STUDIES ON SYSTEMATICS AND BIOLOGY OF ENDEMIC TREE GENERA OF WESTERN GHATS INDIA

Thesis submitted to Goa University
for the award of degree of

Doctor of Philosophy
in
Botany

By

S. Rajkumar

Certified that all the corrections are incorporated in the thesis. This is the final copy

09/2/02
(R. R. VENKATA RAJU)
External Examiner

9/2/02
(M.K. Janarthanam)

Department of Botany
Goa University
Goa - 403 206
India

January 2001

STATEMENT

As required by the University Ordinance 0.19.8. (ii), I state that the present thesis " Studies on Systematics and Biology of Endemic Tree Genera of Western Ghats, India" is my original contribution and the same has not been submitted on any previous occasion for any other degree or diploma of this University or any other University/Institute. To the best of my knowledge, the present study is the first comprehensive work of its kind from the area mentioned. The literature related to the problem investigated has been cited. Due acknowledgements have been made wherever facilities and suggestions have been availed of.

S. Rajkumar

Place: Goa University

(S.Rajkumar)

Date: 22.01.2001

Candidate

CERTIFICATE

As required by the University Ordinance 0.19.8. (vi), this is to certify that the thesis entitled "Studies on Systematics and Biology of Endemic Tree Genera of Western Ghats, India", submitted by Mr. S. Rajkumar for the award of the degree of Doctor of Philosophy in Botany, is based on his original and independent work carried out by him during the period of study, under my supervision.

The thesis or any part thereof has not been previously submitted for any other degree or diploma in any University or institute.

Place: Goa University
Date: 22/01/2001

(M.K. Janarthanam)
Research Guide

ACKNOWLEDGEMENTS

I owe my gratitude to my supervisor Dr. M.K. Janarthanam, Department of Botany, Goa University for inspiring me to work on endemic plants, for support during my field trips, for inciting me to work on my own and for his invaluable suggestions.

My sincere thanks to Prof. D. J. Bhat, Head, Department of Botany, Goa University for his encouragement and facilities.

I thank Ms. Vaishali C. Joshi (cucu tai) for her priceless help and support in various counts during my stay in Goa and the course of my work.

I thank Directors / in-charge of BSI (Pune), HIFP (Pondicherry), JCB (Bangalore), MH (Coimbatore), RPT (Thiruchirapally) and TBGT (Thiruvananthapuram) for permitting me to consult their herbaria and library.

My sincere thanks to Dr. N.P. Balakrishnan, Emeritus Scientist, Dr. R. Gopalan, Mrs. V.Chitra, Mrs. C.P. Malathi and Mr. M. S. Swaminathan all from MH, Coimbatore for their various help.

My thanks to Dr. S. Karthikeyan (Joint Dir. - Retd.), Dr. P. Lakshminarasimhan, Dr. Prasanna and Dr V.P. Prasad for their help during my visit to BSI, Pune.

I am indebted to Prof. S.R. Yadav, Department of Botany, Shivaji University, Kolhapur for his encouragement and invaluable help.

My thanks to Prof. M. Sivadasan and Dr. A.K. Pradeep, Department of Botany, Calicut University, Prof. K.S. Manilal, Professor Emeritus, Malabar Botanical Garden, Calicut, Dr. K. G. Bhat, Poornaprajna College, Udupi, Dr. N. Parthasarathy, Salim Ali School of Ecology, Pondicherry, Dr. Binoj Kumar, Quilon, Dr. Y.N. Seetharam, Gulbarga University, Dr. N. Sasidharan, Kerala Forest Research Institute, Thrissur, Dr. S.N. Yoganarashiman, Bangalore, Dr. C.N. Mohanan, Thiruvananthapuram, Prof. N. Paria, Calcutta Univerisity, Dr. M. Sanjappa, Central National

Herbarium, Calcutta, Dr. S. Ramachandran, Coimbatore, Dr. A.G. Pandurangam, TBGRI, Thiruvananthapuram, Dr. B.R. Ramesh, French Institute, Pondicherry, Mr. H. Bhat and Mr. T. Suresh, Centre for Ecological Sciences, IISC, Bangalore and Prof. K.V. Krishnamurthy, Bharathidasan University, Tiruchirapally for their help in either providing literature or required plant materials.

I am indebted to Dr. K Ravikumar, Scientist, FRLHT, Bangalore for his great help and information on precise field locations of plants.

My thanks to Dr. V.K. Srivastava, SAC, Ahmedabad for encouragement.

I thank Dr. S. Raghukumar, NIO, Goa for permitting me to use SEM and Microscope facility and to Mr. Arif and Mr. Ravindran for their help during my work at NIO, Goa.

I am very much thankful to my pals Mr. S. Muthuramkumar and N. Ayyappan who were always the source of literature and to Mr. D. Alegasapandiyan for his accompaniment.

I thank Dr. Andrea Schwazarbach, Indiana Univeristy, USA, Dr. Peter Wilson, Royal Botanical Garden, Sydney, Prof. Rudolf Schmid, California University, Dr. David A. Baum, Harvard University, Prof. Peter Stevens, Harvard University, Dr. W.S. Judd, Florida University and Dr. Clemans Bayer, Frankfurt Univeristy, Prof. P. Baas, The Netherlands, Dr. K. Klaassen Forest Product Laboratory, Netherlands for providing literature and valuable information for my discussion.

I thank Dr. R. Miller, USDA, Wisconsin for providing wood samples for my work.

I am indebted to Mr. Peter and his family members for helping and assisting me during my field trips to Wynad forests. I am also thankful to innumerable people who helped me during my field trips.

I thank Dr. K. Mahender and Dr. T.A. Viswanath, Department of Geology, Goa University for their help and encouragement.

I thank Dr. R. Panda and Dr. A. N. Mohapatra, Department of Mathematics, Goa University for their timely help during my work.

I thank Mr. M.K. Rajesh, CPCRI, Kasaragod, for his timely help and encouragement.

I thank Dr. S. Krishnan, Dr. Nandkumar Kamat, and other faculty members and research scholars, Department of Botany for their support.

My thanks to non-teaching staff, Messrs. G.Tari, R. Tari, V. Naik, S. Periera and K. Velip, Department of Botany for their help during my work.

Fellowship from GSCST and DOS-DBT projects during the course of my work is gratefully acknowledged.

I thank my co-research scholars of various departments of Goa University for their lively academic discussion and companionship.

Finally I thank my parents and brothers who are always with me to support whatever I endeavor and to Joshi uncle and aunt for their support.

CONTENTS

Chapter 1

INTRODUCTION

Conservation of biodiversity and its sustainable management are recognised as vital global concern. But biodiversity is not evenly distributed on the planet. Some areas in the world, such as tropical forests and coral reefs, teem with biological variations (Gaston 2000). Mittermeier and Werner (1990) recognised that a very small number of countries in the tropics possess high species diversity. As the conservation of whole biosphere is an impossible task, priority areas need to be identified in order to conserve maximum number of species in minimal manageable area. Towards this goal, Myers et al (2000) proposed 25 'hotspots', based on endemic plants and the degree of threat as markers around the globe. Out of 25 hotspots, 17 are represented in tropical forests and only 12% of primary vegetation still remains in these forests (Pimm and Raven 2000). Indo-Burma and Western Ghats/Srilanka are the two hotspots recognised in India.

Islands and peninsular regions are favourable for high rate of endemism (Turrill 1964). Western Ghats, situated in peninsular India, is the second richest center in the country for endemic species , next only to the Eastern Himalayas (Nayar 1996). The Western Ghats run

North-South for almost 1600 km parallel to the west coast. Though there are no families endemic to Western Ghats, the area is rich in endemic genera and species (Nayar 1996). Out of 60 endemic genera only six are trees and they are relictual in nature.

As tree species are ecologically valuable components, their conservation is of paramount importance (WCMC 2000). In order to conserve endemic tree genera of Western ghats, understanding of their systematics, biology and status is important as Kruckeberg and Rabinowitz (1985) have shown that even change in taxonomic level in endemics might alter the threat category. They suggested that systematic approach is required to synthesize data from diverse disciplines in order to interpret relationship and origin of endemic plants. As the critical studies were lacking on endemic tree genera of Western Ghats, work on Systematics and Biology of them has been undertaken with the following **objectives**:

- To reassess the taxonomic position of endemic tree genera of Western Ghats using both external and internal morphological characters.
- To study the systematics, phytogeography and status of these taxa.
- To understand the pollination and popultion biology, seed viabilty, seed germination and seedling performance of these genera in selected cases.

Chapter 2

AREA OF STUDY

Western Ghats constitute an important biogeographical zone in peninsular India. The Western Ghats, called so because of the position they occupy in Peninsular India, lie between 8° 20′ - 20° 40′N and 73° - 77° E and cover a distance of about 1600 km from the Tapti valley in Gujarat to Kannyakumari in Tamil Nadu. These series of hill ranges run north - south along the west coast traversing the states of Gujarat, Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu (Fig. 2.1). East of this hill range lies the Deccan plateau and to the West is the coastal plains and Arabian sea.

Based on the physiognomy it is divided into three sections: 1) Northern Western Ghats (Tapti - Goa), 2) Central Western Ghats (South of Goa - Nigiris) and 3) Southern Western Ghats (South of Palghat gap)(Pascal 1988).

The northern Western Ghats are popularly known as 'Sahyadris'. The altitude ranges between 300-1500m above MSL, excluding higher crests. Along this section, isolated, conical, flat-topped hills occur with steep sides marked with distinct striations. Some of the major peaks in these regions are Harichandragad (1424m) and Mahabaleshwar peak (1438m).

