta travancorica* were transplanted at Upper Moozhiyar and Nilakkal forests (Ranni FD) for evaluating their performance. The seedlings were in the height range of 15-20 cm (Fig. 45). Because of the failure of NE monsoon last year we obtained only 20% survival after 6 months. Transplantation studies conducted at Shenduruney and Ponmudi recorded survival rates of 75-90% (Jose and Pandurangan (2003b).

Figure 45. Seedlings of *G. travancorica* in the nursery.

Conservation biology

Threats for G. travancorica

The timber is reddish in colour and is of great demand for making furniture and hence illicit felling is the only threat for the species. In the Rosemala area agricultural and settlement lands do encroach into natural evergreen forests (Fig. 46) and are potential threats for *G. travancorica*.

Figure 46. The village landscape of Rosemala gradually merging with the forest landscape, where *G. travancorica* is found. Note the encroaching cultivation of coconut and settlements to the forest landscape, which is a threat to the species.

Conservation of G. travancorica in Kerala

As the species is represented in three Wildlife Sanctuaries, Shenduruny WLS, Peppara Wildlife Sanctuary and Neyyar WLS, the risk of affecting the population of the species is not much. Cultivation of the species in plantations in Tamilnadu also reduces the risk of depletion of the population size. In the Kerala part, there have been efforts to augment plant the species in natural forests.

5. *Dysoxylum malabaricum* Hiern
(Fam. Meliaceae)

Introduction

Dysoxylum malabaricum was first described by Hiern in the Flora of British India (1875), apparently based on a specimen collected by Beddome. It is a majestic tree growing to a height of 35 m and is endemic to the Southern Western Ghats in Karnataka, Kerala and Tamilnadu. The wood is aromatic, and is used as aircraft plywood, for paneling, furniture, artificial limbs, and engineering instruments (Nazma *et al.,* 1981).

Very little is known about the ecology of the species. Some plantation technological aspects of the species, including seed biology, propagation and nursery practices have been studied by Nair *et al.* (2002, 2004). Pandurangan (2003) had studied a few aspects of the conservation biology of the species; this includes analysis of population structure in a few Medicinal Plant Conservation Areas (MPCAs) in Kerala, seed biology and storage, propagation using hormones, and reintroduction to natural or near-natural habitats.

Methodology

Relevant herbarium specimens were studied at the Madras Herbarium (MH), Coimbatore. Exploration of the distributional areas was conducted in Southern Kerala. The areas included Ranni Forest Division and Sholayar Reserved Forests, Nelliampathy forests, etc. Stratification of the distribution area and sampling the strata were done for estimation of population of each species. A GIS was organized for the species in selected locations so that the geographic information is stored for future use. Phyto-sociological and demographic details were studied in a number of 0.1 ha sample plots. An estimate of the total population was made based on sample densities. Reproductive phenological studies, germination ecology, and some transplantation experiments were also conducted.

In the following text in this section, Vellakil is used in lieu of *Dysoxylum malabaricum*.

Results

Dysoxylum malabaricum Beddome ex Hiern in Hooker *f.*, Fl. Brit. India 1: 548. 1875; Bourdillon, For. Trs. Travancore 72. 1908; Gamble, Fl. Pres. Madras 1: 128. 1957; Balasubramanyan *et al.*, Field key to Arborescent species of Kerala, 77. 1985. – **Figs. 47 & 48.**

Malayalam: *D. malabaricum*

Large trees; height up to 35 m, diameter up to 1.5 m; bark 5-8 mm thick, pale grey, outer bark corky, warty, lenticels fissured (distinction from *Vepris bilocularis:* Fam. Rutaceae), inner bark mildly aromatic. Leaves alternate, 30-45 cm long, simply imparipinnate, rachis angular, leaflets 7-11, 12.5-22.5 x 3.7-5 cm, opposite or alternate, petiolules 5-6 mm long, glandular at the axils, leaflet blade lanceolate, tip acuminate, base asymmetric, oblique, margin entire, lateral nerves 9-18(-20) pairs; glabrous. Inflorescence axillary panicles. Flowers 5-6 mm across, greenish yellow, bisexual. Calyx syn-sepalous, deeply 4-lobed. Disc cup-shaped, enclosing the ovary. Petals 4-5, oblong, spreading, valvate. Staminal tub cylindrical, crenulate at the mouth; anthers 8-10, included or half-exerted. Disc cup-shaped. Ovary enclosed within the disc, 3-celled, attenuating to form a long style, stigma broadly capitate; ovules 2 in each cell, collateral. Fruit a capsule, loculicidal, 5-7.5 cm long, pear-shaped, yellow, furrowed lengthwise. Seeds 3-4, axillary and superposed, ex-endospermous, blackish, ellipsoid, connective broad, orange-coloured. Embryo 1, large, filling the entire seed cavity, cotyledons 2, elliptic, plano-convex, accumbent, radicle rudimentary.

Herbarium specimens

KERALA: Travancore, Pathanamthitta, Pamba, Sabaramila (R.F): MH 9026 & MH 80578.

Field notes

Dysoxylum malabaricum (Fig. 49 A & B) and *Vepris bilocularis* (Fig. 49 C & D) - a species of the Fam. Rutaceae - both have warty bark and therefore the latter is easily misidentified as *D. malabaricum*. However, the two can be distinguished in that the bark of *V. bilocularis* is not aromatic. The lenticels of *D. malabaricum* are elliptic, vertically oriented and fissured lenthwise. In the case of *V. bilocularis*, the lenticels coalesce and are not fissured. The bipinnate leaves of *D. malabaricum* also distinguish it from *V. bilocularis*, where it is trifoliolate (see Fig. 49).

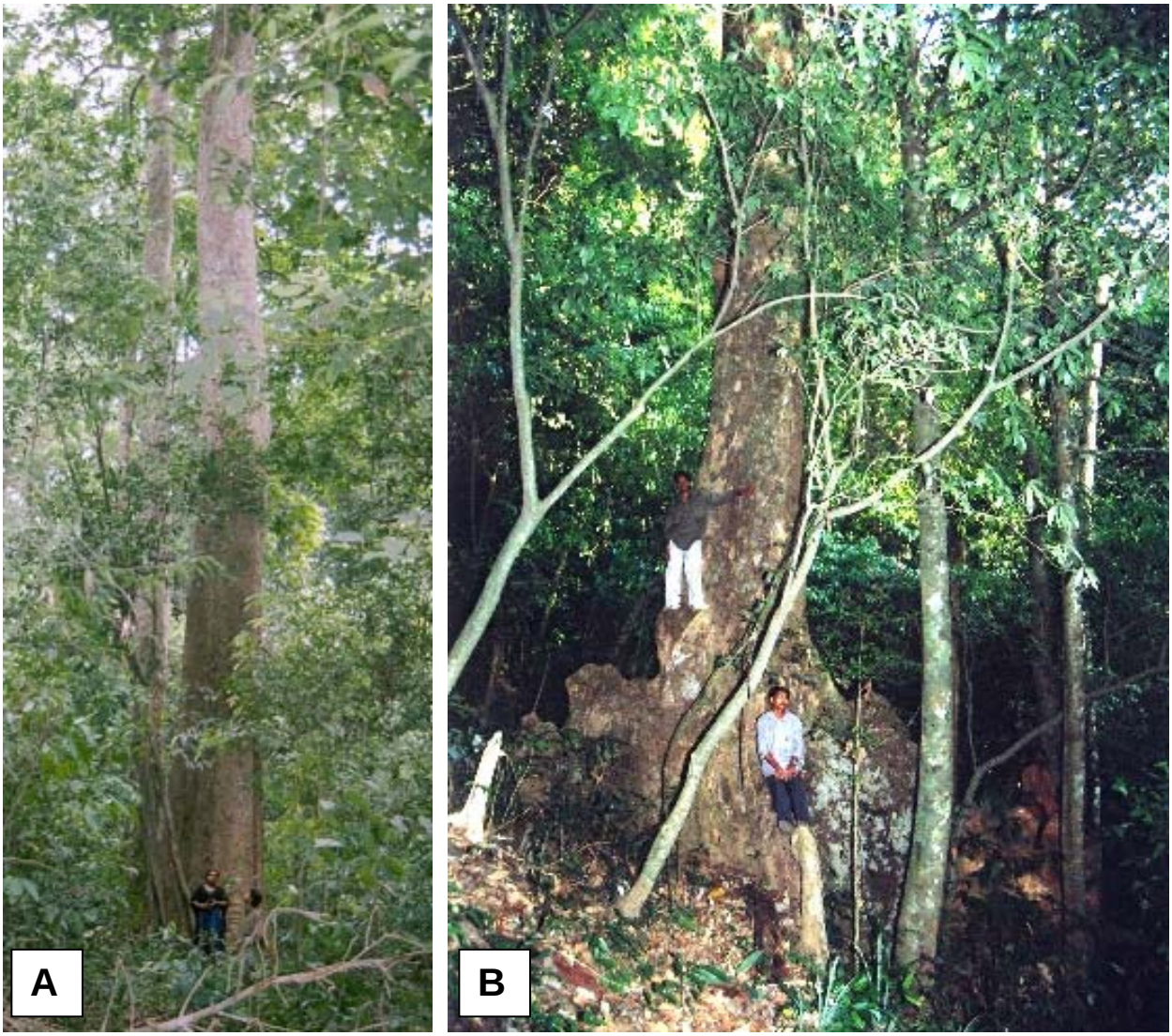


Figure 47. *Dysoxylum bourdillonii.* Fig. 47 A. A fairly large tree from Sholayar. Fig. 47 B. A very large tree from Rosemala (ranni Forest Division).

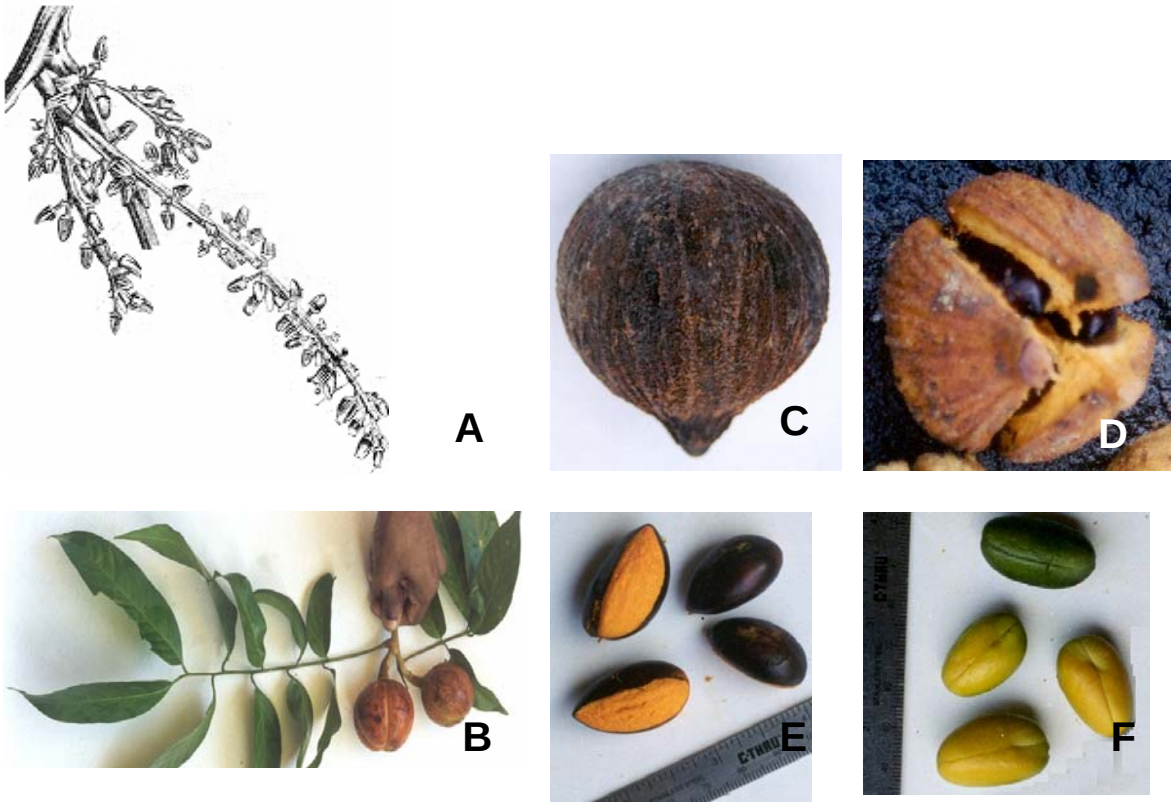


Figure 48. *Dysoxylum malabaricum*. Fig. 48 A. An inflorescence. Fig. 48 B. A twig with fruits. Fig. 48 C. A capsule. Fig. 48 D. Valvular opening of the capsule. Fig. 48 E. Seeds; seeds are attached axially and do not possess a funiculus. Fig. 48 F. Embryos removed off the seed coat.

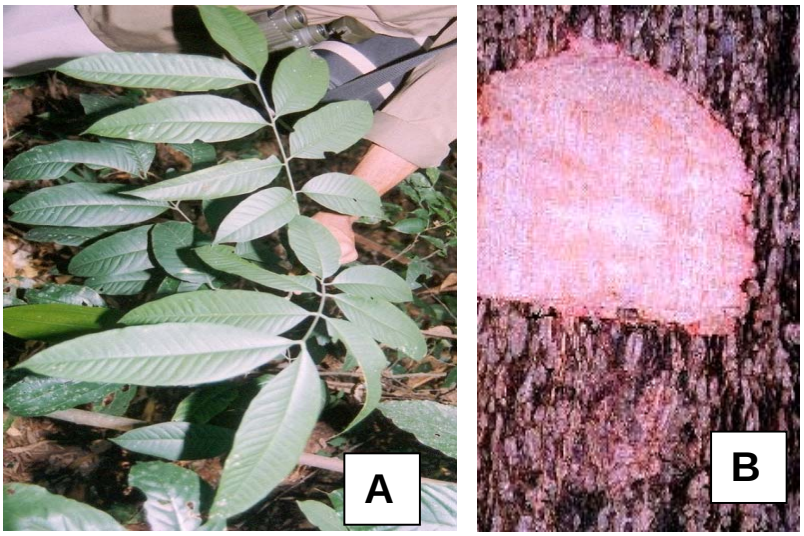
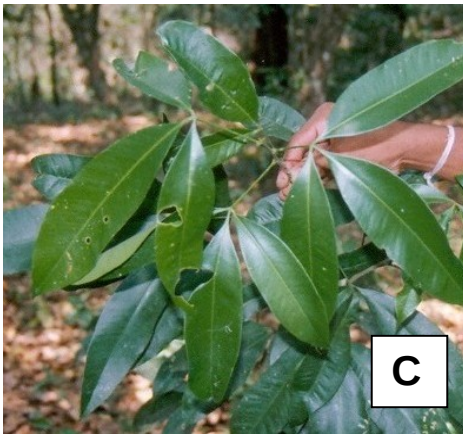
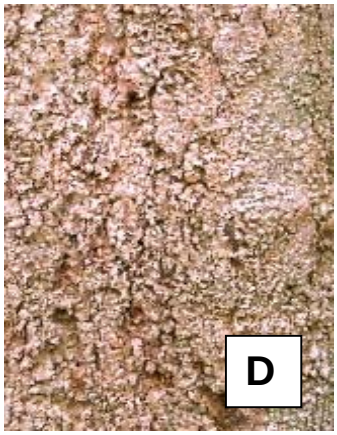


Figure 49. Distinction between *Dysoxylum malabaricum* and *Vepris bilocularis, a species resembling the former in bark characteristics. D. malabaricum* has bipinnate leaves (Fig.49 A), lenticels of the bark are vertically organized (Fig. 49 B) and fissured medianly. *V. bilocularis* has trifoliolate leaves (Fig.49 C) and coals-cing lenticels, not organized in any given direction (Fig.49 D).





Population ecology

Communities supporting D. malabaricum

At Sholayar two 0.1 ha releves were sampled for community ecology and eight samples at Muzhiyar. The outcomes from the study are discussed below. In both the locations, *D. malabaricum* is the most dominant species with 38.7 and 26.3 percent of relative importance values (RIVI= IVI/3) respectively (Tables 25 & 26). In terms of individual parameters of dominance, *viz,* relative density (RD), relative frequency (RF) and relative basal area (RBA) also, compared to other species, *D. malabaricum* has acquired the highest values in the stands.

As per the dominance structure of the stands, the communities at Sholayar and Muzhiyar are respectively:

- *Dysoxylum malabaricum - Knema attenuata - Chukrasia tabularis - Vepris bilocularis - Polyalthia fragrans* Community (Table 25).
- *Dysoxylum malabaricum - Knema attenuata - Myristica dactyloides - Terminalia paniculata - Polyalthia fragrans* Community (Table 26).

However, the common associates of *D. malabaricum* in both locations are: *Knema attenuata, Myristica dactyloides, Vepris bilocularis, Polyalthia fragrans, Syzygium gardneri, Hydnocarpus alpina* and any one of the two species of *Terminalia* (*T. bellirica and T. paniculata*). In locations where, *D. malabaricum* is distributed sparsely, the above positive associations need not be true.

Table 25. Stand structure of semi-evergreen forest at the Kummatti Block, Sholayar, where *Dysoxylum malabaricum* grows gregarious.