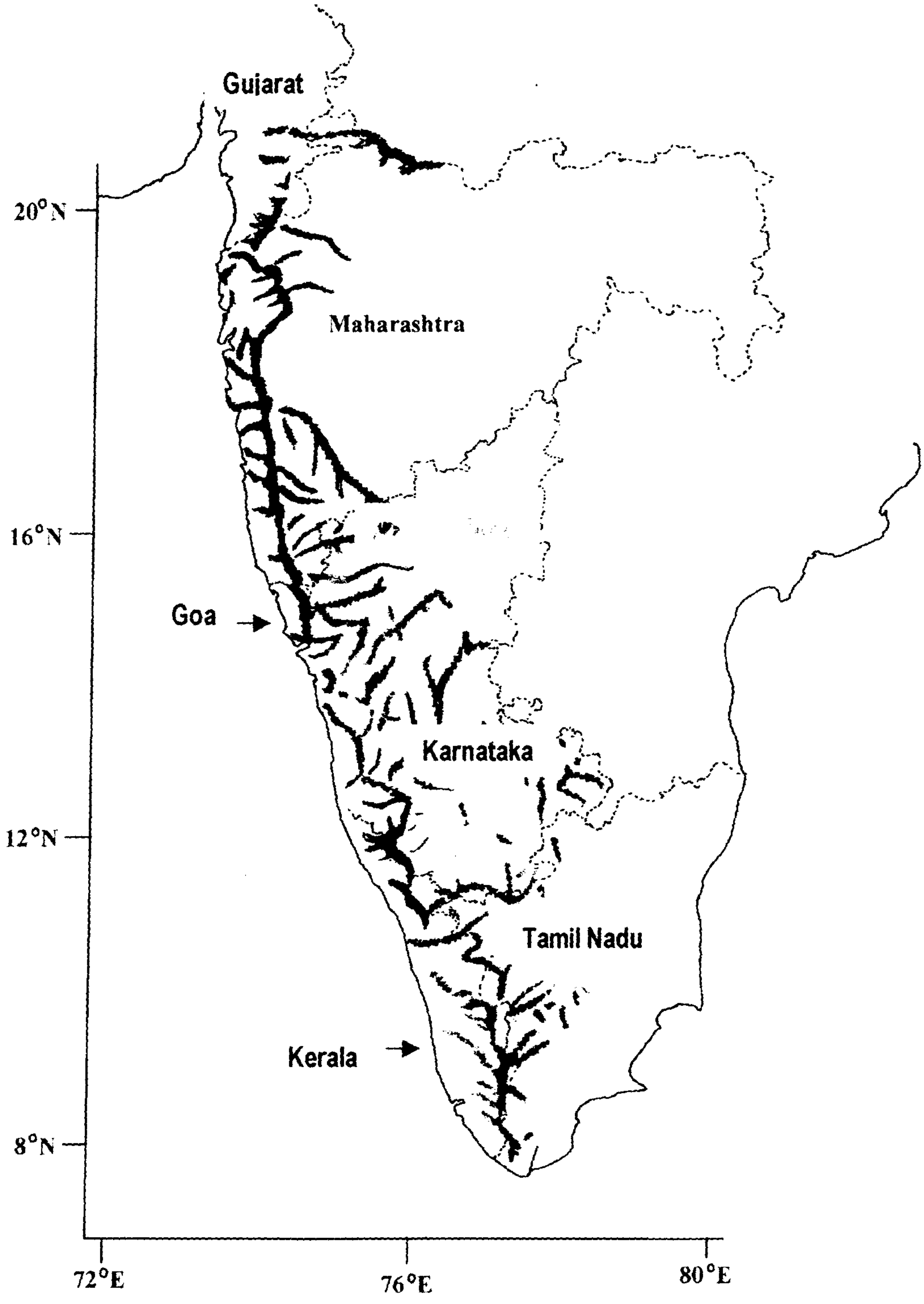


Fig. 2.1. Map of Western Ghats

The central Western Ghats rise sharply south of Goa to form an unbroken, though uneven rampart averaging an altitude of 900m. Kuderamukh (1892m) is the highest peak in Karnataka region. The leeward facet has rolling hills and shallow valleys with mean elevation of about 800m. The windward side of this part of ghats runs southwards very close to the coast and at several place touches the seashore. From Kuderamukh to Palghat gap, the edge of Deccan plateau is above 1000m and has numerous peaks[5]. Nilgiris is the meeting ground of three mountain systems of Peninsular India. The central Western Ghats from the north, the southern Western Ghats and Eastern Ghats in the northeastern corner meet in the 2,590 sq. km compact Nilgiri plateau. Doddabetta, the second highest peak (2637m) in South India is situated at the center of this plateau.

South of Palghat gap the Ghats continue further as southern Western Ghats. Anaimudi, the highest peak (2695m) in peninsular India, is a nodal point in southern Western Ghats from which the hill ranges, viz. the Anamalaias in the north, Palnis in the north east and the Cardamom hills in the south radiate in three different directions. The Ghats display further changes and form Periyar plateau to the south of Anaimudi. Further south, the Ghats are once again interrupted by narrow Shencottah pass. From here the

Ghats continue as a narrow ridge with steep slopes to the west as well as to the east. Agasthyamalai (1968m), well known for its endemic components is situated in the southern end of Western Ghats.

The major rivers which originate from the ghats are the Godavari, the Krishna and the Cauvery (Kaveri), all of which flow eastwardly towards Bay of Bengal. The general drainage however, is westward to Arabian sea, through a number of small rivers.

Geology and Soil:

The ghats north of Krishna basin with fragile rocks of the Deccan Trap are formed of Basalt rock. South of Krishna basin being the region of Pre-cambrian archaen, crystalline hard rocks formed granites, schists, gneisses, quartzites etc. The main groups of soils found along Western Ghats are high and low level laterites, red loam, medium black soils, red gravelly soils and mixed red and black soils. Most of the soils from northern west coast are leached lateritic and reddish and they are originally derived from Deccan trap.

Climate:

The rain fall pattern presents a wide range of spatial variation from over 700 cm per annum at Agumbe to less than 70 cm, 100 km eastwards. Whereas the windward slopes bear the brunt of monsoon, the eastern leeward slopes receive only a fraction after the moisture laden clouds have emptied themselves over the edges of ghats. The annual rainfall may vary from 235 cm in the north to 745 cm in the south. The humidity during monsoon months ranges between 70% - 98%. The mean temperature of the coldest month decreases from more than 23° C in the coast plains to less than 15°C at 1400 m altitude, and 12° C above 2000 m in the hill tops of Palnis and Nilgiris. The length of dry season introduces yet another parameter of large variation. Dry period of 2-3 months in southern Kerala, the region influenced by the southwest and northeast monsoon, gradually increases northwards to 8 months in Gujarat. Thus Mahableshwar, a hill station in the Sahayadris inspite of over 500 cm of rain experiences a dry season of 5-6 months.

Vegetation Types:

Champion and Seth (1968) classified forests of the Western Ghats into the following major categories:

1) Moist Tropical forests: a) Tropical Wet evergreen forests b) Tropical semievergreen forests c) Tropical Moist Deciduous forests d) Littoral and Swamp forests.

2. Dry Tropical forests: a) Tropical Dry Deciduous forests, b) Tropical thorn forests.

3. Montane subtropical forests: a) Subtropical broad leaved hill forests.

4. Montane temperate forests: Montane wet temperate forests.

Scrub forests occur along the foothill and lower elevations where the soil is usually lateritic and gravelly and where the dry period extends up to 8 months. It is also found in eastern side of Western Ghats where the rainfall is less than 100mm.

Dry deciduous forests are found in the eastern side of Western Ghats at elevation between 500-1200m with rainfall of 50-150 cm.

Moist deciduous forests occur between 500-900 m depending upon the rainfall ranging from 250-350 cm along the windward side of the Western Ghats. Some of the evergreen trees of higher elevation may be found here. The canopy formed by the tall trees is not that dense as compared to an evergreen forest. These forests merge with evergreen forests depending on the range of rainfall. The canopy is open and the trees leafless during the summer months. Flowering and fruiting are generally far advanced before the first flush of new leaves.

Montane subtropical evergreen forests occur in the north Western Ghats of Maharashtra. As the trees tend to be dwarf without any tiers of canopies of tropical elements, they cannot be considered as typical tropical evergreen forests. Though this region receives rainfall of 625-750 cm, the dry period is very long.

Semievergreen forests occur as transitional zones between the evergreen and moist deciduous vegetation. Tropical evergreen forests occur at an altitude of 200-1500 m generally along the windward side, wherein the rainfall ranges from 200-500 cm. The top canopy is extremely dense with lofty trees reaching up to 60 m high. Giant trees with buttressed bases and trunks that are unbranched over 30 m with closed canopy and several strata are characterstics of these forests. The composition of canopy trees varies not only from north to south but also depending upon soil, slopes and altitude.

Montane wet temperate forests is called 'Shola' a characteristic features of Western Ghats. It is interspersed with large tracts of southern montane wet grasslands occurring above 1600m altitude. The sholas are compact, sharply well defined small wood confined to sheltered valley hollows and depressions where there is adequate moisture and good drainage. They are distributed in Anamalaias, Nilgiris, Palni hills and higher range of Karnataka and Kerala.

Two biological criteria, viz. i)floristic peculiarities and ii) different types of savannas, are characteristics of the high plateaus of Western Ghats above an altitude of 1600m. These high plateaus are essentially covered with savannas. These are grassy formations, usually dense and low and often traversed by fire. The different types of soil, climate and biotic factors determine their physiognomy, floristic composition and dynamism.

Myristica swamps are found in windward side of southern most part of Kerala and small patches in Karnataka and Goa. They occur in the bottom of valleys inundated during greater part of the year. The floor of the swamps is traversed by the characterstic looped knee-roots of Myristica spp.

Apart from the landforms and vegetation types described above, undulating rocky plateaus with sparse vegetation are found at various places along the West Coast at lower elevations on ghats. They harbour herbaceous species during monsoon and in the crevices and along slopes they harbour representative tree species of moist deciduous forests and bushes. This type of vegetation is mostly common along northern and central Western Ghats.

Chapter 3

REVIEW OF LITERATURE

ENDEMISM:

The term 'endemism' was coined by A.P. de candolle (1855) for the distribution of an organism in a limited geographical area. According to Engler (1882) there are two kinds of endemism, one based on the preservation of ancient forms, which may have originated in entirely different regions and the other based on the development of new, entirely autochthonous forms. Based on the theory of age and area, Willis (1922) quantified the youthful endemics with his J-shaped or "hollow" (hyperbolic) curves. Cain's (1944) put forth the following three dicta on endemics: a) "Endemism includes two types of plants that are confined to single regions-endemics, sensu stricto, which are relatively youthful species, and epibiotics which are relatively old relict species", b) "Youthful endemics may or may not have attained their complete areas by having migrated to their natural barriers. Epibiotics may, but frequently do not contain the biotype richness that will allow or has allowed them an expansion of area, following their historical contraction of area" and c) "a high degree of endemism is usually correlated with age and isolation of an area, and with the diversification of it habitats, as these factors influence both evolution and survival".