Species	D	BA	RD	RF	RBA	RIVI
Dysoxyl. malabaricum	240	36.11	38.7	22.5	54.8	38.7
Knema attenuata	70	7.20	11.3	10.0	10.9	10.7
Chukrasia tabularis	30	5.11	4.8	7.5	7.8	6.7
Vepris bilocularis	40	3.14	6.5	7.5	4.8	6.2
Polyalthia fragrans	40	1.00	6.5	10.0	1.5	6.0
Myristi. dactyloides	30	2.91	4.8	5.0	4.4	4.8
Terminalia bellirica	10	6.46	1.6	2.5	9.8	4.6
Syzygium gardneri	30	1.85	4.8	5.0	2.8	4.2
Baccaur. courtallensis	30	0.25	4.8	5.0	0.4	3.4
Otoneph. stipulaceum	20	0.05	3.2	5.0	0.1	2.8
Lagerstro. microcarpa	10	1.24	1.6	2.5	1.9	2.0
Rein. anamallayanum	10	0.15	1.6	2.5	0.2	1.4
Croton malabaricus	10	0.13	1.6	2.5	0.2	1.4
Schleichera oleosa	10	0.12	1.6	2.5	0.2	1.4
Ixora brachiata	10	0.05	1.6	2.5	0.1	1.4
Mallotus philippensis	10	0.03	1.6	2.5	0.1	1.4
Artocarpus hirsutus	10	0.03	1.6	2.5	0.0	1.4
Vateria indica	10	0.03	1.6	2.5	0.0	1.4
Total	20	65.85	100.0	100.0	100.0	100.0

BA – Basal area (m^2); D – Density (ha^{-1}); RBA – Relative basal area (%); RD – Relative density (%); RF – Relative frequency (%), RIVI – Relative importance value (% = IVI/3).

The stands where *D. malabaricum* inhabits at Kulamavu and Wayanad Medicinal Plant Conservation Areas (MPCAs) also had similar plant compositions and the common floral elements almost always associated with *D. malabaricum* were: *Knema attenuata*, *Myristica dactyloides, Polyalthia* sp., etc. The species RIVI in both the MPCAs was only c. 7.0 whereas it ranged between 21-38.7 (cf. Tables 25 & 26).

Distribution

The species is endemic to the Southern Western Ghats in Karnataka, Kerala and Tamilnadu (Fig. 50 A & B). In Kerala it is distributed almost in all districts but the intensity of occurrence varies. In most of the areas the species is sparsely represented (eg. Nelliampathy hills) whereas in a few locations the species is dense. The distribution map of the species provided by Ramesh & Pascal (1997) indicates this patchy nature of distribution. In southern Kerala the species is preponderant at two

locations. Our field explorations confirmed this. The species is dense at Sholayar (Vazhachal Forest Division) and Mooziyar (Ranni FD).

Table 26. Stand structure at Edappullu (550 m asl) at Muzhiyar, where *D. malabaricum* grows gregarious in semi-evergreen forests.

Species	D	BA	RD	RF	RBA	RIVI
Dysox.malabaricum	130	39.94	19.1	17.3	42.4	26.3
Knema attenuata	90	11.33	13.2	13.5	12.0	12.9
Myrist. dactyloides	80	7.76	11.8	9.6	8.2	9.9
Termin. paniculata	30	15.12	4.4	5.8	16.1	8.8
Polyalthia fragrans	60	8.22	8.9	7.7	8.8	8.4
Croton malabaricus	50	0.91	7.4	7.7	1.0	5.3
Aporusa lindleyana	50	0.13	7.4	5.8	0.1	4.4
Macaranga peltata	40	1.41	5.9	5.8	1.5	4.4
Lagerst. microcarpa	10	7.42	1.5	1.9	7.9	3.8
Lea indica	30	0.09	4.5	5.7	0.4	3.3
Syzygium gardneri	20	0.06	2.9	3.9	0.1	2.3
Baccau.courtallensis	20	0.12	2.9	1.9	0.1	1.7
Vepris bilocularis	10	0.83	1.5	1.9	0.9	1.4
Actino. bourdillonii	10	0.41	15	1.9	0.4	1.3
Hydnocarpus alpina	10	0.31	1.5	1.9	0.3	1.2
Caloph. polyanthum	10	0.02	1.5	1.9	0.1	1.1
Canarium strictum	10	0.03	1.5	1.9	0.1	1.1
Turpinia malabarica	10	0.03	1.5	1.9	0.1	1.1
Persea macrantha	10	0.020	1.5	1.9	0.1	1.1
Total	680	94.15	100.0	100.0	100.0	100.0

BA – Basal area (m^2); D – Density (ha^{-1}); RBA – Relative basal area (%); RD – Relative density (%); RF – Relative frequency (%), RIVI – Relative importance value (% = IVI/3).

Population estimation

At Moozhiyar, eighteen 0.1 ha samples were enumerated for estimation of the population of *D. malabaricum* and five samples studied at Sholayar.

Although the area of occurrence of the species in Kerala might be around 2,380 km^2, the actual area of occupancy of the species would be less. It is very difficult to estimate the area of occurrence as the distribution of the species is patchy and sparse in most of the areas. At Sholayar, 78 ha area was found to belong to the high-density stratum (c. 50-70 tr/ha; >=30 cm gbh; Fig. 51). At Moozhiyar, an area of 1578 ha was found to hold high-density (Fig. 52). The extent of these high-density areas were

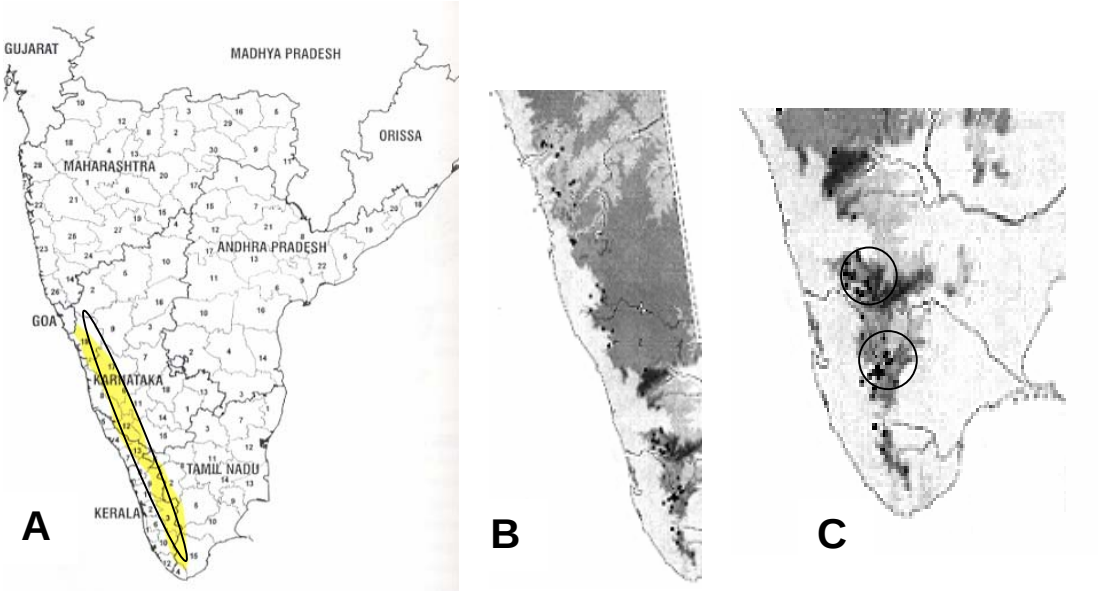


Fig. 50 A. Distribution of *D. malabaricum* along the Western Ghats (Reproduced from Ravikumar and Ved, 2000). Fig. 50 B. Distribution map provided by Ramesh and Pascal (1997) based on available herbarium specimens. Fig. 50 C. Enlarged portion of the lower portion of the map in fig. 50 B. It shows two major patches of distribution (areas encircled) of the species. For details see the text.

estimated from intense field investigations coupled with study of relevant toposheets. Taking a conservative value of 30 trees per hectare, the total tree population in these areas (1,656 ha) would be ca. 50,000 (49,680) trees. Excluding the 17 km^2 of high-density areas of Vellakil, Kerala has another 2,363 km^2 of evergreen (including semi-evergreens) forests. Assuming one tree for every 20 ha area, these landscapes might contain another 11,815 trees. Thus the total mature tree population of the species in Kerala would be around 60,000 trees. Though estimates of tree populations of the species in Karnataka and Tamilnadu though are not available, considering the extent of the evergreen forest belt within the Western Ghats region of these States, assuming another 40,000 trees in these areas would be sensible. The total population of Vellakil therefore should be higher than one hundred thousand trees.

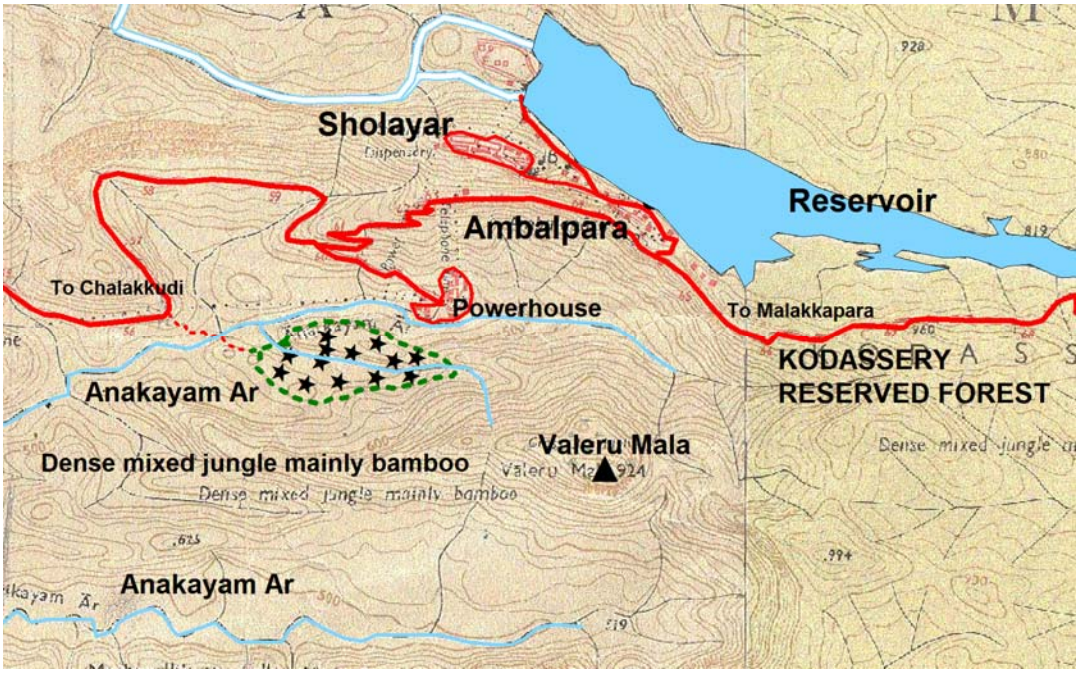


Figure 51. One of the high-density locations of Dysoxylu*m malabaricum* at Sholayar, Vazhachal Forest Division (Enclosure containing asterisk marks).

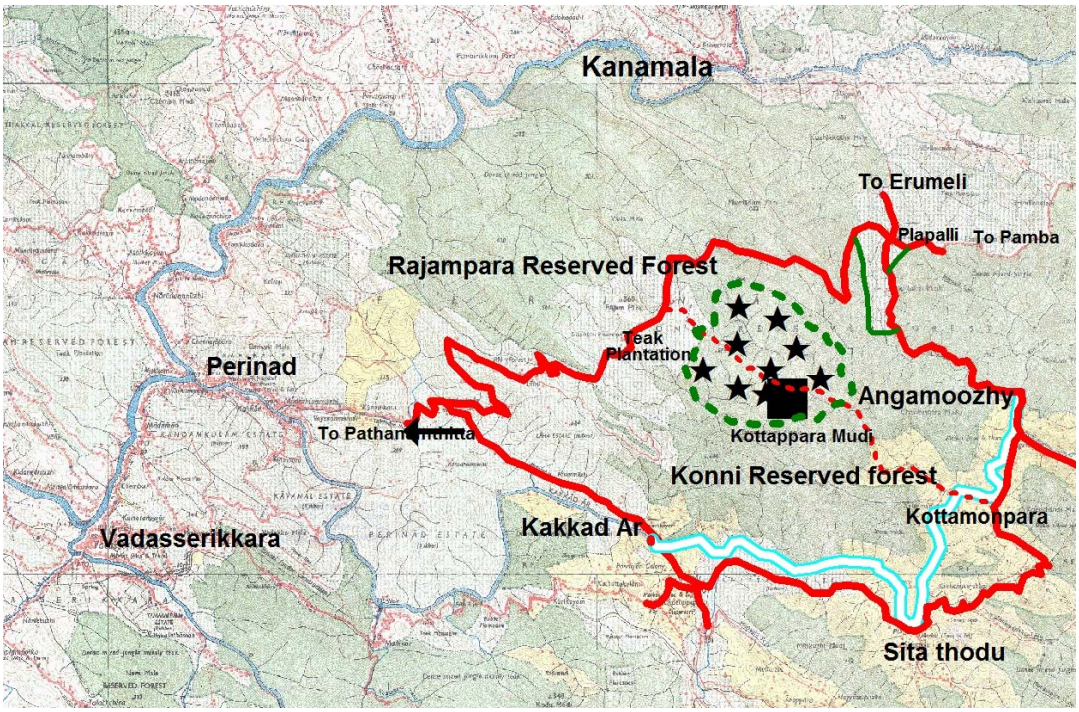


Figure 52. Another high-density location of *Dysoxylum malabaricum* in Ranni Forest Division (Moozhiyar) (Enclosure containing asterisk marks).

Population structure of D. malabaricum

A graphic representation of the population structure of *D. malabaricum* at Sholayar is given in Fig. 54. Unlike the inverse-J shaped stable population structure, the graph is roughly parabolic with ample representation in the lower and upper size classes at the same time with poor representation in the life stage, small trees (dbh 10-20 cm class). While the reason for this anomalous population structure is not clear it is either an indication of some kind of a constraint operating at this life stage or that the species has frequent bad seed years.

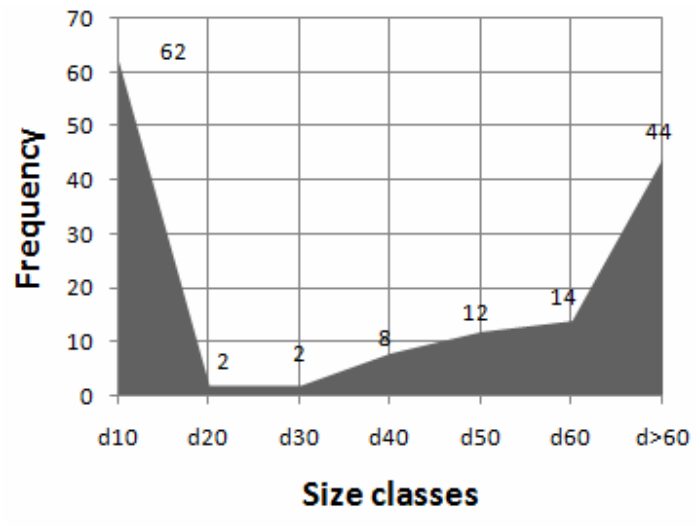


Figure 54. Population structure of *Dysoxylum malabaricum*. Frequencies in ha^{-1}. d10 – DBH 3-10 cm; d20 - DBH 10-20 cm; d>60 – DBH > 60 cm.

Ecological notes on D. malabaricum

Most documented literature mentions *Dysoxylum malabaricum* to be an element of the evergreen forests. However, our field explorations prove that it is very sparse or rare in evergreen forests, but occurs as dense patches in semi-evergreen forests, forming ecotones between moist deciduous and evergreen forests.

Status of D. malabaricum

Most authors who opined on the rarity of plant species along the Western Ghats considered *D. malabaricum* as Endangered. For example, Ravikumar & Ved (2,000) included it among the 100 red listed medicinal plants. As per the IUCN criteria, the species does not qualify the endangered status, as the area of occurrence is more than 10 km^2 and as

the probable population size is ± 100,000 trees. However, the few discontinuous high-density patches and the sparse distribution in the rest of the areas, the species qualifies 'rare' status. The sense of rarity here is regional/local; this sense is certainly valid, particularly when the species is of medicinal value.

Reproductive biology of *D. malabaricum*

Reproductive phenology of D. malabaricum

Twenty-five trees of *Dysoxylum malabaricum* were marked and phenological observations made at a fortnightly interval. Twenty-four fortnightly phenological observations have been made of the 25 trees (Sholayar). The tree flowers during January to February and mature fruits are available during third week of June to third week of July (Fig. 53). The peak season of availability of mature fruits is around third week of June (Fig. 54).

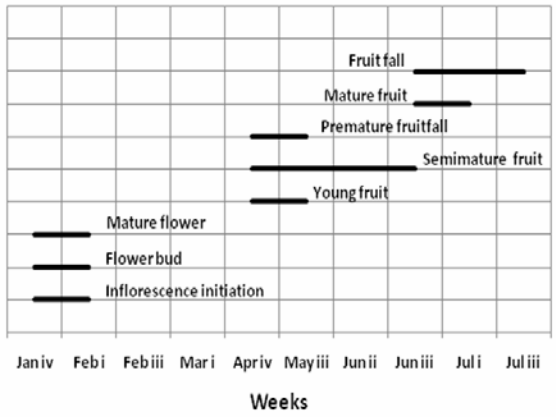


Fig. 53 A. Temporal expression of phenophases of *D. malabaricum.*

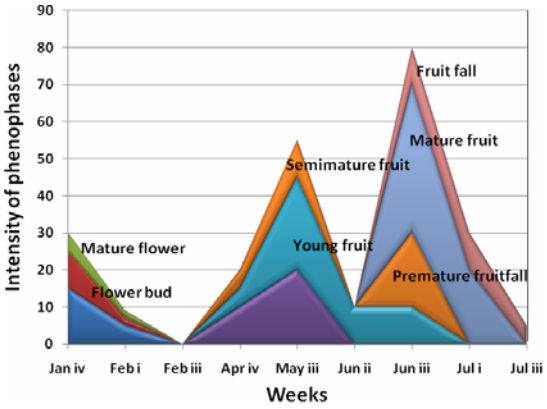


Fig. 54 B. Intensity of expression of phenophases of *D. malabaricum.*

Propagation studies of *D. malabaricum*

One kilogram of seeds of *D. malabaricum* contains c. 140 seeds. The fleshy seed coat degenerates quickly and the naked embryos have a short viability for approximately one week. Because of the oil content of the seed, it is highly attacked by insects and fungi (Fig. 55). Pandurangan (2003) reported high germination percentage up to 100 percent. The

recalcitrant seeds are found to remain viable up to 6 months though with appreciable reduction in viability (20%; Pandurangan, 2003).

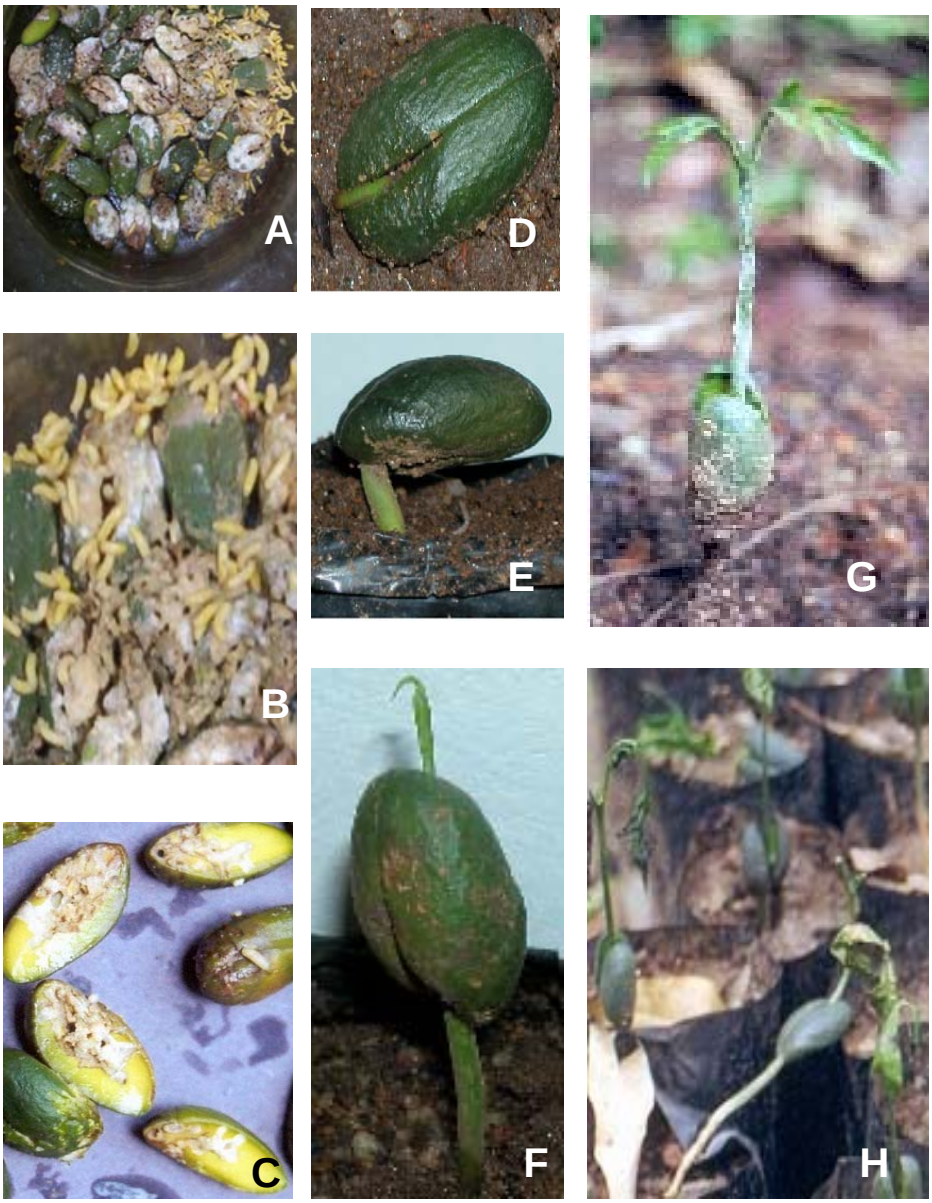


Figure 55. *Dysoxylum malabaricum*. Figs. 55 A & B. Pictures showing the larval infestation on the seeds. Fig. 55 C. An enlarged view of the cotyledons showing, the holes created by the insect larvae. Fig. 55 D. A germinating seed. Figs. 55 E-G. Three stages of the young seedling. Fig. 55 H. Seedlings affected by the wilt fungus.

Germination studies

The seeds (embryos) showed three different colour-types, viz, Green, Yellow and Greenish yellow. Germination trials were conducted with these embryo colour-types in order to understand whether the colour-types differ in germinability. The experiment was conducted in KFRI and the seeds sown on 23-6-2003 and germination monitored till 17 July 2003. The results are reproduced in Table 27.

Table 27. Germination response of different embryo Colour-types.

Sl no	Embryo Colour-types	Replicates	Seeds germinated	Germination (%)	Mean Germination %
1	Green	25	11	44	
		25	15	60	49.3
		25	11	44	
2	Yellow	25	9	36	
		25	15	60	50.7
		25	14	56	
3	Greenish-yellow	25	19	76	
		25	17	68	66.7
		25	14	56	

Germination was completed in 14 days. The percentage of germination ranged between 36 and 76 percent. Greenish-yellow seeds showed maximum germination (66.7%). Green and Yellow seeds showed a mean germination percent of ca. 50%. Reasons for the differing germination percentage is not understood.

Result of seed pre-treatment on germination of D. malabaricum

Seeds collected from Sholayar on 3 July 2003 were pre-treated with bavistin solution and sown on pre-treated nursery beds on 4 July 2003. Seeds were soaked in 1% Bavistin solution (1gm of Bavistin in 1 li of water) for half an hour prior to sowing. Half an hour before sowing, the nursery bed was drenched with 2% Bavistin solution (20g of Bavistin in 10 li of water). The experiment also included necessary control treatments and was performed at the Muthikulam Forest Nursery and germination monitored till 17 July 2003. The results are given below (Table 28).

Table 28. Performance in germination of *D. malabaricum* on seed pre-treatment.

Sl no	Treatments	Seeds Sown	Seeds germinated	Germination (%)	Mean Germination (%)
1	Non-treated (Control)	50	42	84	80.5
		50	44	88	
		50	41	82	
		50	34	68	
2	Pretreated	50	45	90	87.5
		50	41	82	
		50	45	90	
		50	44	88	

While the control seeds displayed 80.5 % germination seeds subjected to pre-treatment with bavistin offered a seven percent increase. This increment in germination percentage may not be economically feasible.

Survival of the seedlings in the nursery bed itself is very low, owing to heavy fungal infection (Fig. 55 H).

Vegetative propagation

Propagation of *D. malabaricum* with the application of growth hormones was experimented by Nair et al. (2002). Juvenile branch cuttings treated with 3000 ppm of IBA has been reported to provide a rooting percentage of up to 12.5.

Conservation biology of D. malabaricum

Transplantation experiments on D. malabaricum

200 seedlings of *Dysoxylum malabaricum* were transplanted in canopy gaps (Nilakkal & Upper Moozhiyar, Ranni FD), to evaluate the survival. Although all the seedlings survived one month only 20% survived 6 months presumably due the failure of NE monsoon last year.

A patch of semi-evergreen forest has been identified at Moozhiyar (Ranni Forest Division) where *D. malabaricum* grows gregarious. This area may

be preserved as a conservation area for the species. The above forest patch also contains two other species of *Dysoxylum*, *viz*, *D. beddomei* and a related species. As such the above forest patch is a gene reserve of *Dysoxylum* in Kerala.

Conclusions: *D. malabaricum*

D. malabaricum though is rare it is widely distributed along the Western Ghats. The area of occupancy of the species is definitely higher than 500 km^2, the mature individuals of the species is well > 500 (27,266 trees in Kerala). A nearly equal population in the joint Tamiladu-Karnataka portion of the W. Ghats is expectable. The probability of extinction of the species in the wild is low (< 0.1). As per the IUCN criteria, therefore, the species qualifies an endangered status.

D. malabaricum finds a place in many social forestry activities, compensation afforestation programmes and augment planting activities; this works out an effective conservation measure for the species. The fact that the species prefers semi-evergreen forests over typical evergreen forests, the afforestation programmes can be made more successful, if the augment planting of the species is focused in semi-evergreen forests.

6. *Anacolosa densiflora* Beddome

(Fam. Olacaceae)

Introduction

Anacolosa densiflora Bedd. (1864) is a lofty straight and clear-boled tree belonging to the family Olaceaceae. The tree reaches a height of 30 m and attains a GBH of 200 cm. The species is extremely rare. A few herbarium specimens are preserved in Kew (K), Madras Herbarium (MH) and FRS; specimens are not available in other herbaria.

The species is not of any known use value except that the poles are used for props in huts and other temporary buildings.

Beddome noted the presence of the species in Anamalai and Travancore. We could not locate the type locality. Dr. N Sasidharan has collected one specimen from Periyar Tiger Reserve. We have conducted the studies based on this specimen.

Methodology

Herbarium specimens at KFRI and TBGRI were examined. As the type locality could not be identified, we relied our studies basing on the specimen collected by Dr. N Sasidharan (KFRI herbarium). Accordingly, in locating the species, we explored Uppupara, Pothumkandam and other areas in the Periyar Tiger Reserve. Fourteen 0.1 ha samples were enumerated for community ecology; 7 from natural stands and 7 from coppicing eucalypt plantations, where it has colonized. Twenty 0.1 ha samples were enumerated for assessing the population and regeneration of the species, 7 from natural forests and 13 from adjacent eucalypt plantations. A GIS has been organized for the area where the species was located. Reproductive biological studies, germination ecology, and transplantation experiments could not be conducted of the species.

Results

Anacolosa densiflora Beddome in Madras J. Sci. 3(1): 38. 1864; Bourdillon, For. Trs. Travancore, 84. 1908; Gamble, Fl. Pres. Madras 1: 137. 1957; Balasubramanyan *et al.,* Field Key Arborescent species Kerala, 50. 1985. – **Figs. 56-58.**

Malayalam: Kal-manikkam, Malam-kara.

Loafty trees, height – 30 m (Fig. 56 A), diameter – 60 cm, bole straight; bark 12-14 mm thick, surface mottled with yellow-brown and white, smooth, inner bark pinkish (Fig. 56 C); crown narrow, ellipsoid (Fig. 56 B); branches horizontal or nearly so, restricted to the crown (Fig. 56 B). Leaves alternate, simple, petioles 10-12 mm long, blade 7.5-15 x 3.7-5 cm, ovate, tip acuminate, base round, margin entire (Fig. 56 D); glossy. Flowers bisexual, in axillary cymes (Figs. 56 D & 56 E), 10-12 x 10-12 mm, white, fragrant. Calyx-cup, 5-7 lobed. Petals 5-6, free, valvate, hairy within. Stamens 5-6, opposite the petals, filaments slender, anthers small, basifixed. Disk cup-shaped, surrounding the ovary. Ovary 1-celled, ovules 2-3, pendulous from a central placentum, style conical, stigma shortly lobed. Fruit a drupe (Figs. 56 F-H), enclosed in the accrescent 4-5 lobed calyx cup/disc, apex slightly constricted into a neck, sometimes the calyx-cup drawn into a cup above the stone, stone 15-18 mm across, ellipsoid, with a longitudinal furrow on one side (Fig. 56 I), seed one.

Herbarium specimens: KERALA: **Travancore:** Forest below Nannattopara, 1000 ft, evergreen for., between 2500 ft – *Bourdillon T.F. 3411* !(FRS).

A. densiflora is extremely rare and we have not been able to see more specimens of the species in regional herbaria. In some of the regional herbaria, *Strombosia ceylanica* has been erroneously identified as *A. densiflora*. For distinction between the two species see the note below.

Field note

Strombosia ceylanica Gardner (Fig. 57 B), another tree of the same family (Fam. Olacaceae), closely resembles *A. densiflora* in tree form, shape of crown and shape and size of leaves. Thus, in the vegetative state it is difficult to distinguish the two. In the case of *S. ceylanica*, the drupe is purple and pyriform whereas in *A. densiflora* it remains green at maturity and is more or ellipsoid or subglobose. For clarity compare Figs. 56 F-H against Fig. 57 B. From Wight's Illustrations, t. 137 and 138, the recurved petal lobes (Figs. 56 E & 57 A) and the lobed disc in *A. densiflora* distinguish it from *S. ceylanica*.

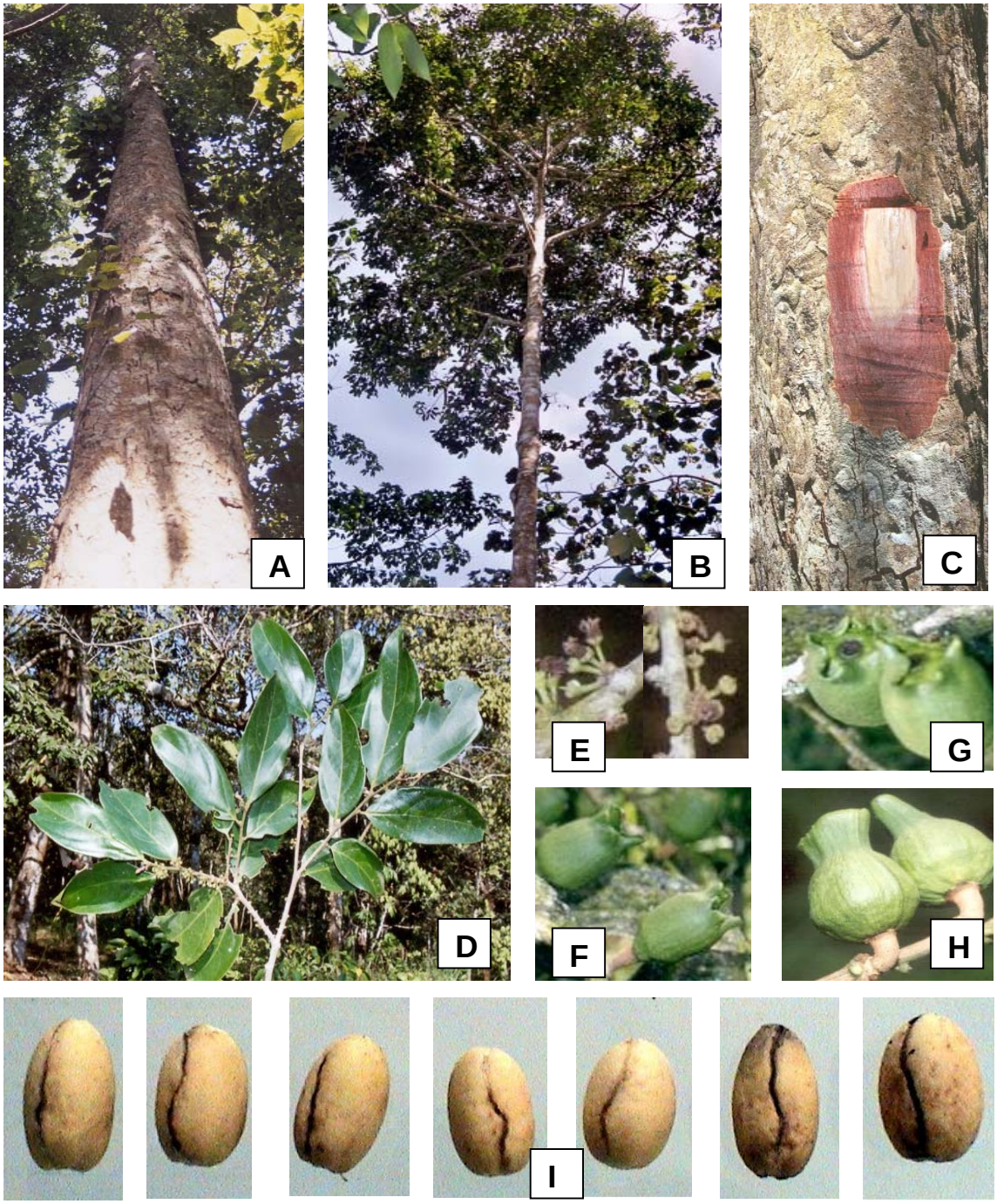


Figure 56. *Anacolosa densiflora*. Fig.56 A. A tree. Fig.56 B. The canopy of a tree. Fig. 56 C. Blaze showing the pink colour of the inner bark. Fig. 56 D. A flowering twig. Fig. 56 E. Cymes showing open flowers. Fig. 56 F. Fruits showing the accrescent calyx cup. Fig. 56 G. Fruits showing the orifice of the calyx cup. Fig. 56 H. Fruits where the calyx cup has overgrown the fruit p*er se.* Fig. 56 I. The stone; note the longitudinal furrow.