Stebbins and Major (1965) modified Cain's observations and renamed two types of endemics as Paleoendemics and Neoendemics. Wherry (1944) classified endemic plants into Primary and Secondary endemics. The latter has been further classified into a) environmentally repressed, b) genetically repressed and c) senescent, based on the reasons for their restricted distribution. According to Stebbins and Major (1965) some species might have lost aggressiveness because, the changing environment restricts them only to a specialised niche. Moreover, the genetic knowledge lends support to the idea that a small population could have lost its genetic variability (Stebbins 1942) leading to genetically suppressed endemics (Wherry 1944). Stebbins (1965) observed that the mode of origin of relicts and newly formed had remained mostly unclarified. He also noted that the use of cytological data might determine the direction and relative ages of origin of taxa.

Favarger and Contandriopoulos (1961) proposed a classification of endemics based on cytological data. They are 1) Paleoendemics, which are isolated systematically, old, with little variation and not necessarily having arisen in their area of present survival, 2) Schizoendemics, produced by gradual speciation having a common origin and identical chromosome numbers, 3) Patroendemics, which are narrow diploids and have given rise to widely distributed polyploids and 4) Apoendemics, which are narrow polyploids arisen from widely distributed diploids. They also discussed the historical and phytogeographical significance of the various kinds of endemics they have differentiated. However, Drury (1974; 1980) argued that neither genetics, ecology nor history alone would suffice to explain the origin of endemic taxa. Richardson (1978) concluded that the nature of plant distribution varied with time and all species start as neoendemics and end as paleoendemics. Between these events some species will loose their endemic status and occupy larger areas and some remain as endemics. He called this intermediate form of endemics as Holoendemics.

WESTERN GHATS - FLORISTICS:

The Western Ghats, especially the malabar coast is well known in the world history and commerce as an important centre for spice trade. The interest of Portuguese settlement at Goa and the Dutch possessions of Malabar at Cochin in the exploration of flora of these regions contributed for the first time to the scientific study of the plants. Garcia de Orta (1565) discussed about few medicinal plants of this region. This was followed by Van Rheede's (1678-1703) monumental work on plants of Malabar, which is still historically and taxonomically important. Wight (1834; 1838-53; 1840-50) and Beddome (1869-74) made systematic approach and brought series of publications. These works were mainly confined to southern parts of Western Ghats. In the northern part Graham (1839) brought out catalogue for the plants of Bombay region followed by Dalzell and Gibson (1861). With assistance of several contemporary botanists, Hooker (1872-1897) compiled Flora of British India in 7 volumes. Later, regional floras including Flora of Presidency of Bombay (Cooke 1901-1908), Flora of Presidency of Madras (Gamble and Fischer 1915-1936) were published. Bourdillon (1908), Rao (1914), Talbot (1909) and Fyson (1932) were some of the important publications of this region prior to independence. After the reorganization of Botanical Survey of India, series of state and district Floras covering Western Ghats region have been published.

WESTERN GHATS - PHYTOGEOGRAPHY:

Hooker and Thomson (1855) in their introductory essay to the "Flora Indica", Clarke (1898), Hooker (1907) and Chatterjee (1940) have analysed phytogeographical regions of India on the basis of species content of the families in each botanical province and classified Western Ghats and West Coast under Malabar botanical province. Prain (1903) classified the whole Indian region based on humidity or dryness and the Western Ghats region figured under '<u>India aquosa</u>' which has humid forests. According to Hooker (1907) there is no clear cut boundary between Deccan and Western Ghats as leeward side of the Western Ghats merges with Deccan. But it was differentiated by the distinctive characters of Malabar flora in contrast to those of Deccan by the presence of families Clusiaceae, Dipterocarpaceae, Myristicaceae and Arecaceae. The major areas in the windward side of the Western Ghats possess evergreen and semievergreen forests. These forests have no marked summer and winter season, but only wet and dry seasons. The seasonal changes in rainfall and temperature lead to the formation of different stories in the evergreen forests (Richards 1952). According to him, the concept of dominance of one species over the other is fallacious in evergreen forests, but association of two or more species can be readily recognised. Based on these associations, the forests along the Western Ghats were variedly classified. Razi (1955) recognised twenty-one botanical provinces in India based on migration of plants and included malabar as one of the region, which includes Srilanka. Blasco (1970) renamed the eight divisions of Chatterjee (1940) as ecofloristic zones, emphasizing the characteristic endemic flora of every division including the Malabar. Subramanyam and Nayar (1974) phytogeographically divided Western Ghats into the following units, viz. 1) Tapti-Goa, 2) Kalinadi - Coorg, 3) Nilgiris and 4) Anaimalais, Palni and Cardamom hills. Ahmedullah and Nayar (1986), based on the distribution of endemic species of peninsular India, considered the following centres of endemism in Western Ghats: 1) Northern Western Ghats, 2) Central Western Ghats and 3) Southern Western Ghats. Meher-Homji (1981) divided India in to 40 zones based on vegetation type, of which eight zones are in Western Ghats. Pascal (1988) recognised three major regions in Western Ghats viz. 1) Surat-Goa, 2) Goa-Nilgiris and 3) South of Palghat gap. Based on phytoclimate, Meher-Homji (1991) divided Western Ghats into three zones having nine types of vegetation. According to Nayar (1996) there are two mega centres viz. 1) Southern Western Ghats and 2) Northern Western Ghats in Western Ghats based on endemism. Moreover he proposed 25 microcentres in India based on endemic patterns and in Western Ghats eight such centres are present.

ENDEMIC PLANTS IN WESTERN GHATS:

The work on endemic plants in India started with Chattterjee (1940), wherein he enumerated 2045 species of Dicotyledons as endemic to British India. Blasco (1970) estimated that there are about 82 endemic species confined to Nilgiri hills alone followed by Palani hills with 18 species and Anaimalais with 13. Ramesh and Pascal (1991) considered Western Ghats as the most important biogeographic zone as it harbours more number of endemics. Subramanyam and Nayar (1974) listed 20 genera and 84 species as endemic to Western Ghats. Henry et al (1984) observed that the Agasthyamalai region in Triunelveli-Travancore hills has about 150 localised endemic species. The major work on enumerating endemic plants on peninsular

India was carried out by Ahmedullah and Nayar (1986). They discussed the concept of endemics, different taxonomic levels of endemic plants and their phytogeography. The above work led to series of publications on endemic plants by various authors. Mostly they dealt on relocation and extended distribution of endemic plants at district level. Nayar (1996) enumerated endemic plants of India and adjoining countries with a detailed account on distribution of these species. He classified Western Ghats into microcentres based on concentration of endemic plants. Ramesh and Pascal (1997) brought out the atlas of distribution of endemic evergreen and semievergreen tree species of Southern Western Ghats. Recently Gopalan and Henry (2000) brought out a book on threat status and conservation strategies for rare and threatened plants of Agasthyamalai region.

GENERIC LEVEL ENDEMISM:

There are no families which are endemic to India (Ahmedullah and Nayar 1986). It is appropriate to consider that larger the taxonomic category concerned the wider the concept of endemics (Good 1964). However, at generic level different workers, as per definition of the area, variously evaluated the number of endemic taxa in India (Nayar 1980). Chatterjee (1940) listed 133 endemic genera in the dicotyledonous flora of British India. Rao (1972) listed 164 genera endemic to Indian floristic region including

Burma and Sri Lanka. Nayar (1980) estimated 141 endemic genera in India, out of which 39 are exclusive to Western Ghats. Nayar and Ahmed (1984) recorded 56 endemic genera to peninsular India. Ahmedullah and Nayar (1986) recorded 58 endemic genera in Peninsular India of which 47 are monotypic. Nair and Daniel (1986) listed 57 endemic genera for Western Ghats of which 47 are monotypic. According to Ahmedullah and Nayar (1986), i) since the endemic genus occurs in a restricted area, reservoir of gene pool specific to its group is limited and hence the chances of its adaptaion and survival are also limited and ii) the taxonomically isolated endemic genus indicates the age of its origin, since intermediate groups might have become extinct due to palaeoclimatic changes.

ENDEMIC TREES:

Tree species are ecologically, culturally and economically valuable components of biodiversity and their conservation is essential to the well being of people in all countries of the world (WCMC 2000). According to Meusel (1952) the woody habit in the endemic group is a relict character. Carlquist (1965) also suggested that woody habit is a derived condition from insular isolation. Nearly 63% of the tree species of the low and the medium elevation evergreen forests of the Western Ghats are found to be endemic

(Ramesh and Pascal 1991). However, trees are poorly represented in the endemic generic category (Ahmedullah and Nayar 1986; Nayar 1996). There are only six tree genera which are endemic to Western Ghats. They are *Poeciloneuron* Bedd., *Erinocarpus* Nimmo. ex Graham, *Otonephelium* Bedd., *Blepharistemma* Wall. ex Benth., *Meteoromyrtus* Gamble and *Pseudoglochidion* Gamble.

RARE AND THREATNED SPECIES OF WESTERN GHATS:

According to Drury (1974), a rare species is the one that occurs in widely separated small sub-populations, so that interbreeding between sub-populations is seriously reduced or is restricted to a single population. Nair and Daniel (1986) indicated that the deforestration and the habitat destruction has been the major threat leading to degradation, depletion and disapperance of the biological diversity of the Western Ghats. Perring and Farewell (1977) adopted a proforma to find the percentage of rarity. Rabinowitz et al (1986) proposed seven forms of rarity based on different type of distributional restriction. The IUCN Red data book (Lucas and Synge 1978) played an important role by focussing concern over rare endemic plants. There are more than 500 species of flowering plants in the Western Ghats which are rare and threatened (Hajra et al 1996). The earlier publication on rare plants (Henry et al 1978; Jain and Sastry 1980; Raghavan and Singh 1984; Vajravelu and Daniel 1983) reveal that the Southern Western

Ghats harbour more number of rare and threatened plants. The Red Data Book of Indian Plants (Nayar and Sastry 1987;1988;1990) list almost 200 plants from Western Ghats alone.