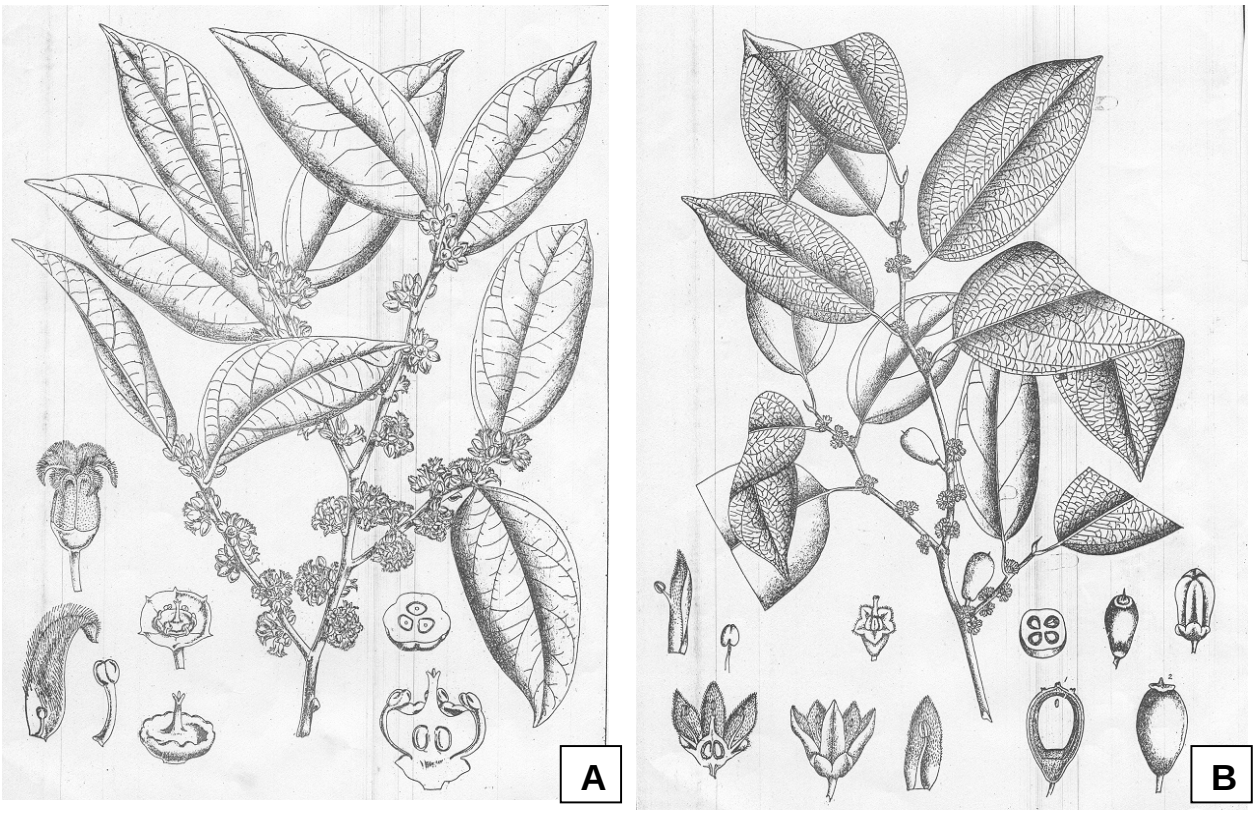


Figure 57. Drawings of *Anacolosa densiflora* (Fig. 57 A) and *Strombosia zeylanica* (Fig. 57 B) from Wight's *Icones*.

Population ecology of A. densiflora

Distribution of A. densiflora

Trees of the species are found along watercourses between 800-900 m (Fig. 58 A). At Vallakkadavu (Pothumkandam) a large number of seedlings and saplings of the species have colonized the coppicing eucalypt plantations (Fig. 58 B).

Beddome (1873) reported the species from Anamalai and Travancore. We could not locate the type locality. Dr. N Sasidharan has collected one specimen from Periyar Tiger Reserve. We explored Uppupara, Pothumkandam and other areas of the Periyar Tiger Reserve during January 2004 and with great difficulty we located 22 trees (>= 30 cm dbh) of the species. A map of the PTR where the species have been located are given in Fig. 59.

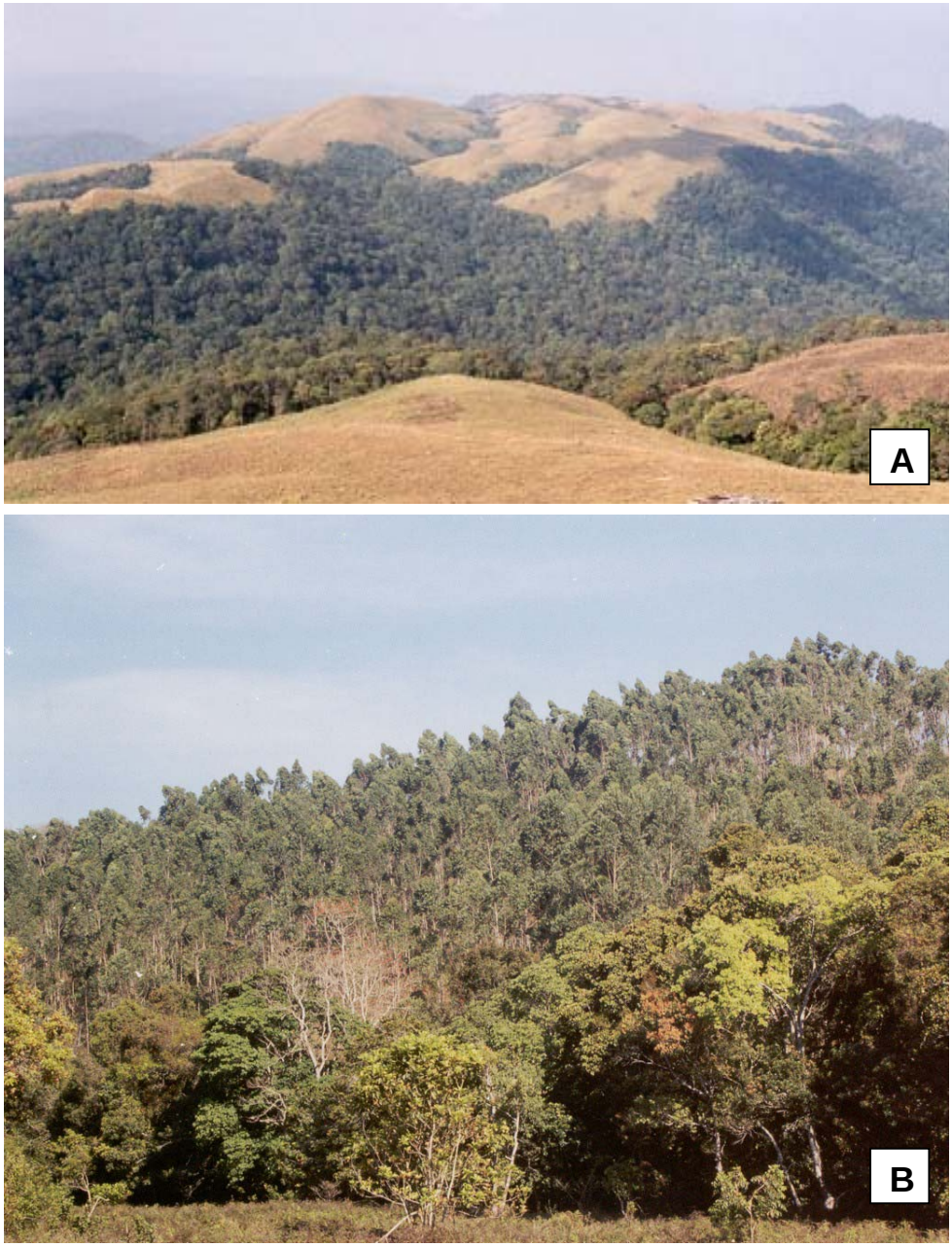


Figure 58. Fig. 58 A. The natural habitat of Anaco*losa densiflora* at the Periyar Tiger Reserve. Fig. 58 B. Eucalypt plantations adjoining the evergreen forests, where A. *densiflora* has invaded.

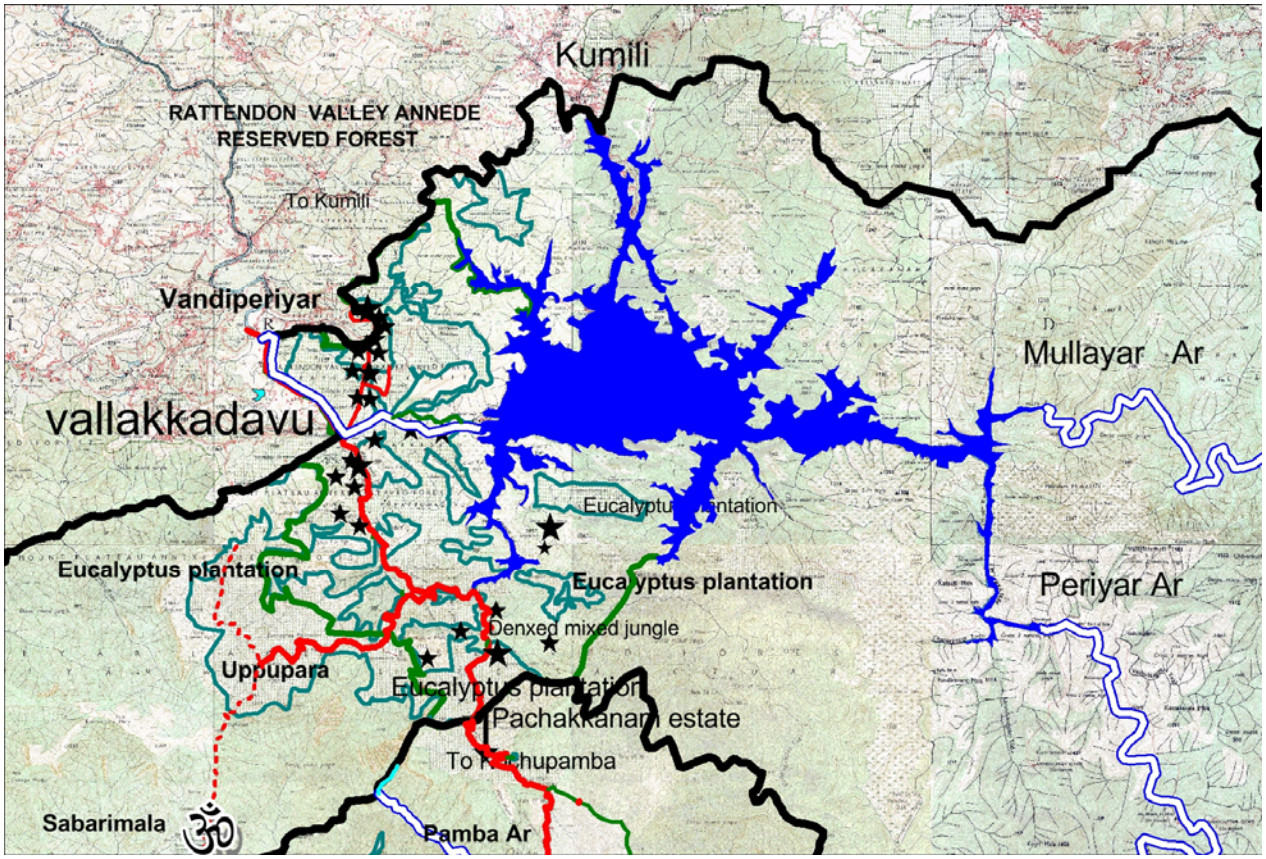


Figure 59. Distribution of *Anacolosa densiflora* in the Periyar Tiger Reserve. The asterisk marks (*) denote the locations of *A. densiflora.*

Communities supporting A. densiflora

Fourteen 0.1 ha samples were enumerated for community ecology; 7 from natural stands and 7 from abandoned eucalypt plantations have been studied. The results provided below are from these data.

The forest type is of medium elevation evergreen forest of the *Mesua ferrea – Cullenia exariallata – Vateria indica* association (Table 29).

Population size of A. densiflora

Twenty 0.1 ha samples were enumerated for assessing the population and regeneration of the species, 7 from natural forest stands and 13felled and coppicing eucalypt plantations. The population of the species is extremely low. We have seen 22 trees (>= 30 cm gbh) in the

field. From the GIS map of the region of the Periyar Tiger Reserve, where the species was found, the total area of occurrence of the species was found to be 73.74 km^2; however, the actual area of occupancy of the species will be very low. The maximum girth observed for the species is 218 cm at breast height. A high estimate of the mature tree may not exceed 200 trees.

Table 29. Structure of evergreen forest at Thenkasi Ar (Vallakkadavu, Periyar Tiger Reserve) containing *A. densiflora*.

Species	D	BA	RD	RBA	RF	RIVI
Vateria indica	240	24.32	21.24	10.81	34.68	22.24
Gordonia obtusa	120	10.67	10.61	10.81	15.22	12.22
Cullenia exarillata	60	15.55	5.31	8.11	22.18	11.87
Anacolosa densiflora	110	2.97	9.73	6.76	4.23	6.91
Lophopet. wightianum	40	9.01	3.54	3.70	12.84	6.69
Hydnocarpus alpina	90	1.06	7.96	8.11	1.51	5.86
Syzygium sp.	90	0.81	7.96	6.76	1.15	5.29
Olea dioica	70	0.91	6.19	8.11	1.30	5.20
Scolopia crenata	50	0.44	4.42	5.41	0.63	3.49
Vernonia arborea	30	2.24	2.65	3.70	3.19	3.18
Cinnam. malabathrum	40	0.32	3.54	4.05	0.45	2.68
Unidentified sp.	20	0.11	1.77	2.70	0.16	1.54
Allophylus cobbe	20	0.07	1.77	2.70	0.10	1.52
Diospyros buxifolia	20	0.07	1.77	2.70	0.10	1.52
Persea macrantha	20	0.09	1.77	1.35	0.13	1.08
Prunus ceylanica	10	0.72	0.88	1.35	0.13	1.08
Canarium strictum	10	0.32	0.88	1.35	0.46	0.90
Flacourtia montana	10	0.16	0.88	1.35	0.22	0.82
Memecylon decanense	10	0.10	0.88	1.35	0.14	0.79
Aporusa lindleyana	10	0.04	0.88	1.35	0.06	0.76
Litsea floribunda	10	0.03	0.88	1.35	0.05	0.76
Myristica dactyloides	10	0.03	0.88	1.35	0.05	0.76
Garcinia cabogea	10	0.03	0.88	1.35	0.04	0.76
Xanthoph. flavescens	10	0.03	0.88	1.35	0.04	0.76
Acronychia laurifolia	10	0.02	0.88	1.35	0.03	0.75
Mesua ferrea	10	0.02	0.88	1.35	0.03	0.75
Total	1130	70.14	99.91	99.98	100.01	99.97

Population structure of A. densiflora

Population structure of *A. densiflora* is given in Fig. 60. The graph is L-shaped and reaches nearer to the stable inverse-J curve. Nevertheless, it has to be remembered that this population structure was obtained for the population that colonized the abandoned eucalypt plantation. In other natural habitats, this need not be true.

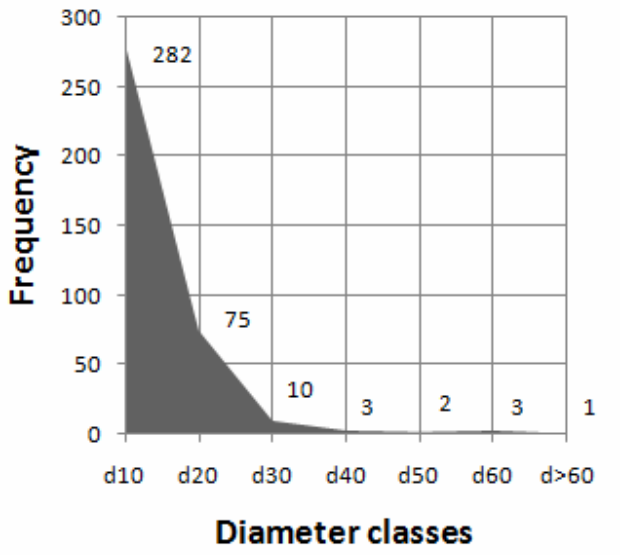


Figure 60. Population structure of *Anacolosa densiflora* in 2 ha samples. d10 – DBH 3-10 cm; d20 – DBH 10-20 cm; d>60 – DBH > 60 cm.

Reproductive biological studies of *A. densiflora*

Phenological studies of A. densiflora

We could not observe mature flowers of the species. By 30 of January 2004, while we were on field trip to Vallakkadavu, the flowers had already withered. Mature fruits of *A. densiflora* were collected in 22 June 2004. We could not conduct prolonged phenological studies as the species is located in remote locations.

Diaspore dispersal and functional trait of A. densiflora

Colonization of abandoned eucalypt plantations by seedlings of *A. densiflora* is an indication of its functional trait as a pioneer evergreen colonizer. As the fruits are drupaceous with a fleshy exocarp, the diaspore populations might have arrived the eucalypt plantations through frugivore animals such as bats. Nevertheless, their ability to germinate and establish in the dry coppice plantations of eucalypt, shows that the species is an evergreen pioneer. Apparently the species would be useful for afforesting the medium elevational natural grasslands, provided reproductive biological and silvicultural aspects of the species are studied beforehand.

Regeneration of A. densiflora

Study of the natural regeneration of *A. densiflora* was rendered difficult due to the striking similarity of the seedlings of *A. densiflora* and *Strombosia ceylanica* and the sympatric distribution of the two species. From Fig. 60 all what we can conclude is that sylvigenesis is not constrained and transition across different size classes does take place without much problems.

Propagation studies of *A. densiflora*

Mature drupes of the species were collected from the Periyar Tiger Reserve and cleaned off the pulpy exocarp. The 'stones' obtained were sown in nursery beds at KFRI and monitored for months. The 'seeds' did not germinate. The stony, crustaceous endocarp that covers the seed might be imposing dormancy over the seed. Further studies would be required to produce the planting stock from the drupes.

Conservation biology of *A. densiflora*

Dr. Sasidharan (2003) ranked *A. densiflora* as 'Endangered'. The estimate of the total population is only 200 trees. The species has not been collected from areas north of the Periyar Tiger Reserve, though the possibility cannot be overruled. Difficulty in distinguishing the species from *Strombosia ceylanica* in the vegetative state creates noise in distribution data. As a matter of fact, the species may be assigned a 'Criticallly Endangered' status.

Conclusions: *A. densiflora*

The population of *Anacolosa densiflora* is extremely low; the estimate of the total population is only 200 trees (>= 30 cm gbh). The species therefore ranks a 'Critically Endangered" status. Further intensive exploratory investigations would be required to make a more precise distribution map of the species and population estimation. As the species is of applied value in afforesting medium elevational grasslands, detailed reproductive biological and silvicultural studies are required.

7. General Conclusions

Streamlines or species clusters of RET taxa

The approximate population size and the status of the five species studied are as follows:

Vateria macrocarpa: ± 41,152 mature trees in Kerala; Endangered (EN)

Dipterocarpus bourdillonii: ± 200 mature trees in Kerala; Critically Endangered (CR)

Gluta travancorica: ± 44,500 mature trees in Kerala; Low Risk/Near threatened (LR/Nt)

Dysoxylum malabaricum: ± 27,226 mature trees in Kerala; Endangered (EN), Locally Rare

Anacolosa densiflora: < 200 mature trees in Kerala; Critically Endangered (CR)

Out of the five species, *Anacolosa densiflora* has the least population size, the posited approximation being < 200 trees. Although the tree populations confine to the stream courses, the species is found to colonize secondary forests, especially along forest edges. *Dipterocarpus burdillonii* is the next in least, the mature tree population being <500. However because of inherent sterility of the seeds, the species deserves serious conservation efforts. There is no immediate risk of loosing 20% or greater of the rest of the species.

Selective logging has been one of the major reasons for impoverishing the population size of *Dipterocarpus bourdillonii* and *Dysoxylum malabaricum*. Some intrinsic reproductive barriers were found to affect regeneration and population decline in *D. bourdillonii*. In the case of *V. macrocarpa* culling the trees while developing plantations of coffee and cardamom and illicit felling of trees for resin had a definitive role in the reduction of its population size. In the case of *Anacolosa densiflora*, none of these factors apply; the species itself is a pioneer which colonizes secondary forests. Whether the species is a neo- or a paleo- endemic remains to be understood.

Out of the five species, four, *viz., Vateria macrocarpa, Gluta travancorica, Dysoxylum malabaricum*, and *Dipterocarpus bourdillonii*, all have large mega-embryonic fruits/seeds. Because of the heavy diaspores, they are not associated with any effective diaspore dispersal mechanism. The fruits/seeds fall around the mother trees, germinate there and the population therefore becomes clumped or mother-centered. In addition to

the niche specificities, this is also one of the reasons for their restricted distribution.

V. macrocarpa, D. bourdillonii and *Anacolosa densiflora* were found to inhabit stream courses. The first one prefers more marshy habitats, *D. bourdillonii* the stream courses on the banks, and *A. densiflora* a little away from the stream course. All the species are therefore moisture/water-loving species. The fourth *Gluta travancorica* inhabits evergreen sholas. The shola forests grow where soil substratum is richer than the adjoining areas and occupy the hill folds and water-flow courses. Because of the deeper soil layers, the moisture availability should also be high. In short, most of the species occupy niches with ample water source either as flowing water, or as moist soil. Many other rare trees like *Myristica magnifica, Semecarpus auriculata* are also found largely in swampy situations. A good number of our herpetofauna are also found restricted to hydric niches. It appears that the hydric/moist environment is a specialized niche. Water courses, water bodies and the related niches therefore appear to be important for biodiversity conservation and its study.

By working out the biology of a handful of the species, now we are in a state to believe that across the various RET species, there is much in common: similar niche, lack of effective dispersal mechanism, inherent reproductive barrier, devastation and deterioration of natural habitats, etc. Further generalities would be visible, only when more species are studied intensively, and the information compared across more number of species. These generalities would ultimately help to identify different streamlines or species clusters and provide general treatments for their conservation.

Skewed information development in RETP research and the remedies

Western Ghats is one of the two mega biodiversity centers in India, holding about 5,000 species of plants. More than 70 percent of the plants (Mani, 1974; Sasidharan, 2004) known from the Western Ghats are recorded from Southern Western Ghats itself. As many as 1,637 endemic plants also belong to this part (Kallarackal *et al.,* 2004). This is indicative of the importance of the segment. Kerala State with the major length of southern Western Ghats falling within this geospace deserves special consideration. Sasidharan (2004) reported 497 red listed plant species from Kerala. Out of which 151 trees included there 2 are Extinct (EX), 26 are Critically endangered (CR), 63 are Endangered (EN), 38 Vulnerable (VU) and 22 belonging to Low risk/ near threatened (LR/nt).

The problem with the RETP (Rare, Endangered and Threatened Plant) research in the country and with the Kerala State seems to be one of information development. Despite the large number of red-listed taxa

reported from this part of the country, the State does not have a general policy or a consolidated programme for the conservation of these species.

Several regional R & D institutions and regional University Botany Departments are involved in biodiversity research and institutions such as Kerala Forest Research Institute (KFRI), Peechi, Jawaharlal Nehru Tropical Botanical Garden and Research Institute (JN-TBGRI), Centre for Earth Science Studies (CESS), Institute Francais, Pondicherry, Calicut University - Botany Department, Madras Herbarium (MH), Coimbatore, Institute for Forest Genetics and Tree Breeding (IFGTB), Coimbatore, etc, have active programmes on RETP research and conservation. As a matter of fact, the thrust area is not information deficient, but the information generated by the various institutions remains segmented. On the one hand, the general scenario of information on RET plants is of much redundancy and on the other, many taxa remain unattended and information-deficient. Abnormal, in the sense of non-uniform information development, across the taxa pervades when much of it is incomplete and often turns out to be not useful and not available for practical conservation purposes.

In the first place, the rarity or the population status of species is evaluated based on collections available in regional herbaria. Species-focused population biological studies have shown that many of the so called RET species do not qualify the 'Rare' status. There are instances, where, the species is extremely rare but where population ecological studies are wanting altogether. Extent of representation of species in regional herbaria thus is not capable of conveying the actual population status.

In order to facilitate systematic and sound information development on RET species KFRI has organized a database (Yesodharan & Jose, 2012). This database provides species-wise information, whether: (a) Detailed geographic analyses of distribution, (b) Population ecological and Demographic studies, (c) Reproductive biological studies, (d) Propagation studies, (e) Edapho-climatic studies, (f) Species recovery studies, (g) Ex-situ conservation, etc, have been achieved of the species and the relevant references thereof. Review writings on individual taxa of RET species are to be accomplished as a follow of the above-mentioned database, so that all available information on individual taxa is made available at one place.

Organizing a Working Group on Research and Conservation of Rare, Endangered and Threatened Plants (WG-RETP) is a suggestive institutional mechanism. The Kerala Forests and Wildlife Department (KFD) and the Kerala Forest Research Institute (KFRI) may have cardinal roles to play in this context.

Need for larger live plant conservatories

One another major impediment for RETP (Rare, Endangered and Threatened Plants) research is the peculiar distribution of a majority of the species. By and large their extent of occurrence is restricted to smaller areas and the areas of occupancy are located in remote, often inaccessible places hindering frequent field visits. Facilitative it would be, if live plants are available in accessible locations. By virtue of its magnitude and spatial extent it is generally agreed that conservation can be achieved only with the participation of people. It is a fact that, effective biodiversity conservation then is possible only by providing a mechanism for familiarization of our native biodiversity to the various sectors of the society/public. Suggestions for development of fairly large live conservatories make sense in this context, containing nearly all plants of the region. Such conservatories can hold live collections of RET species in near-natural environments and can facilitate RETP research.

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9. Appendices

Appendix-1:
Structure of evergreen forest stands containing *Vateria macrocarpa.*

Table A-1. Composition of forest plot, PPara14-8, Poolappara, Compartment 4, Muthikulam RF, 700m, Low density stratum.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Vateria macrocarpa	320	32.5600	34.41	15.09	54.36	103.86	34.62	34.62
Cullenia exarillata	60	15.1250	6.45	7.55	25.25	39.25	13.08	47.70
Palaquium ellipticum	100	5.5450	10.75	13.21	9.26	33.22	11.07	58.77
Agrostistachys borneensis	110	1.3200	11.83	13.21	2.20	27.24	9.08	67.85
Xanthophyllum arnottianum	110	1.8980	11.83	9.43	3.17	24.43	8.14	75.99
Syzygium mundagam	30	0.4040	3.23	3.77	0.67	7.67	2.56	78.55
Garcinia morella	20	0.5440	2.15	3.77	0.91	6.83	2.28	80.83
Drypetes oblongifolia	20	0.5380	2.15	3.77	0.90	6.82	2.27	83.10
Reinwardt. anamalaiense	20	0.4460	2.15	3.77	0.74	6.66	2.22	85.32
Fahrenheitia zeylanica	20	0.2010	2.15	3.77	0.34	6.26	2.09	87.41
Baccourea courtallensis	20	0.1220	2.15	3.77	0.20	6.12	2.04	89.45
Calophyllum polyanthum	10	0.3360	1.08	1.89	0.56	3.53	1.18	90.63
Drypetes elata	10	0.2680	1.08	1.89	0.45	3.42	1.14	91.77
Litsea deccanensis	10	0.2490	1.08	1.89	0.42	3.39	1.13	92.90
Hydnocarpus pentandra	10	0.1340	1.08	1.89	0.22	3.19	1.06	93.96
Schleichera oleosa	10	0.0720	1.08	1.89	0.12	3.09	1.03	94.99
Neolitsea cassia	10	0.0390	1.08	1.89	0.07	3.04	1.01	96.00
Polyalthia coffeoides	10	0.0390	1.08	1.89	0.07	3.04	1.01	97.01
Strombosia ceylanica	10	0.0260	1.08	1.89	0.04	3.01	1.00	98.01
Myristica dactyloides	10	0.0180	1.08	1.89	0.03	3.00	1.00	99.01
Syzygium gardneri	10	0.0130	1.08	1.89	0.02	2.99	1.00	100.01
Total:	930	59.8970	100.05	100.01	100.00	300.06	100.01	100.01

Table A-2 . Composition of forest plot, Koo3-2, Koodam, Compartment 3, Muthikulam RF, 675m, Low density stratum.

Sp	d	Ba	rd	rf	rba	ivi	rivi	crivi
Vateria macrocarpa	230	34.6420	28.05	13.04	50.09	91.18	30.39	30.39
Cullenia exarillata	100	7.8710	12.20	10.87	11.38	34.45	11.48	41.87
Diospyros bourdilloni	60	11.4220	7.32	8.70	16.52	32.54	10.85	52.72
Syzygium mundagam	110	2.4020	13.41	15.22	3.47	32.10	10.70	63.42
Xanthophyllum arnottianum	90	0.7600	10.98	6.52	1.10	18.60	6.20	69.62
Palaquium ellipticum	30	4.6360	3.66	6.52	6.70	16.88	5.63	75.25
Reinwardt. anamalaiense	40	0.8430	4.88	6.52	1.22	12.62	4.21	79.46
Agrostistachys borneensis	40	0.2340	4.88	6.52	0.34	11.74	3.91	83.37
Myristica dactyloides	30	0.3140	3.66	6.52	0.45	10.63	3.54	86.91
Fahrenheitia zeylanica	10	3.8500	1.22	2.17	5.57	8.96	2.99	89.90
Garcinia morella	20	0.3660	2.44	4.35	0.53	7.32	2.44	92.34
Polyalthia coffeoides	20	0.2410	2.44	4.35	0.35	7.14	2.38	94.72
Holigarna arnottiana	10	1.2030	1.22	2.17	1.74	5.13	1.71	96.43
Meiogyne pannosa	10	0.1610	1.22	2.17	0.23	3.62	1.21	97.64
Persea macrantha	10	0.1270	1.22	2.17	0.18	3.57	1.19	98.83
Aporusa lindleyana	10	0.0870	1.22	2.17	0.13	3.52	1.17	100.00
Total:	820	69.1590	100.02	99.98	100.00	300.00	100.00	100.00

Table A-3. Composition of forest plot, Koo4-3R Koodam, Compartment 4, Muthikulam RF, 700m, Low density stratum.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Vateria macrocarpa	90	23.7770	9.57	9.23	37.07	55.87	18.62	18.62
Cullenia exarillata	80	10.0900	8.51	7.69	15.73	31.93	10.64	29.26
Syzygium mundagam	70	7.7870	7.45	9.23	12.14	28.82	9.61	38.87
Palaquium ellipticum	90	5.6260	9.57	9.23	8.77	27.57	9.19	48.06
Drypetes oblongifolia	80	5.0790	8.51	7.69	7.92	24.12	8.04	56.10
Agrostistachys borneensis	100	1.0850	10.64	6.15	1.69	18.48	6.16	62.26
Garcinia morella	50	1.1530	5.32	7.69	1.80	14.81	4.94	67.20
Myristica dactyloides	60	1.5940	6.38	4.62	2.49	13.49	4.50	71.70
Reinwardt. anamalaiense	70	0.6970	7.45	4.62	1.09	13.16	4.39	76.09
Holigarna arnottiana	20	2.9580	2.13	3.08	4.61	9.82	3.27	79.36
Mallotus philippensis	40	0.4860	4.26	4.62	0.76	9.64	3.21	82.57
Xanthophyllum arnottianum	40	0.3280	4.26	3.08	0.51	7.85	2.62	85.19
Fahrenheitia zeylanica	20	1.1620	2.13	3.08	1.81	7.02	2.34	87.53
Mesua ferrea	20	0.7750	2.13	3.08	1.21	6.42	2.14	89.67
Diospyros bourdilloni	20	0.6390	2.13	3.08	1.00	6.21	2.07	91.74
Drypetes elata	20	0.1970	2.13	3.08	0.31	5.52	1.84	93.58
Polyalthia coffeoides	20	0.0800	2.13	3.08	0.12	5.33	1.78	95.36
Macaranga peltata	10	0.2230	1.06	1.54	0.35	2.95	0.98	96.34
Sterculia guttata	10	0.1150	1.06	1.54	0.18	2.78	0.93	97.27
Knema attenuata	10	0.1090	1.06	1.54	0.17	2.77	0.92	98.19
Meiogyne pannosa	10	0.0970	1.06	1.54	0.15	2.75	0.92	99.11
Antidesma menasu	10	0.0760	1.06	1.54	0.12	2.72	0.91	100.02
Total:	940	64.1330	100.00	100.03	100.00	300.03	100.02	100.02

Table A-4. Composition of forest plot, Koo12-1, Koodam, Compartment 12, Muthikulam RF, 600m, Medium density stratum.