STATUS OF WESTERN GHATS:

Mittermier (1988) and Mittermier and Werner (1990) recognised megadiversity countries with most of them in tropics. According to Gentry (1986), tropical forests deserved more attention than temperate zone ecosystems, not only because of their greater species richness but also because of the greater concentration of local endemism in many of them. Countries along tropical belt possess maximum number of species. By compiling data on vertebrates, butterflies and higher plant diversity McNeely et al (1990) identified 12 megadiversity countries in the world and India is one of them. The degree of threat and richness of endemism is one of the major aspect in prioritizing areas for conservation. Focussing on tropical forests, Myers (1988) identified 10 "hotspots" which are rich in endemic species and subsequently added 8 more hotspots to the earlier list (Myers 1990). Recently Myers et al (2000) redefined the "hotspots" as the areas which have more than 0.5% of plants as endemics out of total plant species worldwide. Western Ghats (along with Srilanka) is one such "hotspot" out of total 25 identified by them. About 17 of the 'hotspots' represent tropical forests and in them only

12% of the primary vegetation still remains compared with 50% for tropical forests as a whole (Pimm and Raven 2000).

SYSTEMATICS AND BIOLOGY OF ENDEMIC PLANTS:

Richardson (1978) and Kruckeberg and Rabinowitz (1985) observed that the change in taxonomic status by monographic studies of a group leads to the reduction or increase in the number of endemics and the change in threat category. The biological comparison with widely distributed close relatives (Emig and Kadereit 1993), reproductive biology (Holderegger 1996; Smith and Pham 1996), genetic diversity (Richter et al. 1994) and comparison of genetic diversity with close relatives (Pleasants and Wendel 1989) were also carried out in endemic plants outside the country. But such an approach was lacking on the endemic plants of Western Ghats, except for recent work (Joshi 2000) at regional level. No major work is available on endemic tree genera of Western Ghats. The sporadic works available on each genus are discussed under the treatment of respective genus.

Chapter 4

MATERIALS AND METHODS

COLLECTION:

The endemic tree genera of Western Ghats were listed based on earlier works (Ahmedullah and Nayar 1986; Nayar 1996). They are *Poeciloneuron* Bedd., *Erinocarpus* Nimmo ex Graham, *Otonephelium* Radlk., *Blepharistemma* Wall. ex Benth., *Meteoromyrtus* Gamble and *Pseudoglochidion* Gamble. From the available literature, Herbarium data and through personal communication the localities of these endemic tree genera were identified. Field trips were carried out to the identified localities along the Western Ghats during various seasons. Twigs with flowers and fruits were collected for the morphological studies. Fresh flowers, fruits and leaves were preserved in FAA solution for the laboratory studies. The wood samples were collected from mature branches for wood anatomical studies. Specimens were processed for herbarium by treating with alcohol saturated with mercuric chloride. The processed and dried specimens were mounted on standard herbarium sheets and deposited at Herbarium, Department of Botany, Goa University. The identification was confirmed by matching either with type specimens or with authentic materials available in the Herbaria (BSI, MH, HIFP).

FIELD OBSERVATIONS:

The characters such as flower colour, habitat, association etc., were observed in the field itself. The phenology including flowering and fruiting was observed. Observation on pollination was carried out in selected cases. Main branches with large number of flowers, which were clearly visible, were chosen for analysis. Five such branches were selected for observations. The observations were carried out during 7.00 - 12.00hrs for a day in three different geographical locations. The time of anthesis, success rate and visitation were noted down. The visitors were identified using standard manuals. The frequency and duration of visitation were also recorded. Fruiting phenology and dispersal mechanism were noted down. The observation on seedling and sapling growth and their morphology were also carried out. Seed germination was tried under laboratory conditions. The viabilty of the seeds were tested using Tetrazolium test.

COMPARATIVE STUDY:

From the protologue of the endemic tree genera the closely related genera were identified. The representative species of the closely related genera were taken for analysis and comparative studies. The samples of related genera, which are distributed outside the country were procurred from various Herbaria, viz. Missouri Botanical

Garden (MO), Madras Herbarium (MH), U.S. Department of Agriculture, Forest Products Laboratory, Madison, Wisconsin. The voucher specimens are deposited in the Herbarium, Department of Botany, Goa University. The additional data on the endemic tree genera and closely related genera were also taken from the available literature.

MORPHOLOGICAL STUDIES:

The vegetative and floral morphological characters of endemic tree genera and their close relatives were studied and described. Illustrations for endemic tree genera were drawn using Leica Wild M3Z stereo microscope and drawing tube. The terminology of morphological descriptions was based on Lawrence (1951).

ANATOMICAL STUDIES:

For wood anatomy, free hand sections (T.S.,T.L.S. and R.L.S.) were made. The sections were stained in safranin for 1-2 minutes and washed and processed for the permanent mount following Johansen (1940). For leaf and petiole anatomy, the sections were made using Leica CM 2000 cryostat with the thickness of 5-10 μ. The sections were double stained as per Johansen (1940) and processed for permanent mount for observations. Some wood sections were left unstained, dried and mounted on aluminium stubs, sputter coated, observed under scanning electron microscope

JEOL JSM 5800LV. All the stained sections were observed under Leica or Olympus BX50 compound microscope and photographs were taken using either Leica MPS 32 system or Olympus PM 20. The terminology of IAWA Committee on Nomenclature (1964) was used to describe wood anatomical characters.

MACERATION:

For vessel and fibre characterisation, maceration technique was used. The dry thin chips of wood were digested with conc. Nitric acid and Pottasium chlorate and heated for few minutes. The digested wood samples were repeatedly washed in water, stained with safranin and washed again and mounted in DPX.

EPIDERMAL PEELING:

Epidermal peeling was removed from the lower epidermis of leaves using razor blade. The epidermal peel was stained with safranin for 1-2 minutes, washed several times in acid water to remove excess of stain. The peel was mounted in a drop of dilute glycerine on a slide (Payne 1969). The stomata types were identified using manual.

VEIN CLEARING:

The modified method of Arnott (1959) was employed. The leaves were kept in 5% NaOH for overnight and further treated with Trichloroacetic acid and phenol solution in the ratio of 2:1 and left for a day. The cleared leaves were washed and stained in safranin for one hour. The stain was removed by repeated washing in tap water. The cleared leaves were kept in between the blotting papers for drying. The vein pattern was identified using Hickey's manual (1973).

POLLEN MORPHOLOGY:

Modified (Nair 1960) Acetolysis (Erdtman 1952) method was used for pollen morphological analysis.

STATISTICS:

For comparative study, the characters (internal and external morphology) were scored in a binary mode and dendrograms were constructed using centroid linkage group to define clusters and distance between genera were measured on an Euclidean scale. The list of characters and the data set for each endemic genus with closely related genera are given in Appendices. PCA analysis was carried out to identify the principal characters which delimit the endemic tree genera from the closely related ones. Component plots were constructed for grouping of tree genera. The cluster analysis and PCA analysis were carried out using SPSS software (SPSS Inc. ver. 7.1.5).

THREAT STATUS:

The status of the each endemic tree genus was assessed using IUCN red list categories (1994). The major categories are Extinct (EX), Critically Endangered (CR), Endangered

(EN), Vulnerable (VU) and Low risk (LR). Graphs were constructed using collection details available from herbaria for analysing status of the endemic genera.

DISTRIBUTION:

The distribution of each endemic tree genus along the Western Ghats is shown using dot mapping. Field, Herbarium and literature data was considered for mapping purposes. For few endemic tree genera coordinates were recorded using Garmin GPS 12 for mapping. For closely related genera the circle mapping at global level is used.

Chapter 5

POECILONEURON Bedd.

INTRODUCTION:

Poeciloneuron Bedd. is an endemic tree genus with two species and belongs to the family Clusiaceae. The family Clusiaceae comes under the order Theales and considered to be one of the primitive families along with Theaceae (Cronquist 1968; Takhtajan 1980; Dahlgren 1980). The circumscription /taxonomy of Clusiaceae along with other families such as Bonnetiaceae, Hypericaceae and Theaceae has undergone lot of changes. Bentham and Hooker (1862-67) considered Bonnetiaceae and Hypericaceae as distinct families, but considered the former as an intermediate between Clusiaceae and Theaceae. Later Engler (1888) amended the description of Clusiaceae to include Hypericaceae and also a few genera of Ternstroemiaceae. Thorne (1976) and Cronquist (1981) treated Bonnetiaceae and Hypericaceae as subfamilies under Theaceae, whereas Seetharam (1985) treated them under Clusiaceae. However, Takhtajan (1980) considered them as distinct families which was supported by Thorne (1992) in his revised classification.

The genus Poeciloneuron was described by Beddome (1865) under the family Ternstroemiaceae as a monotypic genus. Bentham and Hooker (1862-67) also treated this genus under Ternstroemiaceae whereas Engler (1888) treated this under Clusiaceae. Later Beddome (1869-73) added another species, viz. Poeciloneuron paucifloum to the genus. This genus was later transferred to the family Bonnetiaceae which was earlier considered a subfamily of Clusiaceae (Takhtajan 1980). This treatment was supported by Baretta-Kuipers (1976) due to the presence of fibre trachieds, a character of the family Bonnetiaceae. The family Bonnetiaceae, included a number of neotropical genera and Poeciloneuron, a old World genus (Hutchinson 1969; Maguire 1972). Currently Poeciloneuron and few neotropical genera are positioned in the family Clusiaceae, supporting earlier treatment by Engler (1888). Though Poeciloneuron has anatomical similiarities with the family Bonnetiaceae, based on basal placentation, opposite leaves and drupaceous fruit (Seetharam 1985) and presence of secretory canals (Metcalfe and Chalk 1950; Dickson and Weitzman 1996) it has been included in the family Clusiaceae.

The detailed floral morphological work categorised the genus Poceiloneuron into tribe Callophylleae, which represents the genera Calophyllum, Mesua, Mammea and Paramammea (Seetharam 1985). The anatomical characters also support this grouping (Metcalfe and Chalk 1950). The phylogenetic analysis based on the pollen morphology reveals that within the tribe Callophylleae, the genus Mammea is an early evolved one compared to other genera and the genus Poeciloneuron is considered to be a 'neo-endemic' (Seetharam 1985).