Sp	d	Ba	rd	rf	rba	ivi	rivi	crivi
Vateria macrocarpa	130	41.5810	12.62	12.33	59.62	84.57	28.19	28.19
Agrostistachys borneensis	200	2.6900	19.42	12.33	3.86	35.61	11.87	40.06
Palaquium ellipticum	150	5.9640	14.56	12.33	8.55	35.44	11.81	51.87
Cullenia exarillata	90	4.6890	8.74	9.59	6.72	25.05	8.35	60.22
Fahrenheitia zeylanica	70	3.4210	6.80	8.22	4.91	19.93	6.64	66.86
Reinwardt. anamalaiense	40	2.3270	3.88	4.11	3.34	11.33	3.78	70.64
Neolitsea cassia	50	0.2560	4.85	5.48	0.37	10.70	3.57	74.21
Syzygium mundagam	40	0.2290	3.88	4.11	0.33	8.32	2.77	76.98
Knema attenuata	20	2.9870	1.94	1.37	4.28	7.59	2.53	79.51
Myristica dactyloides	30	0.3400	2.91	4.11	0.49	7.51	2.50	82.01
Actinodaphne malabarica	30	0.7610	2.91	2.74	1.09	6.74	2.25	84.26
Garcinia morella	30	0.2190	2.91	2.74	0.31	5.96	1.99	86.25
Drypetes elata	20	0.4630	1.94	2.74	0.66	5.34	1.78	88.03
Vateria macrocarpa	10	2.0360	0.97	1.37	2.92	5.26	1.75	89.78
Diospyros bourdilloni	20	0.3680	1.94	2.74	0.53	5.21	1.74	91.52
Holigarna arnottiana	20	0.1240	1.94	2.74	0.18	4.86	1.62	93.14
Aporusa lindleyana	20	0.1120	1.94	2.74	0.16	4.84	1.61	94.75
Drypetes oblongifolia	10	0.9110	0.97	1.37	1.31	3.65	1.22	95.97
Mangifera indica	10	0.0760	0.97	1.37	0.11	2.45	0.82	96.79
Litsea deccanensis	10	0.0620	0.97	1.37	0.09	2.43	0.81	97.60
Calophyllum polyanthum	10	0.0580	0.97	1.37	0.08	2.42	0.81	98.41
Meiogyne pannosa	10	0.0350	0.97	1.37	0.05	2.39	0.80	99.21
Syzygium gardneri	10	0.0350	0.97	1.37	0.05	2.39	0.80	100.01
Total:	1030	69.7440	99.97	100.01	100.01	299.99	100.01	100.01

Table A-5. Composition of forest plot, SI11-13, Above Siruvani Estate, 800m, Medium density.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Vateria macrocarpa	130	18.7870	13.68	12.99	35.57	62.24	20.75	20.75
Cullenia exarillata	170	13.7550	17.89	12.99	26.04	56.92	18.97	39.72
Acronychia pedunculata	90	1.6540	9.47	10.39	3.13	22.99	7.66	47.38
Syzygium cumini	30	5.9710	3.16	3.90	11.30	18.36	6.12	53.50
Fahrenheitia zeylanica	60	1.3420	6.32	6.49	2.54	15.35	5.12	58.62
Xanthophyllum arnottianum	50	0.4760	5.26	6.49	0.90	12.65	4.22	62.84
Elaeocarpus serratus	20	3.7440	2.11	1.30	7.09	10.50	3.50	66.34
Calophyllum polyanthum	30	1.7810	3.16	3.90	3.37	10.43	3.48	69.82
Agrostistachys borneensis	40	0.1780	4.21	3.90	0.34	8.45	2.82	72.64
Myristica dactyloides	30	0.1800	3.16	3.90	0.34	7.40	2.47	75.11
Polyalthia fragrans	20	1.0620	2.11	2.60	2.01	6.72	2.24	77.35
Persea macrantha	30	0.4630	3.16	2.60	0.88	6.64	2.21	79.56
Drypetes oblongifolia	20	0.7950	2.11	2.60	1.51	6.22	2.07	81.63
Litsea floribunda	20	0.1470	2.11	2.60	0.28	4.99	1.66	83.29
Garcinia spicata	20	0.1260	2.11	2.60	0.24	4.95	1.65	84.94
Neolitsea sp.	20	0.1220	2.11	2.60	0.23	4.94	1.65	86.59
Drypetes elata	30	0.1980	3.16	1.30	0.37	4.83	1.61	88.20
Mangifera indica	20	0.0640	2.11	2.60	0.12	4.83	1.61	89.81
Syzygium mundagam	20	0.3100	2.11	1.30	0.59	4.00	1.33	91.14
Olea dioica	10	0.5880	1.05	1.30	1.11	3.46	1.15	92.29
Pterospermum reticulatum	10	0.3360	1.05	1.30	0.64	2.99	1.00	93.29
Palaquium ellipticum	10	0.2770	1.05	1.30	0.52	2.87	0.96	94.25
Hydnocarpus pentandra	10	0.1150	1.05	1.30	0.22	2.57	0.86	95.11
Artocarpus heterophyllus	10	0.0920	1.05	1.30	0.17	2.52	0.84	95.95
Dimocarpus longan	10	0.0720	1.05	1.30	0.14	2.49	0.83	96.78
Diospyros sp.	10	0.0720	1.05	1.30	0.14	2.49	0.83	97.61
Cinnamomum malabatrum	10	0.0500	1.05	1.30	0.09	2.44	0.81	98.42
Dillenia sp. (?)	10	0.0320	1.05	1.30	0.06	2.41	0.80	99.22
Syzygium sp.	10	0.0320	1.05	1.30	0.06	2.41	0.80	100.02
Total:	950	52.8210	100.01	100.05	100.00	300.06	100.02	100.02

Table A-6. Composition of forest plot, SI11-14, Above Siruvani Estate, 850m, Medium density stratum.

Sp	d	BA	rd	rf	rba	ivi	rivi	crivi
Vateria macrocarpa	180	49.2780	20.93	16.07	67.04	104.04	34.68	34.68
Xanthophyllum arnottianum	200	2.8380	23.26	14.29	3.86	41.41	13.80	48.48
Drypetes elata	50	4.2000	5.81	7.14	5.71	18.66	6.22	54.70
Syzygium mundagam	60	2.5350	6.98	7.14	3.45	17.57	5.86	60.56
Fahrenheitia zeylanica	40	1.3760	4.65	5.36	1.87	11.88	3.96	64.52
Acronychia pedunculata	50	0.9490	5.81	3.57	1.29	10.67	3.56	68.08
Vernonia arborea	40	0.2600	4.65	5.36	0.35	10.36	3.45	71.53
Cullenia exarillata	30	2.1100	3.49	3.57	2.87	9.93	3.31	74.84
Drypetes oblongifolia	30	0.7470	3.49	5.36	1.02	9.87	3.29	78.13
Hydnocarpus pentandra	30	0.6640	3.49	5.36	0.90	9.75	3.25	81.38
Mesua ferrea	10	2.4360	1.16	1.79	3.31	6.26	2.09	83.47
Flacourtia montana	20	0.0710	2.33	3.57	0.10	6.00	2.00	85.47
Persea macrantha	10	1.5590	1.16	1.79	2.12	5.07	1.69	87.16
Diospyros candolleana	10	1.3650	1.16	1.79	1.86	4.81	1.60	88.76
Artocarpus hirsutus	10	0.8770	1.16	1.79	1.19	4.14	1.38	90.14
Mangifera indica	10	0.7330	1.16	1.79	1.00	3.95	1.32	91.46
Syzygium cumini	10	0.6590	1.16	1.79	0.90	3.85	1.28	92.74
Diospyros sp.	10	0.3680	1.16	1.79	0.50	3.45	1.15	93.89
Mallotus philippensis	10	0.2410	1.16	1.79	0.33	3.28	1.09	94.98
Knema attenuata	10	0.1340	1.16	1.79	0.18	3.13	1.04	96.02
Cinnamomum malabatrum	10	0.0320	1.16	1.79	0.04	2.99	1.00	97.02
Neonauclea purpurea	10	0.0260	1.16	1.79	0.04	2.99	1.00	98.02
Croton malabaricus	10	0.0230	1.16	1.79	0.03	2.98	0.99	99.01
Dimocarpus longan	10	0.0230	1.16	1.79	0.03	2.98	0.99	100.00

Total:	860	73.5040	99.97	100.06	99.99	300.02	100.00	100.00

Table A-7. Composition of forest plot, SI11-15, Above Siruvani estate, Muthikulam RF, 800m, Medium density stratum.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Vateria macrocarpa	170	32.7100	17.89	13.24	50.02	81.15	27.05	27.05
Cullenia exarillata	150	15.4370	15.79	11.76	23.61	51.16	17.05	44.10
Palaquium ellipticum	90	4.1720	9.47	10.29	6.38	26.14	8.71	52.81
Drypetes oblongifolia	60	1.6230	6.32	7.35	2.48	16.15	5.38	58.19
Xanthophyllum arnottianum	80	0.3020	8.42	5.88	0.46	14.76	4.92	63.11
Fahrenheitia zeylanica	40	1.5890	4.21	5.88	2.43	12.52	4.17	67.28
Hydnocarpus pentandra	40	1.2610	4.21	4.41	1.93	10.55	3.52	70.80
Stereospermum colais	30	1.3140	3.16	4.41	2.01	9.58	3.19	73.99
Neolitsea sp.	40	0.4280	4.21	4.41	0.65	9.27	3.09	77.08
Polyalthia fragrans	20	0.7150	2.11	2.94	1.09	6.14	2.05	79.13
Syzygium cumini	20	0.6900	2.11	2.94	1.06	6.11	2.04	81.17
Canarium strictum	20	0.5270	2.11	2.94	0.81	5.86	1.95	83.12
Knema attenuata	20	0.4030	2.11	2.94	0.62	5.67	1.89	85.01
Toona ciliata	20	0.9490	2.11	1.47	1.45	5.03	1.68	86.69
Dimocarpus longan	10	0.9280	1.05	1.47	1.42	3.94	1.31	88.00
Agrostistachys borneensis	20	0.1930	2.11	1.47	0.30	3.88	1.29	89.29
Myristica dactyloides	20	0.1050	2.11	1.47	0.16	3.74	1.25	90.54
Syzygium sp.	10	0.6590	1.05	1.47	1.01	3.53	1.18	91.72
Diospyros sp.	10	0.4840	1.05	1.47	0.74	3.26	1.09	92.81
Syzygium montanum	10	0.4840	1.05	1.47	0.74	3.26	1.09	93.90
Mangifera indica	10	0.0970	1.05	1.47	0.15	2.67	0.89	94.79
Nothopegia colebrookeana	10	0.0970	1.05	1.47	0.15	2.67	0.89	95.68
Drypetes elata	10	0.0670	1.05	1.47	0.10	2.62	0.87	96.55
Holigarna arnottiana	10	0.0620	1.05	1.47	0.09	2.61	0.87	97.42
Cinnamomum malabatrum	10	0.0420	1.05	1.47	0.06	2.58	0.86	98.28
Syzygium mundagam	10	0.0320	1.05	1.47	0.05	2.57	0.86	99.14
Garcinia morella	10	0.0260	1.05	1.47	0.04	2.56	0.85	99.99
Total:	950	65.3960	100.00	99.97	100.01	299.98	99.99	99.99

Table A-8. Composition of forest plot, MChola19-4, Muthukannichola, Muthikulam RF, 900m, High density stratum.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Vateria macrocarpa	440	35.2230	47.83	24.39	59.43	131.65	43.88	43.88
Mesua ferrea	90	14.4930	9.78	17.07	24.45	51.30	17.10	60.98
Syzygium mundagam	130	1.5540	14.13	17.07	2.62	33.82	11.27	72.25
Diospyros bourdilloni	50	3.6620	5.43	9.76	6.18	21.37	7.12	79.37
Polyalthia coffeoides	50	0.9120	5.43	9.76	1.54	16.73	5.58	84.95
Myristica dactyloides	70	2.2610	7.61	4.88	3.82	16.31	5.44	90.39
Knema attenuata	20	0.5420	2.17	2.44	0.91	5.52	1.84	92.23
Agrostistachys borneensis	20	0.0970	2.17	2.44	0.16	4.77	1.59	93.82
Hopea parviflora	10	0.1830	1.09	2.44	0.31	3.84	1.28	95.10
Reinwardt. anamalaiense	10	0.1610	1.09	2.44	0.27	3.80	1.27	96.37
Cinnamomum malabathrum	10	0.1400	1.09	2.44	0.24	3.77	1.26	97.63
Hydnocarpus pentandra	10	0.0260	1.09	2.44	0.04	3.57	1.19	98.82
Actinodaphne malabarica	10	0.0110	1.09	2.44	0.02	3.55	1.18	100.00
Total:	920	59.2650	100.00	100.01	99.99	300.00	100.00	100.00

Table A-9. Composition of forest plot, APara20-6, Aduthukkipara, Muthikulam RF, 1000m, High density stratum.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Vateria macrocarpa	150	30.5140	23.08	15.22	49.30	87.60	29.20	29.20
Cullenia exarillata	110	18.3450	16.92	13.04	29.64	59.60	19.87	49.07
Agrostistachys borneensis	70	0.8150	10.77	8.70	1.32	20.79	6.93	56.00
Garcinia morella	50	0.6720	7.69	8.70	1.09	17.48	5.83	61.83
Hydnocarpus pentandra	50	0.3860	7.69	6.52	0.62	14.83	4.94	66.77
Mesua ferrea	30	1.8790	4.62	6.52	3.04	14.18	4.73	71.50
Hopea parviflora	30	1.6510	4.62	6.52	2.67	13.81	4.60	76.10
Litsea deccanensis	30	0.3370	4.62	6.52	0.54	11.68	3.89	79.99
Mastixia arborea	20	1.3290	3.08	4.35	2.15	9.58	3.19	83.18
Myristica dactyloides	20	1.1750	3.08	4.35	1.90	9.33	3.11	86.29
Ficus sp.	10	2.8720	1.54	2.17	4.64	8.35	2.78	89.07
Polyalthia coffeoides	20	0.2360	3.08	4.35	0.38	7.81	2.60	91.67
Diospyros bourdilloni	10	1.4280	1.54	2.17	2.31	6.02	2.01	93.68
Mallotus philippensis	10	0.1150	1.54	2.17	0.19	3.90	1.30	94.98
Syzygium mundagam	10	0.0420	1.54	2.17	0.07	3.78	1.26	96.24
Cinnamomum malabatrum	10	0.0390	1.54	2.17	0.06	3.77	1.26	97.50
Neolitsea cassia	10	0.0320	1.54	2.17	0.05	3.76	1.25	98.75
Syzygium gardneri	10	0.0260	1.54	2.17	0.04	3.75	1.25	100.00
Total:	650	61.8930	100.03	99.98	100.01	300.02	100.00	100.00

Table A-10. Composition of forest plot, MChola19-5, Muthukannichola, Muthikulam RF, 1050m, High density stratum.

Sp	d	BA	rd	rf	rba	ivi	rivi	crivi
Vateria macrocarpa	470	43.5590	64.38	30.30	77.68	172.36	57.45	57.45
Mesua ferrea	60	4.0050	8.22	15.15	7.14	30.51	10.17	67.62
Myristica dactyloides	70	1.5730	9.59	15.15	2.81	27.55	9.18	76.80
Syzygium gardneri	30	0.2930	4.11	9.09	0.52	13.72	4.57	81.37
Elaeocarpus serratus	10	3.7800	1.37	3.03	6.74	11.14	3.71	85.08
Polyalthia fragrans	20	0.5460	2.74	6.06	0.97	9.77	3.26	88.34
Litsea deccanensis	20	0.2060	2.74	6.06	0.37	9.17	3.06	91.40
Persea macrantha	10	1.1080	1.37	3.03	1.98	6.38	2.13	93.53
Hydnocarpus pentandra	10	0.4470	1.37	3.03	0.80	5.20	1.73	95.26
Canarium strictum	10	0.4010	1.37	3.03	0.72	5.12	1.71	96.97
Knema attenuata	10	0.1400	1.37	3.03	0.25	4.65	1.55	98.52
Antidesma menasu	10	0.0200	1.37	3.03	0.04	4.44	1.48	100.00
Total:	730	56.0780	100.00	99.99	100.02	300.01	100.00	100.00

Table A-11. Composition of forest plot, KMed20-7, Keralamedu, Muthikulam RF, 1050m, High Density Stratum.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Vateria macrocarpa	210	70.3870	33.33	25.00	79.68	138.01	46.00	46.00
Mallotus philippensis	140	5.8020	22.22	16.67	6.57	45.46	15.15	61.15
Myristica dactyloides	120	2.0920	19.05	16.67	2.37	38.09	12.70	73.85
Reinwardt. anamalaiense	40	0.8900	6.35	8.33	1.01	15.69	5.23	79.08
Cinnamomum malabatrum	30	0.6800	4.76	8.33	0.77	13.86	4.62	83.70
Calophyllum polyanthum	10	4.3930	1.59	2.78	4.97	9.34	3.11	86.81
Holigarna arnottiana	10	1.4280	1.59	2.78	1.62	5.99	2.00	88.81
Agrostistachys borneensis	10	1.2430	1.59	2.78	1.41	5.78	1.93	90.74
Mesua ferrea	10	1.0520	1.59	2.78	1.19	5.56	1.85	92.59
Diospyros bourdilloni	10	0.1400	1.59	2.78	0.16	4.53	1.51	94.10
Hopea parviflora	10	0.1340	1.59	2.78	0.15	4.52	1.51	95.61
Aporusa lindleyana	10	0.0620	1.59	2.78	0.07	4.44	1.48	97.09
Knema attenuata	10	0.0180	1.59	2.78	0.02	4.39	1.46	98.55
Litsea deccanensis	10	0.0110	1.59	2.78	0.01	4.38	1.46	100.01
Total:	630	88.3320	100.02	100.02	100.00	300.04	100.01	100.01