The morphological and ecological studies on the species Poeciloneuron indicum has been carried out elaborately compared to P. pauciflorum, since it is one of the major component of west coast evergreen forest type (Pascal 1988). The floral morphology and palynological studies reveal its position in the family Clusiaceae (Seetharam and Pocock 1978; Seetharam 1985). Kadambi (1938) carried out ecological studies, particularly on seedling growth. Two varieties, namely black and white have been recognised based on the fruit size and color in P. indicum (Kadambi 1942).

The other species, P. pauciflorum a narrow endemic was relocated after almost a century (Ravikumar unpubl.) and later it was recorded in the work on endemic and rare plants (Mohanan et al 1997; Gopalan and Henry 2000). Seetharam and Pocock (1978) carried out pollen morphological studies on this species.

The collections are meagre and the position of this genus is always under confusion. It is very much essential to reassess the taxonomic position and the threat status.

SYSTEMATIC TREATMENT AND OBSERVATIONS:

Poeciloneuron Bedd. was represented by two species, viz. *P. indicum* and *P. pauciflorum*. In the present study, after critical evaluation, it is proposed to elevate the rank of *P. pauciflorum* to a genus. Hence *Poeciloneuron s.l.* is considered in this study under two genera, viz. *Poeciloneuron* Bedd. *s. str.* and *Agasthiyamalaia* gen. nov.

Key to genera:

Flowers in terminal or axillary panicles; sepals in a single whorl; stamens 12; leaves with fine reticulation .... *Poeciloneuron*

Flowers solitary or paired in fallen axils; sepals 2-whorled; stamens 16-22; leaves with distantly parallel venation .... *Agasthiyamalaia*

Poeciloneuron Bedd. s. str.

Poeciloneuron indicum Bedd. in J. Linn. Soc. Bot. 8: 267. t.17. 1865; Dyer in Hook. f. Fl. Brit. India 1: 278. 1874; Gamble, Fl. Madras 1: 56. 1967 (repr. ed.); Ramamurthy in Nair & Henry Fl. Tamil Nadu 1: 29. 1983; Saldanha & Eswar Rao in Saldanha, Fl. Karnataka 1: 210. 1984; Manilal, Fl. Silent Valley 22. 1988; Ramachandran & Nair, Fl. Cannanore 54. 1988; Singh in Sharma et al. Fl. India 3: 146. 1993; Mohanan & Henry, Fl. Thiruvananthapuram 73. 1994; Sasidaran & Sivadasan, Fl. Thrissur 54. 1996.

Trees, up to 23 m high, clear bole, bark greyish. Leaves simple, opposite, petiolate; petiole up to 4 cm long, rough, channelled; lamina ovate to oblong, up to 25 x 6 cm, coriaceous, rounded or acute at base, entire along the margins, acuminate at apex. Inflorescence an axillary or a terminal panicle. Flowers ca. 2.5 cm across, pedicellate; pedicel up to 4.5 cm long, glabrous, green in colour. Sepals 5, basally fused, forming a cup, thick, ovate, up to 1.5 x 0.2 cm, obtuse at apex, green in color, wrinkled. Petals 5, free, twisted in the bud, ovate, up to 2 x 0.5 cm, obtuse at apex, cream colored, purplish at base inside, glandular hairy within. Stamens 12, ca. 0.5 cm long, attached to elevated disc around ovary; anthers lobulate, cleft along margins, dehiscence longitudinal. Ovary globose, ca.0.2 cm; style 2, divided halfway, undulate along the margins, greenish yellow, ca. 0.4 cm long. Fruit a capsular drupe, ellipsoid or ovoid with thick pedicel and accrescent calyx, line on ventral and dorsal sides, beaked, sap yellow, pericarp fleshy when young, endocarp yellowish, one seeded, remaining ovules aborted, seed coat cartilaginous (Fig. 5.1; Plate 5.1 A-C).

Wood anatomy:

Diffuse porous wood, vessels solitary, rounded in outline, up to 148µ (102-199µ) in tangential diameter, mean member length 956µ (561-1412µ), tailed; tail 112µ (42-

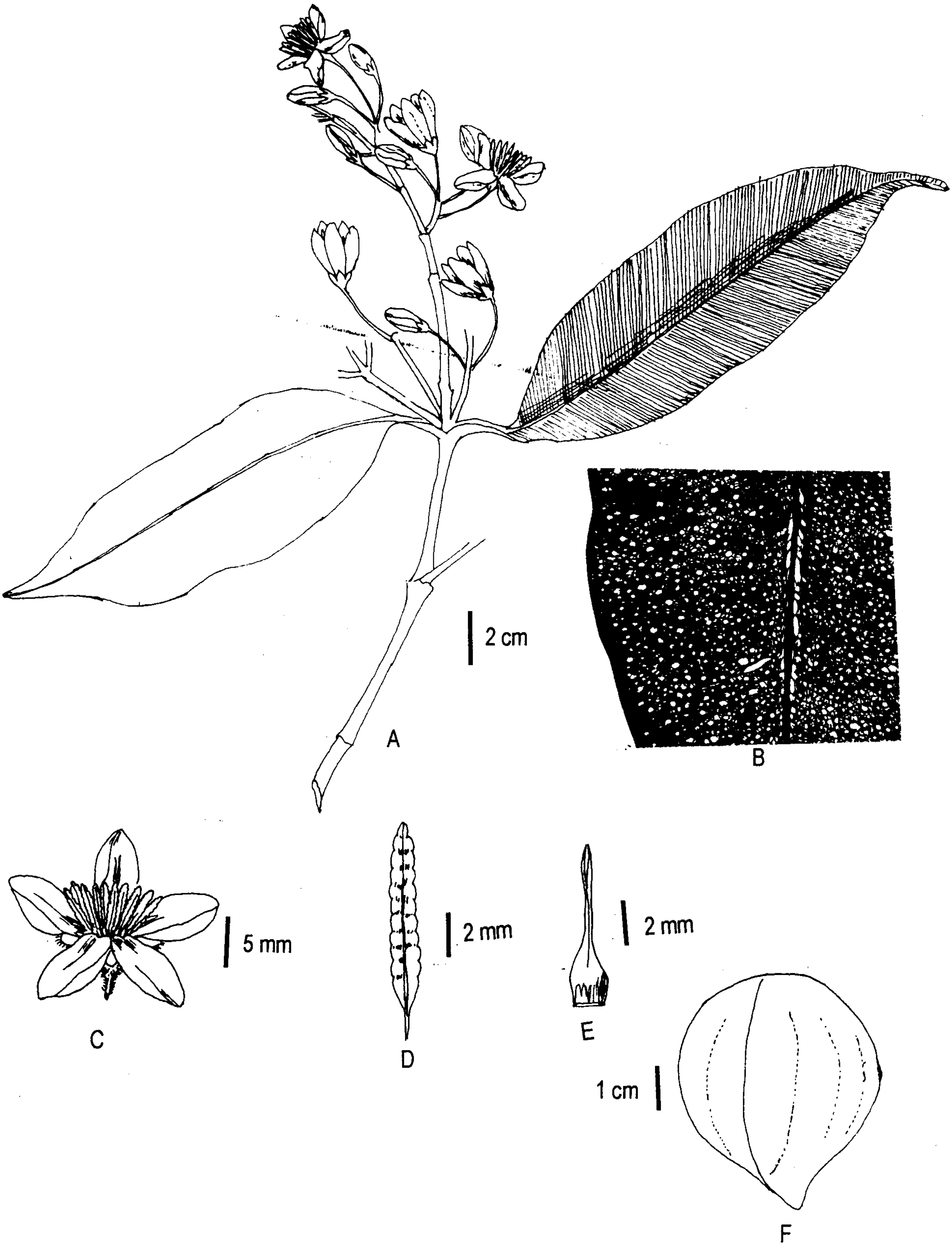


Fig 5.1: *Poeciloneuron indicum* Bedd. A. Flowering twig; B. Leaf venation; C. Flower; D. Anther; E. Ovary with style; F. Fruit.

Plate 5.1: ***Poeciloneuron indicum*** **A.** Flowering branch; **B.** Fruiting branch; **C.** Flowers; **D.** Seedlings; **E.** T.S. of wood; **F.** T.L.S. of wood; **G.** Vessel.

210µ); perforation simple; vessels to ray pits are simple, alternate. Rays uniseriate, heterocellular, 8-12 cells in height, up to 280µ. Parenchyma paratracheal aliform. Fibres thick walled, 977-2027µ in length, pits bordered, numerous on tangential wall; fibre tracheids present (Plate 5.1E-G).

Leaf anatomy:

Petiole:

Epidermis single layered with thick cuticle, cells anticlinal, outer cortex collenchymatous, 5-7 cell layered with resin canals; inner cortex parenchymatous, 2-cell wide, with resin canals. Vascular bundles arc shaped with incurved ends forming a tube like structure. Resin canals covered by 5-7 thick walled cells.

Lamina:

Lamina ca. 308µ in thickness; upper epidermis single layered, ca. 12µ in thickness including thick cuticle of 6µ thickness. Palisade single layer, ca. 30µ in thickness with elongated polygonal cells; veins vertically transcurrent, resin canals present in spongy parenchyma, ca. 126µ in diameter, surrounded by thick walled cells.

Stomata:

Paracytic (Rubiaceous type), sunken, guard cells with dark stained cell content (Plate 5.3B).

Pollen morphology:

Tricoloporate type, isopolar; polar axis 15.6 ±1.5μ, equatorial axis 14.6 ±0.9μ, P/E ration 1.0, ectoaperature 8-12 x 1 μ, endoaperature 2x4 μ, tectum 6-8 μ, perforate, irregular with smooth tectal crest.

Ecology:

Found along the evergreen forests at an altitude of 400-1200 m in the windward side of the Western Ghats. One of the abundant component of the evergreen forests of south as well as central Western Ghats. Mostly distributed along the streams. Some trees which are adjacent to the streams develop stilt roots. The associated trees are Dimocarpus longan, Carallia integerrima, Diospyros spp. and Myristica spp.

Phenology:

The flowering starts in the month of October and ends in the month of January. The peak flowering was observed in the month of December. Fruiting starts in the month of November and continues till May. No pollinators were observed in the studied locality.

Pollination:

In the present study, no visitors were observed. However, it was observed that arboreal mammals were foraging on the flower buds. In one season (December 1998) it was observed that all the buds were damaged by caterpillars.

Dispersal:

Fruits dehisce incompletely and fall on maturity with twigs. The seeds get dispersed through water since most of the plants are found along the streams and slopes.

Seedlings:

In the month of June to December abundant seedlings were observed underneath the trees and surrounding areas. Seeds show hypogeal type of germination and were found to be germinating even on rock surfaces and maximum height of seedling observed was 75 cm. Seedlings were observed growing abundantly on humus (Plate 5.1D). Though numerous seedlings were observed during monsoon and post monsoon seasons, they do not seem to be growing further as only few sapling were observed in the wild.

Economic value:

Wood used for heavy constructional work such as beams, trussers, joints and rafters and for bridges. Used also for agricultural implements, rice pounders, walking sticks, electric transmission polls, railway sleepers, and paving blocks(from "Useful plants of India", CSIR):.

Specimens examined:

Karnataka: South Kanara 1893, R.H. Beddome 3221 (MH); Balehalli forest, Agumbe, 1. 12. 1959, B.S. Shiya 65359

(BSI); Cattleshed area, Agumbe, 2.11.1960, R. Sundara Raghavan 81980 (BSI); Barakona in Balehalli forest, 19.5.1960, R. Sundara Raghavan 62686 (BSI); Chyatramane - Galingudda, Agumbe, 14.5. 1962, R. Sundara Raghavan 80598 (BSI); Hulical ghat, Shimoga Dt. 15.2.1963, R. Sundara Raghavan 86262 (BSI); Bhavati kalasa, Mysore Dt. 1.4.1964, R. Sundara Raghavan 97242 (BSI); Mallur Ghat, South Kanara Dt. 15.4.1978, C.J. Saldanha KFP 927 (JCB); South Kanara 24.5. 1980, Cecil J. Saldanha (JCB); Agumbe check post, 23.12. 1997, S. Rajkumar s.n. (GUH); S.K. Border, South Kanara, 25.12.1997, 14. 12. 1998, 27.11.1999, S.Rajkumar s.n. (GUH).

Tamil Nadu: Sispara ghat, 1866, R.H. Beddome 3248 (MH); Parali, Anaimalais, 19.4.1900, s.l. s.n. (MH); Iyerpadi, Anamalai, 5.10.1901, s.l. 3201 (MH); Udumpanparai, Anaimalais, 30.4.1903, 3208 (MH); Way to Muthukuzhivayal, Kanniyakumari Dt., 1.19.1978, A.N. Henry 52486 (MH); Muthukuzhi to Balamore, Kanyakumari Dt., 16.3.1979, A.N. Henry 60731 (MH).

Kerala: Karamanyar - Thiruvananthapuram, 8.4.1989, s.l. s.n. (TBGT); Karamanyar - Thiruvananthapuram 7.11.1990, N. Mohanan 5529 (TBGT); Attayar - Thiruvanathapuram, 1.3.1991, N. Mohanan, 10534 (TBGT); Chenikala, 21.12.1992, A. E. Sanvaskhan 6403 (TBGT); Charpa - Thrissur, 27.6.1996, A.G.

Pandurangan and Raj 30624 (TBGRI); Pandimotta to Thiruvananthapuram, s.d. Abdul Jabbar 6754 (TBGT).

* **Agasthiyamalaia** S. Rajkumar, gen nov.

Poeciloneuron Bedd. similis sed flores axillares solitarius vel duo, sepala in duo verticilli, stamina sedecim ad duo et viginti folia venae distantae atque parallelae differt.

It is closely related to *Poeciloneuron* Bedd. and differs from it by the presence of solitary or paired axillary flowers, sepals two whorled, 16-22 stamens and leaves with distantly parallel venations.

Type: *Agasthiyamalaia pauciflora* (Bedd.) S. Rajkumar (=*Poeciloneuron pauciflorum* Bedd.)

Trees with clear bole. Leaves simple, opposite, petiolate; petiole rough, channelled; lamina oblong, coriaceous, rounded or acute at base, entire along the margins, bluntly acuminate at apex. Flowers solitary or paired in the axils of the fallen leaves, pedicellate; Sepals 4, in two whorls, inner two are bigger than outer ones, puberulous. Petals 6, imbricate, ovate, obtuse at apex, white, pubescent within. Stamens up to 22, attached to an elevated disc below ovary, anthers lobulate, dehiscence longitudinal. Ovary globose, 2- celled, with pair of ovules in each; style 2, divided halfway, undulate along the margins, greenish yellow. Fruit globose, pointed at the tip, dehiscent into 2 valves, one seeded. Seed hard,

---

* The name *Stevensia* proposed for this genus in synopsis is preoccupied under the family Rubiaceae. Hence the name *Agasthiyamalaia* (as it occurs in Agasthiyamalai and its environs) is proposed and being published.

round, testa loose, membranaceous, striated, easily separable from the seed; cotyledons very large, fleshy.

Agasthiyamalaia pauciflora (Bedd.) S. Rajkumar comb. nov. Poeciloneuron pauciflorum Bedd. Fl. Sylv. t. 93. 1871; Dyer in Hook. f. Fl. Brit. India. 1: 278. 1874; Gamble, Fl. Madras 1: 56. 1967 (repr. ed.); Singh in Sharma et al. Fl. India 3: 146.1993.

Trees, up to 15 m high, clear bole, bark greyish. Leaves simple, opposite, petiolate; petiole up to 1.5 cm long, rough, channelled; lamina oblong, up to 12 x 4 cm, coriaceous, rounded or acute at base, entire along the margins, bluntly acuminate at apex. Flowers solitary or paired in the axils of the fallen leaves, pedicellate; pedicels up to 2.5 cm long, glabrous, green in colour. Sepals 4, in two whorls, inner two are bigger than outer ones, ovate, up to 0.8 cm long, obtuse at apex, green in color, puberulous. Petals 6, imbricate, ovate, ca. 0.3 x 0.2 cm, obtuse at apex, white, pubescent within. Stamens up to 22, ca. 0.6 cm long, attached to an elevated disc below ovary, anthers lobulate, dehiscence longitudinal. Ovary globose, ca. 0.2 cm, 2- celled, with pair of ovules in each; style 2, ca. 0.3 cm long, divided halfway, undulate along the margins, greenish yellow. Fruit globose, pointed at the tip, dehiscent into 2 valves, one seeded. Seed hard, round, testa loose, membranaceous, striated, easily

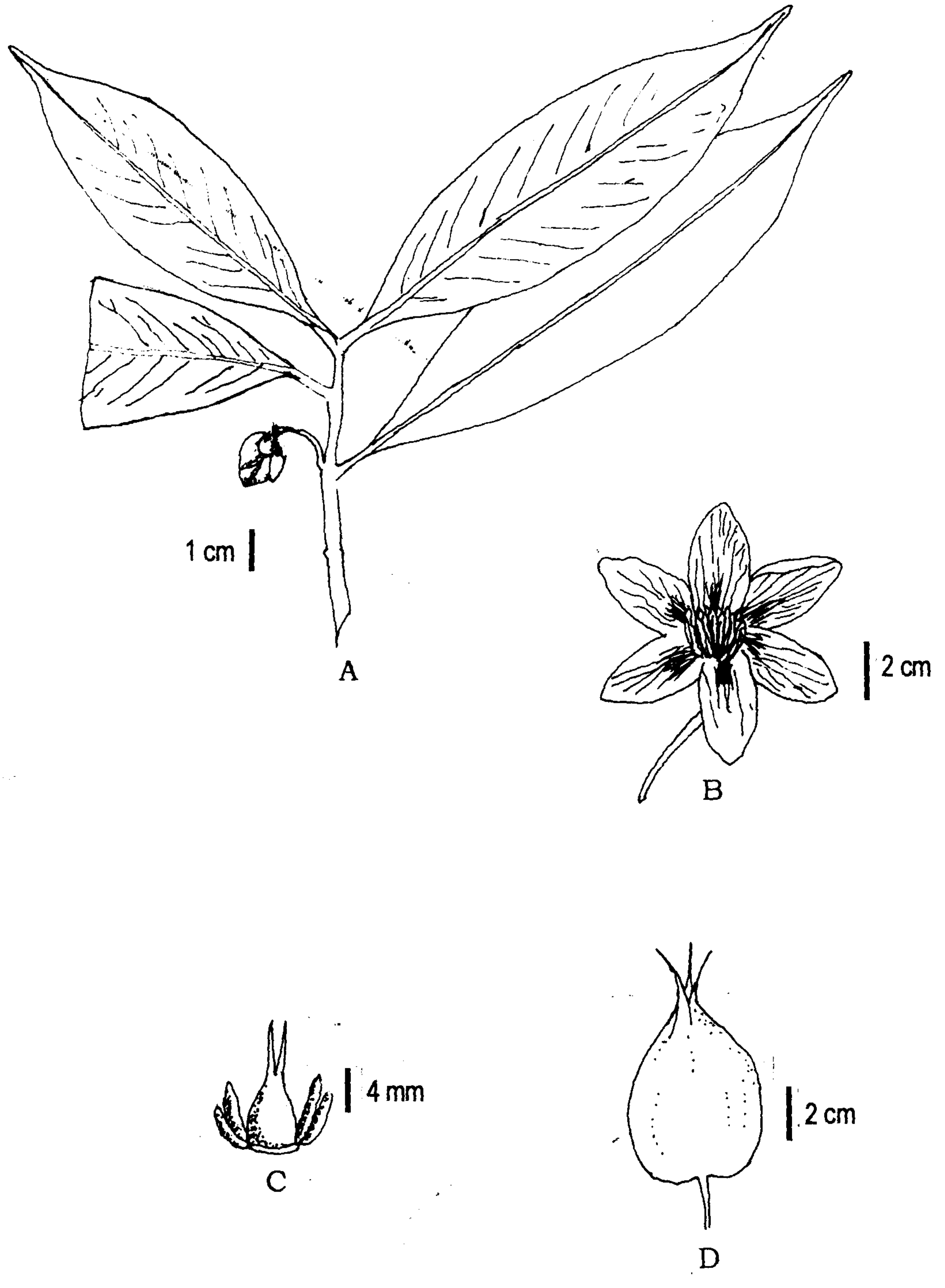


Fig. 5.2: *Agasthiyamalaia pauciflora* (Bedd.) S. Rajkumar comb. nov (= *Poeciloneuron pauciflorum* Bedd.). A. Flowering twig; B. Flower; C. Ovary with Stamens; D. Fruit.

separable from the seed; cotyledons very large, fleshy (Fig. 5.2; Plate 5.2A-B).