Table A-12. Composition of coffee estate plot, KM1-cof, Siruvani Group of estates, 900m.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Vateria macrocarpa	50	13.7560	13.51	14.29	48.50	76.30	25.43	25.43
Dimocarpus longan	80	1.4990	21.62	17.14	5.29	44.05	14.68	40.11
Pterospermum reticulatum	10	3.7110	2.70	2.86	13.08	18.64	6.21	46.32
Mallotus philippensis	20	1.2510	5.41	5.71	4.41	15.53	5.18	51.50
Evodia lunu-ankenda	20	0.9180	5.41	5.71	3.24	14.36	4.79	56.29
Aglaia barberi	20	0.8950	5.41	5.71	3.16	14.28	4.76	61.05
Macaranga peltata	20	0.5370	5.41	5.71	1.89	13.01	4.34	65.39
Diospyros candolleana	10	1.0520	2.70	2.86	3.71	9.27	3.09	68.48
Terminalia paniculata	10	0.8770	2.70	2.86	3.09	8.65	2.88	71.36
Holigarna grahami	10	0.6300	2.70	2.86	2.22	7.78	2.59	73.95
Palaquium ellipticum	10	0.4960	2.70	2.86	1.75	7.31	2.44	76.39
Canarium strictum	10	0.3900	2.70	2.86	1.38	6.94	2.31	78.70
Olea dioica	10	0.3260	2.70	2.86	1.15	6.71	2.24	80.94
Syzygium sp.	10	0.3160	2.70	2.86	1.11	6.67	2.22	83.16
Hydnocarpus pentandra	10	0.3160	2.70	2.86	1.11	6.67	2.22	85.38
Xanthophyllum arnottianum	10	0.2960	2.70	2.86	1.04	6.60	2.20	87.58
Aglaia lawii	10	0.2680	2.70	2.86	0.94	6.50	2.17	89.75
Cinnamomum malabatrum	10	0.2490	2.70	2.86	0.88	6.44	2.15	91.90
Myristica dactyloides	10	0.2230	2.70	2.86	0.79	6.35	2.12	94.02
Fahrenheitia zeylanica	10	0.1680	2.70	2.86	0.59	6.15	2.05	96.07
Syzygium montanum	10	0.1610	2.70	2.86	0.57	6.13	2.04	98.11
Cullenia exarillata	10	0.0260	2.70	2.86	0.09	5.65	1.88	99.99
Total:	370	28.3610	99.97	100.03	99.99	299.99	99.99	99.99

Table A-13. Composition of coffee estate plot, KM2-cof, Siruvani Group of estates, 900m.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Vateria macrocarpa	100	6.7420	20.00	18.18	27.95	66.13	22.04	22.04
Cullenia exarillata	40	2.9210	8.00	6.82	12.11	26.93	8.98	31.02
Garcinia morella	40	1.0210	8.00	9.09	4.23	21.32	7.11	38.13
Fahrenheitia zeylanica	40	1.1350	8.00	6.82	4.71	19.53	6.51	44.64
Palaquium ellipticum	30	1.6340	6.00	4.55	6.77	17.32	5.77	50.41
Mesua ferrea	30	0.9210	6.00	6.82	3.82	16.64	5.55	55.96
Artocarpus hirsutus	30	0.5140	6.00	6.82	2.13	14.95	4.98	60.94
Dimocarpus longan	30	0.8370	6.00	4.55	3.47	14.02	4.67	65.61
Bischofia javanica	10	2.1660	2.00	2.27	8.98	13.25	4.42	70.03
Holigarna arnottiana	20	1.0340	4.00	4.55	4.29	12.84	4.28	74.31
Polyalthia coffeoides	20	0.9980	4.00	4.55	4.14	12.69	4.23	78.54
Mallotus philippensis	20	0.5180	4.00	4.55	2.15	10.70	3.57	82.11
Syzygium cumini	10	1.0520	2.00	2.27	4.36	8.63	2.88	84.99
Toona ciliata	10	0.7180	2.00	2.27	2.98	7.25	2.42	87.41
Hydnocarpus pentandra	10	0.4240	2.00	2.27	1.76	6.03	2.01	89.42
Drypetes oblongifolia	10	0.3680	2.00	2.27	1.53	5.80	1.93	91.35
Mangifera indica	10	0.2860	2.00	2.27	1.19	5.46	1.82	93.17
Actinodaphne malabarica	10	0.2410	2.00	2.27	1.00	5.27	1.76	94.93
Olea dioica	10	0.2410	2.00	2.27	1.00	5.27	1.76	96.69
Litsea floribunda	10	0.1830	2.00	2.27	0.76	5.03	1.68	98.37
Cinnamomum malabatrum	10	0.1680	2.00	2.27	0.70	4.97	1.66	100.03
Total:	500	24.1220	100.00	100.00	100.03	300.03	100.03	100.03

Table A-14. Composition of coffee estate plot, Ky5-cof, Siruvani Group of estates, 900m.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Vateria macrocarpa	130	30.1250	29.55	25.64	63.19	118.38	39.46	39.46
Evodia lunu-ankenda	30	2.2840	6.82	7.69	4.79	19.30	6.43	45.89
Drypetes oblongifolia	40	1.0090	9.09	7.69	2.12	18.90	6.30	52.19
Persea macrantha	30	1.5100	6.82	5.13	3.17	15.12	5.04	57.23
Cullenia exarillata	20	2.0030	4.55	5.13	4.20	13.88	4.63	61.86
Xanthophyllum arnottianum	20	0.3560	4.55	5.13	0.75	10.43	3.48	65.34
Canarium strictum	10	1.3650	2.27	2.56	2.86	7.69	2.56	67.90
Strombosia ceylanica	10	1.3030	2.27	2.56	2.73	7.56	2.52	70.42
Drypetes elata	10	1.2430	2.27	2.56	2.61	7.44	2.48	72.90
Prunus zeylanica	10	1.1650	2.27	2.56	2.44	7.27	2.42	75.32
Dimocarpus longan	10	0.7180	2.27	2.56	1.51	6.34	2.11	77.43
Litsea floribunda	10	0.6880	2.27	2.56	1.44	6.27	2.09	79.52
Cinnamomum malabatrum	10	0.6590	2.27	2.56	1.38	6.21	2.07	81.59
Terminalia paniculata	10	0.6160	2.27	2.56	1.29	6.12	2.04	83.63
Artocarpus hirsutus	10	0.5880	2.27	2.56	1.23	6.06	2.02	85.65
Knema attenuata	10	0.4960	2.27	2.56	1.04	5.87	1.96	87.61
Garcinia morella	10	0.2960	2.27	2.56	0.62	5.45	1.82	89.43
Macaranga peltata	10	0.2960	2.27	2.56	0.62	5.45	1.82	91.25
Vernonia arborea	10	0.2960	2.27	2.56	0.62	5.45	1.82	93.07
Mangifera indica	10	0.2490	2.27	2.56	0.52	5.35	1.78	94.85
Neolitsia sp.	10	0.1680	2.27	2.56	0.35	5.18	1.73	96.58
Olea dioica	10	0.1340	2.27	2.56	0.28	5.11	1.70	98.28
Toona ciliata	10	0.1030	2.27	2.56	0.22	5.05	1.68	99.96
Total:	440	47.6700	99.97	99.93	99.98	299.88	99.96	99.96

Table A-15. Composition of coffee estate plot, Ky8-cof, Siruvani Group of estates, 900m.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Vateria macrocarpa	70	20.8530	20.00	20.59	37.06	77.65	25.88	25.88
Elaeocarpus serratus	30	6.6930	8.57	8.82	11.89	29.28	9.76	35.64
Fahrenheitia zeylanica	30	1.8080	8.57	8.82	3.21	20.60	6.87	42.51
Persea macrantha	20	4.0760	5.71	5.88	7.24	18.83	6.28	48.79
Artocarpus hirsutus	20	3.0330	5.71	5.88	5.39	16.98	5.66	54.45
Holigarna arnottiana	20	0.8360	5.71	5.88	1.49	13.08	4.36	58.81
Drypetes oblongifolia	20	1.9640	5.71	2.94	3.49	12.14	4.05	62.86
Ficus sp.	10	3.0250	2.86	2.94	5.38	11.18	3.73	66.59
Prunus ceylanica	10	2.3260	2.86	2.94	4.13	9.93	3.31	69.90
Holigarna grahami	10	2.3260	2.86	2.94	4.13	9.93	3.31	73.21
Cinnamomum malabatrum	10	1.7900	2.86	2.94	3.18	8.98	2.99	76.20
Calophyllum polyanthum	10	1.6960	2.86	2.94	3.01	8.81	2.94	79.14
Canarium strictum	10	1.4500	2.86	2.94	2.58	8.38	2.79	81.93
Dimocarpus longan	10	0.9800	2.86	2.94	1.74	7.54	2.51	84.44
Mallotus philippensis	10	0.9630	2.86	2.94	1.71	7.51	2.50	86.94
Syzygium cumini	10	0.7330	2.86	2.94	1.30	7.10	2.37	89.31
Evodia lunu-ankenda	10	0.5750	2.86	2.94	1.02	6.82	2.27	91.58
Macaranga peltata	10	0.4960	2.86	2.94	0.88	6.68	2.23	93.81
Beilschmiedia sp.	10	0.2410	2.86	2.94	0.43	6.23	2.08	95.89
Mangifera indica	10	0.2410	2.86	2.94	0.43	6.23	2.08	97.97
Syzygium sp.	10	0.1680	2.86	2.94	0.30	6.10	2.03	100.00
Total:	350	56.2730	100.02	99.97	99.99	299.98	100.00	100.00

Table A-16. Composition of coffee estate plot, Ky6-cof, Siruvani Group of estates, 900m.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Vateria macrocarpa	80	31.3270	25.00	21.43	43.91	90.34	30.11	30.11
Cullenia exarillata	70	16.9270	21.88	21.43	23.73	67.04	22.35	52.46
Xanthophyllum arnottianum	50	1.1090	15.63	14.29	1.55	31.47	10.49	62.95
Bischofia javanica	10	9.7440	3.13	3.57	13.66	20.36	6.79	69.74
Fahrenheitia zeylanica	20	1.7390	6.25	7.14	2.44	15.83	5.28	75.02
Drypetes oblongifolia	20	1.1650	6.25	7.14	1.63	15.02	5.01	80.03
Unidentified sp. 1	10	2.2990	3.13	3.57	3.22	9.92	3.31	83.34
Mesua ferrea	10	2.0360	3.13	3.57	2.85	9.55	3.18	86.52
Myristica dactyloides	10	1.4710	3.13	3.57	2.06	8.76	2.92	89.44
Drypetes elata	10	1.4500	3.13	3.57	2.03	8.73	2.91	92.35
Artocarpus heterophyllus	10	1.0700	3.13	3.57	1.50	8.20	2.73	95.08
Dimocarpus longan	10	0.9280	3.13	3.57	1.30	8.00	2.67	97.75
Alstonia scholaris	10	0.0720	3.13	3.57	0.10	6.80	2.27	100.02
Total:	320	71.3370	100.05	99.99	99.98	300.02	100.02	100.02

Table A-17. Composition of coffee estate plot, Ky7-cof, Siruvani Group of estates, 900m.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Vateria macrocarpa	140	54.4440	35.00	29.03	78.11	142.14	47.38	47.38
Drypetes oblongifolia	60	3.8840	15.00	16.13	5.57	36.70	12.23	59.61
Cullenia exarillata	50	3.4090	12.50	6.45	4.89	23.84	7.95	67.56
Dimocarpus longan	30	2.7020	7.50	9.68	3.88	21.06	7.02	74.58
Fahrenheitia zeylanica	20	1.0340	5.00	6.45	1.48	12.93	4.31	78.89
Litsea floribunda	20	0.5430	5.00	6.45	0.78	12.23	4.08	82.97
Aglaia lawii	10	1.2430	2.50	3.23	1.78	7.51	2.50	85.47
Cinnamomum malabatrum	10	0.7640	2.50	3.23	1.10	6.83	2.28	87.75
Actinodaphne malabarica	10	0.7330	2.50	3.23	1.05	6.78	2.26	90.01
Syzygium mundagam	10	0.4470	2.50	3.23	0.64	6.37	2.12	92.13
Xanthophyllum arnottianum	10	0.1470	2.50	3.23	0.21	5.94	1.98	94.11
Bischofia javanica	10	0.1270	2.50	3.23	0.18	5.91	1.97	96.08
Flacourtia montana	10	0.1270	2.50	3.23	0.18	5.91	1.97	98.05
Artocarpus heterophyllus	10	0.0970	2.50	3.23	0.14	5.87	1.96	100.01
Total:	400	69.7010	100.00	100.03	99.99	300.02	100.01	100.01

Table 44. Composition of cardomom estate plot, KM3-cdf, Siruvani Group of estates, 900m.

Sp	d	ba	rd	rf	rba	ivi	rivi	crivi
Vateria macrocarpa	110	33.0740	22.92	21.95	58.47	103.34	34.45	34.45
Toona ciliata	60	2.5160	12.50	9.76	4.45	26.71	8.90	43.35
Mangifera indica	40	1.6360	8.33	9.76	2.89	20.98	6.99	50.34
Reinwardt. anamalaiense	30	1.9100	6.25	7.32	3.38	16.95	5.65	55.99
Mesua ferrea	30	3.1880	6.25	4.88	5.64	16.77	5.59	61.58
Terminalia paniculata	40	1.1860	8.33	4.88	2.10	15.31	5.10	66.68
Fahrenheitia zeylanica	20	1.4840	4.17	4.88	2.62	11.67	3.89	70.57
Drypetes elata	20	1.0120	4.17	4.88	1.79	10.84	3.61	74.18
Cullenia exarillata	10	2.5200	2.08	2.44	4.46	8.98	2.99	77.17
Palaquium ellipticum	10	2.3810	2.08	2.44	4.21	8.73	2.91	80.08
Macaranga peltata	10	1.1650	2.08	2.44	2.06	6.58	2.19	82.27
Canarium strictum	10	1.1080	2.08	2.44	1.96	6.48	2.16	84.43
Sterculia guttata	10	0.6300	2.08	2.44	1.11	5.63	1.88	86.31
Syzygium mundagam	10	0.5750	2.08	2.44	1.02	5.54	1.85	88.16
Garcinia morella	10	0.5480	2.08	2.44	0.97	5.49	1.83	89.99
Dimocarpus longan	10	0.4590	2.08	2.44	0.81	5.33	1.78	91.77
Artocarpus hirsutus	10	0.3470	2.08	2.44	0.61	5.13	1.71	93.48
Olea dioica	10	0.2490	2.08	2.44	0.44	4.96	1.65	95.13
Artocarpus heterophyllus	10	0.2410	2.08	2.44	0.43	4.95	1.65	96.78
Baccarurea courtallensis	10	0.1680	2.08	2.44	0.30	4.82	1.61	98.39
Drypetes oblongifolia	10	0.1680	2.08	2.44	0.30	4.82	1.61	100.00
Total:	80	56.5650	99.96	100.03	100.02	300.01	100.00	100.00

Table A-18. Composition of cardomom estate plot, KM4-cdf, Siruvani Group of estates, 900m.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Vateria macrocarpa	120	20.8160	25.00	21.95	40.99	87.94	29.31	29.31
Persea macrantha	90	9.2380	18.75	12.20	18.19	49.14	16.38	45.69
Mangifera indica	30	2.3840	6.25	7.32	4.69	18.26	6.09	51.78
Cinnamomum malabatrum	30	2.1520	6.25	7.32	4.24	17.81	5.94	57.72
Syzygium cumini	10	3.3430	2.08	2.44	6.58	11.10	3.70	61.42
Actinodaphne malabarica	20	0.9400	4.17	4.88	1.85	10.90	3.63	65.05
Evodia lunu-ankenda	20	0.7870	4.17	4.88	1.55	10.60	3.53	68.58
Mesua ferrea	20	0.7480	4.17	4.88	1.47	10.52	3.51	72.09
Canarium strictum	20	0.4710	4.17	4.88	0.93	9.98	3.33	75.42
Prunus zeylanica	10	2.7220	2.08	2.44	5.36	9.88	3.29	78.71
Strombosia zeylanica	10	1.3240	2.08	2.44	2.61	7.13	2.38	81.09
Cullenia exarillata	10	0.9630	2.08	2.44	1.90	6.42	2.14	83.23
Calophyllum polyanthum	10	0.7800	2.08	2.44	1.54	6.06	2.02	85.25
Litsea floribunda	10	0.6880	2.08	2.44	1.35	5.87	1.96	87.21
Holigarna grahami	10	0.6590	2.08	2.44	1.30	5.82	1.94	89.15
Knema attenuata	10	0.6300	2.08	2.44	1.24	5.76	1.92	91.07
Toona ciliata	10	0.6300	2.08	2.44	1.24	5.76	1.92	92.99
Garcinia morella	10	0.5880	2.08	2.44	1.16	5.68	1.89	94.88
Palaquium ellipticum	10	0.4240	2.08	2.44	0.83	5.35	1.78	96.66
Dimocarpus longan	10	0.3680	2.08	2.44	0.72	5.24	1.75	98.41
Agrostistachys borneensis	10	0.1340	2.08	2.44	0.26	4.78	1.59	100.00
Total:	480	50.7890	99.97	100.03	100.00	300.00	100.00	100.00