Wood anatomy:

Diffuse porous wood; vessels solitary, rounded in outline, ca. 56μ in diameter, mean member length 745μ (580-910μ), tailed, 16 per mm^2, perforation simple; vessels to ray pits simple or bordered, alternate. Rays uniseriate, heterogenous, 5-16 cells in height, 280μ high, 70 per mm^2. Parenchyma apotracheal, banded. Fibres thick walled, bordered pits numerous; fibre tracheids present(Plate 5.2E).

Leaf anatomy:

Petiole:

Epidermis single layered with thick cuticle, cells anticlinal, cortex collenchymatous, 3 layered, with resin canals. Vascular bundles arc shaped with incurved ends forming a tube like structure. Resin canals covered by thick walled cells.

Lamina:

Lamina ca. 238μ in thickness. Upper epidermis single layered, ca. 12μ in thickness, cuticle 3μ in thickness. Palisade single layered, 42μ in thickness with elongated polygonal cells, veins vertically transcurrent, spongy

Plate 5.2 : ***Agasthiyamalaia pauciflora*** **A.** Flowering branch; **B.** Fruiting branch; **C.** Young leaves; **D.** Stomata; **E.** T.L.S. of wood; **F.** T.S. of leaf.

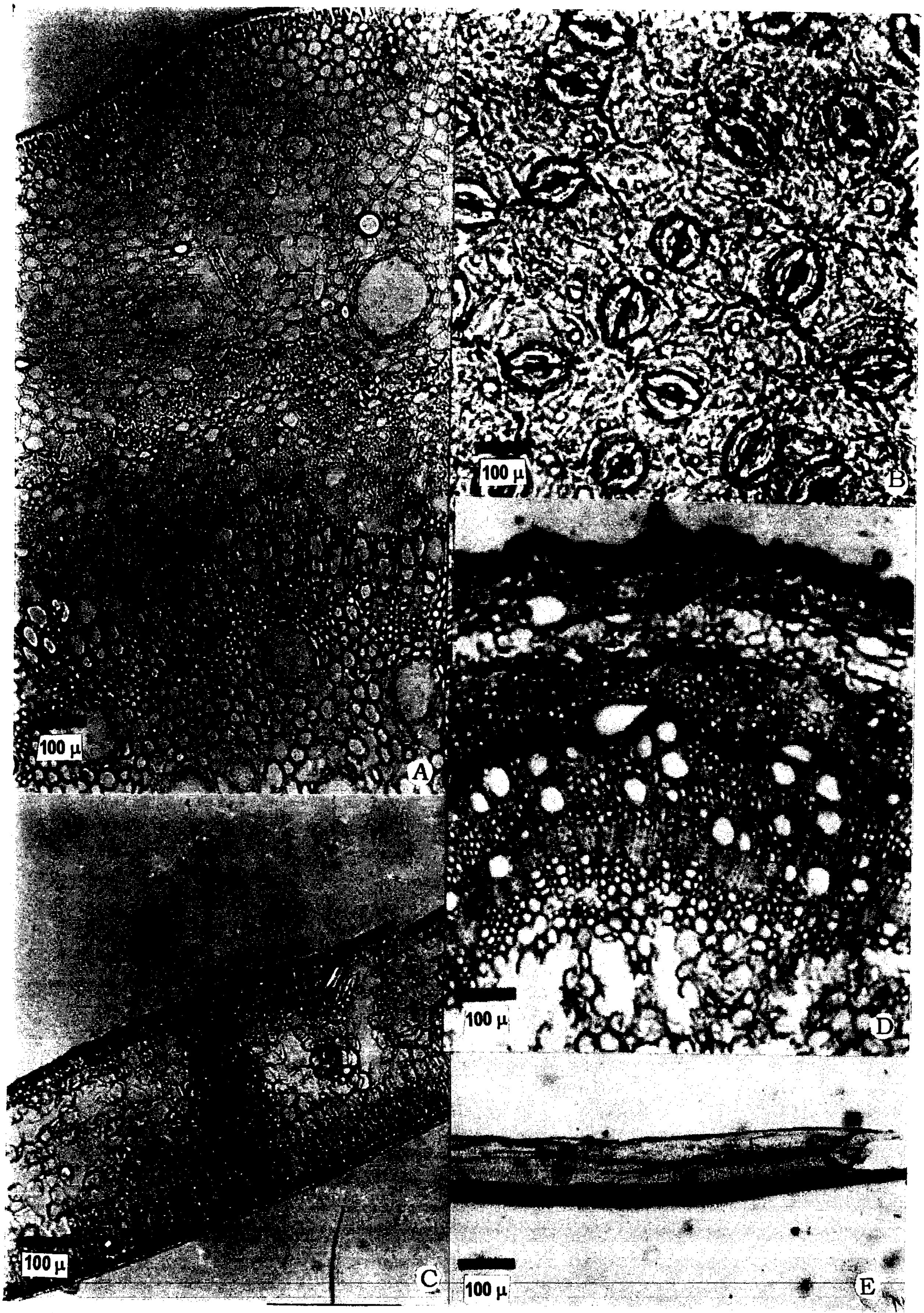


Plate 5.3: ***Poeciloneuron indicum*** **A.** T.S. of young stem; **B.** Stomata; **C.** T.S. of leaf. ***Agasthiyamalaia pauciflora*** **C.** T.S of young stem; **D.** Vessel.

parenchyma 7-layered, 120μ in thickness, resin canals embeded in spongy parenchyma as well as in upper epidermis.

Stomata:

Paracytic (Rubiaceous) type, guard cells with darkly stained cell content (Plate 5.2D).

Pollen morphology:

Tricolporate type, isopolar, polar axis 20.8 ±2.2μ, Equatorial axis 22.6 ± 2.0μ, P/E ratio 0.9, ectoaperture 7-12 x 1.5 μ, endoaperture 4-6 x 1-2μ, tectum 11-20 μ, perforate, more or less regular, bear warty projections.

Habitat:

Found along the banks of streams or rivers. In evergreen forests surrouded by grasslands.

Ecology:

Locally dominant species, it is associated with Cinnamomum spp. Glochidion spp. Knema attenuata and Ochlandra spp. Young leaves are membranous, white turning pinkish. Saplings were observed.

IUCN category:

Based on IUCN norms it is here categorized as "endangered". The following are the norms by which it qualifies the endangered category:

B. Extent of occurrence estimated to be less than 5000km^2 and occupancy estimated to be less than 500km^2

B1. Known to exist at no more than five locations

B2. Area of occupancy is very less.

Specimens examined:

TamilNadu: Mundanthurai to Kannikatti, 17.3.1917, s.l. 14647(MH); Way to Nagapothigai from Inchikuzhi, 8.2.1989, R. Gopalan 90105; Etha river bank , 1000m 24.4.1990, R. Gopalan 93232; Bank of Sigapparu, way to Ngapothigai, 750m, 22.1.1991, R. Gopalan 94640; Valayar river bank, 900m, 3.4.1991, R. Gopalan 96216; way to Poonkulam, 900m, 17.4.1992, R. Gopalan 99305; Banks of Chittar, 8km above Keeriparai, Kaniyakumari Dt. 23. 2. 1998, S. Rajkumar s.n.; 2.11.2000, S. Rajkumar s.n. (GUH).

Kerala: Travancore, s.d. s.l. acc. no. 3224(MH).

Comparative studies between endemic tree genera:

External Morphology:

The reticulate conspicuous veins of leaves of Poeciloneuron differ from inconspicuous penninerved leaves of Agasthiyamalaia. In the genus Agasthiyamalaia the flowers are axillary and solitary (or paired) whereas in Poeciloneuron they are in terminal or axillary panicles. The sepals are in two whorls in Agasthiyamalaia, whereas they are single whorl of five sepals in Poeciloneuron (Table 5.1).

Wood anatomy:

The major difference between these two genera based on wood anatomy is wood parenchyma arrangement. The genus Agasthiyamalaia shows Apotracheal banded and the

Table 5.1: Comparative morphological features between endemic tree genera

Characters	Poeciloneuron	Agasthiyamalaia
Habit	Tree	Tree
Leaves	Simple, opposite, up to 25 x 6 cm	Simple, opposite, up to 12 x 4 cm
Leaf shape	Ovate to oblong, acuminate at apex	oblong, bluntly acuminate at apex
Leaf surface	Coriaceous, veins prominent	Coriaceous, glaucous beneath, veins inconspicuous
Inflorescense	Axillary and terminal panicle	Solitary or paired on fallen axils
Sepals	5, ovate, all equal in size, campanulate	4, in 2 whorls, inner two larger
Petal	5, twisted	6, imbricate
Stamens	12, attached to disc	16-22, attached to disc
Anthers	Lobulate, cleft along margins, dehiscense longitudinal	Lobulate, dehiscense longitudinal
Ovary	Globose, 2-celled	Globose, 2-celled
Style	2, stigma indistinct	2, stigma indistinct
Fruit	Capsular drupe, dehiscent, with vertical line	Capsular drupe, dehiscent, 2 lobed, pointed at apex
Seed	Single, testa smooth	Single, testa wrinkled

Table 5.2: Comparative wood anatomical features of endemic tree genera

Characters	Poeciloneuron	Agasthiyamalaia
Porosity	Diffuse	Diffuse
Vessels		
Diameter	56 - 112μ	42-70μ
Length	630-980μ	560-720μ
Perforation	Simple	Simple
Pit	Simple, bordered	Simple or bordered
Abundance	17 per mm^2	16 per mm^2
Rays		
Type	Uniseriate, heterogenous	Uniseriate, heterogenous
Height	280μ (8-12 cells)	280μ (4-14 cells)
Abundance	70 per mm^2	70 per mm^2
Parenchyma	Paratracheal, aliform	Apotracheal, banded
Fibres	Thick walled, fibre tracheids present	Thick walled, fibre tracheids present

Table 5.3: Comparative Leaf anatomical features of endemic tree genera

Characters	Poeciloneuron	Agasthiyamalaia
Leaf thickness	308μ	238μ
UppperEpidermis		
Layers	single	single
Thickness	12μ	12μ
Cuticle thickness	6μ	3μ
Palisade		
Layers	single	single
Thickness	30μ	42μ
Spongy		
Layers	9	7
Thickness	192μ	120μ
Position of minor veins	Transcurrent	Transcurrent
Lower Epidermis		
Layers	single	single
Thickness	6μ	9μ
Resin canals	embedded in mesophyll	embedded in mesophyll and upper epidermis
Stomata		
Type	Rubiaceous	Rubiaceous
Frequency	588 per mm^2	430 per mm^2
Petiole vasculature	arc shaped with incurved ends	arc shaped with incurved ends

Table 5.4: Comparative pollen morphological characters of endemic tree genera

Characters	Poeciloneuron	Agasthiyamalaia
Pollen type	Tricolporate	Tricolporate
Polar axis	15.6 ± 1.5μ	20.8 ±2.2μ
Equatorial axis	14.6 ±0.9μ	22.6 ±2.0μ
P/E ratio	1	0.9
Ectoaperature	8-12 x 1μ	7-12 x 1.5 μ
Endoaperature	2 x 4μ	4-6 x 1-2μ
Arrangement	perpendicular to ectoaperture	paraellel to ectoaperture
Tectum	6-8μ, Peforated, reticulate	11-20μ, perforated, reticulate
Tectal crests	smooth	warty
Tectal perforation	Irregular	Regular

Poeciloneuron shows Paratracheal aliform wood parenchyma. Other characters show quantitative differences(Table 5.2).