Table A-19. Composition of cardomom estate plot, SI10-cdf, Siruvani group of estates, 900m.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Vateria macrocarpa	60	12.6260	16.22	14.71	39.20	70.13	23.38	23.38
Calophyllum polyanthum	20	3.4380	5.41	5.88	10.67	21.96	7.32	30.70
Mesua ferrea	30	1.5770	8.11	5.88	4.90	18.89	6.30	37.00
Syzygium mundagam	30	0.6040	8.11	8.82	1.88	18.81	6.27	43.27
Evodia lunu-ankenda	30	0.9320	8.11	5.88	2.89	16.88	5.63	48.90
Artocarpus hirsutus	20	0.8120	5.41	5.88	2.52	13.81	4.60	53.50
Bischofia javanica	10	2.5770	2.70	2.94	8.00	13.64	4.55	58.05
Myristica dactyloides	10	1.2430	2.70	2.94	3.86	9.50	3.17	61.22
Prunus ceylanica	10	0.9800	2.70	2.94	3.04	8.68	2.89	64.11
Macaranga peltata	10	0.9630	2.70	2.94	2.99	8.63	2.88	66.99
Actinodaphne malabarica	10	0.8770	2.70	2.94	2.72	8.36	2.79	69.78
Dillenia sp. (?)	10	0.8770	2.70	2.94	2.72	8.36	2.79	72.57
Holigarna arnottiana	10	0.7480	2.70	2.94	2.32	7.96	2.65	75.22
Fahrenheitia zeylanica	10	0.7330	2.70	2.94	2.28	7.92	2.64	77.86
Diospyros candolleana	10	0.7180	2.70	2.94	2.23	7.87	2.62	80.48
Knema attenuata	10	0.4840	2.70	2.94	1.50	7.14	2.38	82.86
Syzygium mundagam	10	0.4590	2.70	2.94	1.42	7.06	2.35	85.21
Cullenia exarillata	10	0.3260	2.70	2.94	1.01	6.65	2.22	87.43
Cinnamomum malabatrum	10	0.3160	2.70	2.94	0.98	6.62	2.21	89.64
Garcinia spicata	10	0.2680	2.70	2.94	0.83	6.47	2.16	91.80
Persea macrantha	10	0.2580	2.70	2.94	0.80	6.44	2.15	93.95
Litsea floribunda	10	0.1340	2.70	2.94	0.42	6.06	2.02	95.97
Toona ciliata	10	0.1340	2.70	2.94	0.42	6.06	2.02	97.99
Dimocarpus longan	10	0.1270	2.70	2.94	0.39	6.03	2.01	100.00
Total:	370	32.2110	99.97	99.97	99.99	299.93	100.00	100.00

Table A-20. Composition of cardomom estate plot, SI11-cdf, Siruvani Group of estates, 900m.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Vateria macrocarpa	80	13.5820	15.09	14.58	38.07	67.74	22.58	22.58
Cullenia exarillata	50	5.9380	9.43	10.42	16.64	36.49	12.16	34.74
Fahrenheitia zeylanica	60	1.4280	11.32	10.42	4.00	25.74	8.58	43.32
Drypetes oblongifolia	50	1.7670	9.43	8.33	4.95	22.71	7.57	50.89
Macaranga peltata	40	1.8030	7.55	4.17	5.05	16.77	5.59	56.48
Toona ciliata	30	0.5440	5.66	6.25	1.52	13.43	4.48	60.96
Canarium strictum	20	1.1080	3.77	4.17	3.11	11.05	3.68	64.64
Olea dioica	20	1.0350	3.77	4.17	2.90	10.84	3.61	68.25
Cinnamomum malabatrum	20	0.6620	3.77	4.17	1.86	9.80	3.27	71.52
Litsea floribunda	20	0.4970	3.77	4.17	1.39	9.33	3.11	74.63
Mesua ferrea	10	1.7420	1.89	2.08	4.88	8.85	2.95	77.58
Drypetes elata	10	0.8770	1.89	2.08	2.46	6.43	2.14	79.72
Persea macrantha	10	0.7640	1.89	2.08	2.14	6.11	2.04	81.76
Palaquium ellipticum	10	0.7330	1.89	2.08	2.05	6.02	2.01	83.77
Bischofia javanica	10	0.5880	1.89	2.08	1.65	5.62	1.87	85.64
Actinodaphne malabarica	10	0.4960	1.89	2.08	1.39	5.36	1.79	87.43
Dillenia sp. (?)	10	0.4470	1.89	2.08	1.25	5.22	1.74	89.17
Artocarpus heterophyllus	10	0.3680	1.89	2.08	1.03	5.00	1.67	90.84
Hydnocarpus pentandra	10	0.3360	1.89	2.08	0.94	4.91	1.64	92.48
Syzygium montanum	10	0.2410	1.89	2.08	0.68	4.65	1.55	94.03
Agrostistachys borneensis	10	0.2230	1.89	2.08	0.63	4.60	1.53	95.56
Myristica dactyloides	10	0.2070	1.89	2.08	0.58	4.55	1.52	97.08
Mangifera indica	10	0.1910	1.89	2.08	0.54	4.51	1.50	98.58
Syzygium sp.	10	0.1030	1.89	2.08	0.29	4.26	1.42	100.00
Total:	530	35.6800	100.02	99.97	100.00	299.99	100.00	100.00

Table A-21. Composition of cardomom estate plot, SI12-cdf, Siruvani Group of estates, 900m.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Bischofia javanica	10	415.6880	3.33	4.17	87.33	94.83	31.61	31.61
Vateria macrocarpa	110	27.9170	36.67	29.17	5.86	71.70	23.90	55.51
Cullenia exarillata	60	19.9650	20.00	20.83	4.19	45.02	15.01	70.52
Drypetes oblongifolia	30	2.0890	10.00	12.50	0.44	22.94	7.65	78.17
Syzygium montanum	20	0.6380	6.67	4.17	0.13	10.97	3.66	81.83
Fahrenheitia zeylanica	10	3.6770	3.33	4.17	0.77	8.27	2.76	84.59
Mesua ferrea	10	1.6960	3.33	4.17	0.36	7.86	2.62	87.21
Artocarpus heterophyllus	10	1.5590	3.33	4.17	0.33	7.83	2.61	89.82
Syzygium mundagam	10	1.1650	3.33	4.17	0.24	7.74	2.58	92.40
Dillenia sp. (?)	10	0.9630	3.33	4.17	0.20	7.70	2.57	94.97
Dimocarpus longan	10	0.5880	3.33	4.17	0.12	7.62	2.54	97.51
Syzygium sp.	10	0.0540	3.33	4.17	0.01	7.51	2.50	100.01
Total:	300	475.9990	99.98	100.03	99.98	299.99	100.01	100.01

Table A-22. Composition of cardomom estate plot, si9-cdf, Siruvani Group of estates, 900m.

Species	D	BA	RD	RF	RBA	IVI	RIVI	CRIVI
Vateria macrocarpa	40	12.4680	9.76	10.26	29.99	50.01	16.67	16.67
Drypetes oblongifolia	50	3.8880	12.20	12.82	9.35	34.37	11.46	28.13
Cullenia exarillata	30	5.8300	7.32	5.13	14.02	26.47	8.82	36.95
Bischofia javanica	20	4.2860	4.88	5.13	10.31	20.32	6.77	43.72
Holigarna arnottiana	20	3.0990	4.88	5.13	7.46	17.47	5.82	49.54
Toona ciliata	30	0.8050	7.32	5.13	1.94	14.39	4.80	54.34
Litsea floribunda	20	1.3470	4.88	5.13	3.24	13.25	4.42	58.76
Artocarpus hirsutus	20	1.0840	4.88	5.13	2.61	12.62	4.21	62.97
Canarium strictum	20	0.8990	4.88	5.13	2.16	12.17	4.06	67.03
Dimocarpus longan	20	0.5180	4.88	5.13	1.25	11.26	3.75	70.78
Evodia lunu-ankenda	20	0.4970	4.88	5.13	1.20	11.21	3.74	74.52
Syzygium mundagam	20	0.1930	4.88	5.13	0.46	10.47	3.49	78.01
Mangifera indica	10	1.6720	2.44	2.56	4.02	9.02	3.01	81.02
Myristica dactyloides	10	1.1450	2.44	2.56	2.75	7.75	2.58	83.60
Unidentified sp.	10	1.0700	2.44	2.56	2.57	7.57	2.52	86.12
Knema attenuata	10	0.7330	2.44	2.56	1.76	6.76	2.25	88.37
Drypetes elata	10	0.5750	2.44	2.56	1.38	6.38	2.13	90.50
Actinodaphne malabarica	10	0.5220	2.44	2.56	1.26	6.26	2.09	92.59
Palaquium ellipticum	10	0.2580	2.44	2.56	0.62	5.62	1.87	94.46
Dillenia sp. (?)	10	0.2410	2.44	2.56	0.58	5.58	1.86	96.32
Syxygium sp.	10	0.2320	2.44	2.56	0.56	5.56	1.85	98.17
Hydnocarpus pentandra	10	0.2070	2.44	2.56	0.50	5.50	1.83	100.00
Total:	410	41.5690	100.04	99.98	99.99	300.01	100.00	100.00

Appendix-2:
Population structure of *Vateria macrocarpa*

Table A-23. Frequency distribution of *V. macrocarpa* in various size classes (Forest samples; sample size: 0.1 ha).

Density stratum: Low

Sample	Alt	d10	d20	d30	d40	d50	d60	d70	d80	d90	dg90	Total
Koo4-2R	750	20	40	10	10	10	10	20	-	-	10	130
Koo4-3R	700	-	-	10	10	30	-	10	30	-	-	90
Koo9-5R	600	60	20	80	40	40	-	20	20	20	40	340
Koo9-6R	600 m	30	20	20	-	10	10	-	10	10	-	110
PPara14-16R	700 m	70	90	20	50	10	30	30	-	20	-	320
PPara14-17R	650 m	20	-	30	20	10	30	-	20	20	40	190

Density stratum: Medium

Sample	Alt	d10	d20	d30	d40	d50	d60	d70	d80	d90	dg90	Total
APara12-23R	600 m	80	-	-	10	20	30	-	10	-	10	160
Koo12-1R	600 m	10	10	-	20	20	-	20	-	-	30	110
Koo12-2R	650 m	20	-	10	10	30	20	20	10	-	20	140
PPara13-19R	650 m	-	-	-	20	20	40	40	40	-	60	220
SI11-8R		-	-	-	10	30	-	30	10	-	10	90
SI11-21R	800 m	10	10	10	10	50	30	-	-	-	-	120
SI11-22R	850 m	10	-	50	30	10	10	10	50	10	10	190
SI11-23R	800 m	20	10	40	-	-	30	40	20	-	-	160
SI11-24R	850 m	190	-	10	-	-	-	30	30	-	-	260

Density stratum: Medium

Sample	Alt	d10	d20	d30	d40	d50	d60	d70	d80	d90	dg90	Total
APara20-21R		90	30	20	30	20	20	30	-	-	10	250
APara20-22R	850 m	90	110	90	10	10	10	20	20	40	30	430
KMed19-20R	900 m	180	30	-	40	-	20	40	-	-	10	320
KMed20-11R	1,050 m	110	50	10	10	20	-	10	20	-	40	270
KMed20-12R	1,000 m	20	20	10	10	20	20	20	10	-	20	150
KMed20-13R	1,200 m	310	30	10	20	-	-	-	-	-	20	390
KMed20-14R	1,200 m	150	10	-	-	50	20	40	20	-	10	300
KMed20-15R	1,250 m	-	10	-	30	20	20	30	20	10	40	180
MChola19-1R	1,200 m	-	-	-	-	20	-	10	30	20	-	80
MChola19-7R	1,050 m	-	80	10	30	20	20	40	-	-	60	260
MChola19-11R	1,000 m	-	20	30	10	40	50	10	20	20	30	230

Table A-24. Frequency distribution of *V. macrocarpa* in various size classes (Siruvani Group of Estates; sample size: 0.1 ha).

Cardamom Estates:

Sample	Locality	Alt	d10	d20	d30	d40	d50	d60	d70	d80	d90	dg90	Total
KM4-Cd	Kizhakkambalam	900 m	-	20	20	30	20	10	10	-	-	10	120
KM5-Cd	Kizhakkambalam	900 m	-	-	-	10	20	10	20	-	10	30	100
KM6-Cd	Kizhakkambalam	900 m	-	-	-	40	10	-	-	-	10	30	90
KM7-Cd	Kizhakkambalam	900 m	90	80	30	30	-	10	20	10	-	-	270
SI13-Cd	Siruvani	800 m	-	-	-	-	-	20	10	10	-	-	40
SI14-Cd	Siruvani	900 m	-	10	10	10	10	10	-	-	-	10	60
SI15-Cd	Siruvani	900 m	-	-	20	20	10	20	10	-	-	-	80
SI16-Cd	Siruvani	900 m	-	10	20	10	30	-	20	-	10	10	110
SI17-Cd	Siruvani	900 m	-	-	-	-	-	-	40	-	20	-	60
SI18-Cd	Siruvani	900 m	10	-	10	-	10	10	20	10	-	10	80
SI19-Cd	Siruvani	900 m	-	-	-	-	-	30	30	10	-	-	70
SI20-Cd	Siruvani	900 m	-	-	-	-	10	20	30	-	-	-	60

Coffee Estates:

Sample	Locality	Alt	d10	d20	d30	d40	d50	d60	d70	d80	d90	dg90	Total
KM1-Cof	Kizhakkambalam	900 m	-	-	10	10	10	10	-	-	-	10	50
KM2-Cof	Kizhakkambalam	900 m	-	30	40	10	20	-	-	-	-	-	100
KM3-Cof	Kizhakkambalam	900 m	-	-	-	-	20	30	40	10	10	-	110
Ky9-Cof	Kuruvambady	900 m	-	-	10	50	-	20	20	20	10	-	130
Ky10-Cof	Kuruvambady	900 m	-	-	10	-	-	30	-	20	10	10	80
Ky11-Cof	Kuruvambady	900 m	-	-	10	50	20	10	-	-	-	50	140
Ky12-Cof	Kuruvambady	900 m	-	-	-	20	-	10	30	10	-	-	70

Table A-25. Population structure of *V. macrocarpa* in various Lower size classes (Forest samples; sample size: 0.1 ha).

Density stratum: Low

Sample	Locality	Stratum	Alt	Total	Unest	Est	Adv	Sapl	Poles	Trs
Koo4-2R	Koodam	Very Low	750 m	130	70	20	-	20	40	70
Koo4-3R	Koodam	Very Low	700 m	90	40	-	-	-	-	90
Koo9-5R	Koodam	Low	600 m	340	310	10	60	60	20	260
Koo9-6R	Koodam	Low	600 m	110	130	-	20	30	20	60
PPara14-16R	Poolappara	Low	700 m	320	920	40	10	70	90	160
PPara14-17R	Poolappara	Low	650 m	190	370	30	60	20	-	170

Density stratum: Medium

Sample	Locality	Stratum	Alt	Total	Unest	Est	Adv	Sapl	Poles	Trs
APara12-23R	Aduthukkippa	Medium		160	-	-	100	80	-	80
Koo12-1R	Koodam	Medium	600 m	110	1390	20	50	10	10	90
Koo12-2R	Koodam	Medium	650 m	140	80	-	-	20	-	120
PPara13-19R	Poolappara	Medium	650 m	220	1580	250	80	-	-	220
SI11-8R	Siruvani	Medium	800 m	90	-	-	-	-	-	90
SI11-21R	Siruvani	Medium	800 m	120	-	40	-	10	10	100
SI11-22R	Siruvani	Medium	850 m	190	-	30	-	10	-	180
SI11-23R	Siruvani	Medium	800 m	160	2830	2830	-	20	10	130
SI11-24R	Siruvani	Medium	850 m	260	30	10	-	190	-	70

Density stratum: Medium

Sample	Locality	Stratum	Alt	Total	Unest	Est	Adv	Sapl	Poles	Trs
APara20-21R	Aduthukkippa	High		250	-	-	400	90	30	130
APara20-22R	Aduthukkippa	High	850 m	430	-	-	280	90	110	230
KMed19-20R	Keralamed	High	900 m	320	-	-	460	180	30	110
KMed20-11R	Keralamed	High	1,050 m	270	400	100	180	110	50	110
KMed20-12R	Keralamed	High	1,000 m	150	80	-	20	20	20	110
KMed20-13R	Keralamed	High	1,200 m	390	940	110	550	310	30	50
KMed20-14R	Keralamed	High	1,200 m	300	240	60	160	150	10	140
KMed20-15R	Keralamed	High	1,250 m	180	40	-	-	-	10	170
MChola19-1R	Muthukanichola	High	1,250 m	80	510	60	100	-	-	80
MChola19-7R	Muthukanichola	High	1,050 m	260	100	-	-	-	80	180
MChola19-11R	Muthukanichola	High	1,000 m	230	40	-	-	-	20	210

Table A-26. Population structure of *V. macrocarpa* (Siruvani Group of Estates; sample size: 0.1 ha).

Cardamom Estates

Sample	Loc	Alt	Sapl	Poles	Trs	Total
KM4-Cd	Kizhakkambalam	900 m	-	20	100	120
KM5-Cd	Kizhakkambalam	900 m	-	-	100	100
KM6-Cd	Kizhakkambalam	900 m	-	-	90	90
KM7-Cd	Kizhakkambalam	900 m	90	80	100	270
SI13-Cd	Siruvani	800 m	-	-	40	40
SI14-Cd	Siruvani	900 m	-	10	50	60
SI15-Cd	Siruvani	900 m	-	-	80	80
SI16-Cd	Siruvani	900 m	-	10	100	110
SI17-Cd	Siruvani	900 m	-	-	60	60
SI18-Cd	Siruvani	900 m	10	-	70	80
SI19-Cd	Siruvani	900 m	-	-	70	70
SI20-Cd	Siruvani	900 m	-	-	60	60

Coffee Estates

Sample	Loc	Alt	Sapl	Poles	Trs	Total
KM1-Cof	Kizhakkambalam	900 m	-	-	50	50
KM2-Cof	Kizhakkambalam	900 m	-	30	70	100
KM3-Cof	Kizhakkambalam	900 m	-	-	110	110
Ky9-Cof	Kuruvambady	900 m	-	-	130	130
Ky10-Cof	Kuruvambady	900 m	-	-	80	80
Ky11-Cof	Kuruvambady	900 m	-	-	140	140
Ky12-Cof	Kuruvambady	900 m	-	-	70	70