Leaf anatomy:

Leaf anatomy of these endemic genera, do not show much difference except for the arrangement of resin canals. In the genus Agasthiyamalaia the resin canals are present both in mesophyll and epidermal cells but in Poeciloneuron they are present only in mesophyll (Table 5.3).

Pollen morphology:

Both the genera differ in the arrangement of endoaperature. In Poeciloneuron the endoaperature is perpendicular to ectoaperature, whereas in Agasthiyamalaia it is parallel. Tectal perforations are irregular in Poeciloneuron and regular in Agasthiyamalaia. Tectal crests are smooth in Poeciloneuron whereas they are warty in Agasthiyamalaia (Table 5.4).

Comparative study between endemic tree genera and closely related genera:

In the tribe Calophylleae, the genus Mesua is presumed closely related to Poeciloneuron (Seetharam 1985). In order to assess the systematic position of this genus comparative studies between the endemic genera and other related genera viz. Mammea, Mesua and Calophyllum were taken up.

Table 5.5. Comparative morphological features of endemic tree genera and closely related genera

Characters	Poeciloneuron	Agasthiyamalaia	Mammea	Mesua	Calophyllum
Habit	Tree	Tree	Tree	Tree	Tree
Leaf	Simple, opposite, up to 25 x 6 cm	Simple, opposite, up to 12 x 4 cm	Simple, opposite, 18-25x 6- 8 cm	Simple, opposite 10-15 x 3-5 cm	Simple, opposite 12 – 20 x 6 –10 cm
Leaf shape	Ovate-oblong, acuminate at apex	Oblong, bluntly acuminate at apex	Oblong, bluntly acuminate at apex	Oblong-lanceolate, acute to acuminate at apex	Broadly elliptic, rounded at apex
Leaf surface	Coriaceous, veins prominent reticulate	Coriaceous, glaucous beneath, veins inconspicuous	Coriaceous, reticulate at maturity	Glaucous beneath, finely penninerved	Coriaceous, shortly penninerved
Infloresc ense	Axillary and terminal panicle	Axillary, solitary or paired	Axillary fascicles	Axillary, solitary	Axillary or terminal panicles
Sepals	5, ovate, campanulate	4, 2 whorled, inner two larger	4, 2 whorled, inner two larger	4, 2 whorled, inner two larger	4-12, 2 whorled, inner larger
Petals	5, twisted	6, imbricate	4- more	4, obovate	4- 12 or absent, ovate
Stamens	12, attached to disc,	16-22, attached to disc	numerous, free	numeous, attached to disc	numerous, free
Anthers	Lobulate, cleft along margins, longitudinal dehiscence	Lobulate, longitudinal dehiscence	2-celled, longitudinal dehiscence	2-celld, longitudinal dehiscence	2-celled, longitudinal dehiscence
Ovary	Globose, 2-celled	Globose, 2-celled	Globose, 2 –celled	Globose, 2- celled	1- celled,
Style	2; stigma indistinct	2; stigma indistinct	1, short; stigma 3 lobed or peltate	1, elongate; stigma peltate	1, long; stigma peltate
Fruit	Capsular drupe, dehiscent, with vertical line	Capsular drupe, dehiscent, 2 lobed, pointed at apex	Drupe, indehiscent	Drupe, fleshy or woody, 4valves, dehiscent	Drupe globose, indehiscent,
Seed	Single, hard	Single, testa wrinkled, hard	1-4 seeded	1-4 seeded, testa fragile	Single seeded, testa thin

Morphology:

The genus Mesua and endemic genus Agasthiyamalaia show axillary flowers, whereas other closely related genera including Poeciloneuron show panicle inflorescence. Sepals of all the genera are in two whorls except Poeciloneuron, in which it is in single whorl. Except Mammea and Calophyllum where the stamens are free, in other genera stamens are attached to the disc. The anthers of endemic genera are lobulate with marginal clefts whereas the closely related genera show 2-celled anthers. The stigma of closely related genera are solitary and peltate whereas in endemic tree genera they are two and indistinct from style. The fruits of closely related genera are drupaceous, whereas Poeciloneuron and Agasthiyamalaia show capsular drupes (Table 5.5).

Wood anatomy:

The vessel-ray pits are simple in the genus Poeciloneuron wheras the genus Agasthiyamalaia and closely related genera show simple as well as bordered pits. The rays of all the genera are uniseriate and heterogeneous except Mammea where it is multiseriate with intercellular canals. Poeciloneuron is the only genus with paratracheal aliform type of wood parenchyma whereas other genera show apotracheal wood type. Fibre tracheids are present only in the endemic tree genera (Table 5.6).

Table 5.6. Wood anatomical features of endemic tree genera and their closely related genera.

Characters	Poeciloneuron	Agasthiyamalaia	Mammea	Mesua	Calophyllum
Porosity	diffuse	diffuse	diffuse	diffuse	diffuse
Vessels					
V-diameter	56 - 112μ	42-70μ	42-70μ	54-82μ	70 - 84μ
V-length	630-980μ	560-720μ	490-700μ	645-960μ	280 - 700μ
V-perforation	Simple	Simple	Simple	Simple	Simple
V-pit	Simple	Simple or bordered	Bordered or scalarifom	Bordered, opposite	Boarded, alternate
V-abundance	17 per mm^2	16 per mm^2	36 per mm^s	24 per mm^2	29 per mm^2
Rays Type Height Abundance	Uniseriate, heterogenous 280μ (8-12 cells) 70 per mm^2	Uniseriate, heterogenous 280μ (4-14 cells) 70 per mm^2	2-4 cell wide, heterogenous 490μ 13 per mm^2	Uniseriate, Heterogenous 260μ 16 per mm^2	Uniseriate, heterogenous 280 – 350 μ 21 per mm^2
Parenchyma	Paratracheal aliform	Apotracheal banded	Apotracheal, scattered	Apotracheal banded	Apotracheal banded
Fibre	Thick walled, 977-2027μ, fibre tracheids present	Thick walled, 950-1230μ, fibre tracheids present	Thick walled 770 - 1260μ, fibre tracheids absent	Thick walled, fibre tracheids absent	Thick walled, 840 -910μ, fibre trachieds absent

Leaf anatomy:

The genus Mammea shows 2 layers of palisade mesophyll cells as compared to single layer in other genera. The resin canal cells are present in all the genera and they are positioned in the mesophyll cells except in Agasthiyamalaia where they are also present in epidermal cells (Table 5.7).

Pollen morphology:

All genera show 3-zonocolporate type, but the size of the pollen differs. In the endemic tree genera the pollen size is smaller compared to the closely related genera. The P/E ratio of endemic tree genera are nearly one but in the closely related genera it is more than one (Table 5.8).

Phytogeography:

The genus Poeciloneuron is distributed in central and southern Western Ghats whereas Agasthiyamalaia is distributed in southern Western Ghats only. The closely related genera are widely distributed viz. Mammea in Tropical Asia, Africa, America, Malesia, Madagascar and New Caledonia, Mesua in Tropical Asia, Indo-Malesia to Australia and Calophyllum in Tropical Asia and America (Table 5.9; Fig 5.3)

DISCUSSION:

Poeciloneuron pauciflorum was relocated after almost a century (Ravikumar unpubl.) and very few collections are

Table 5.7. Leaf anatomical features of endemic tree genera and their closely related genera

Characters	Poeciloneuron	Agasthiyamalaia	Mammea	Mesua	Calophyllum
Leaf thickness	308μ	238μ	332μ	192μ	280μ
UppperEpidermis Layers Thickness Cuticle thickness	single 12μ 6μ	single 12μ 3μ	single 18μ 6μ	single 9μ 5μ	single 24μ 6μ
Palisade Layers Thickness	single 30μ	single 42μ	Two 84μ	single 39μ	single 69μ
Spongy Layers Thickness	9 192μ	7 120μ	10 210μ	6 120μ	7 150μ
Postion of minor veins	Transcurrent	Transcurrent	Transcurrent	Transcurrent	Transcurrent
Lower Epidermis Layers Thickness	single 6μ	single 9μ	single 6μ	single 5μ	single 7μ
Stomata	Rubiaceous	Rubiaceous	Rubiaceous	Rubiaceous	Rubiaceous
Petiole vasculature	arc shaped with incurved ends	arc shaped with incurved ends	arc shaped with incurved ends	arc shaped with incurved ends	arc shaped with incurved ends

Table 5.8. Pollen morphological features of endemic tree genera and closely related genera

Characters	Poeciloneuron	Agasthiyamalaia	Mammea	Mesua	Calophyllum
Pollen type	3- zonocolporate	3- zonocolporate	3- zonocolporate	3-zonocolporate	3- zonocolporate
Polar axis Equatorial axis P/E ratio	15.6 ± 1.5μ 14.6 ±0.9μ 1	20.8 ±2.2μ 22.6 ±2.0μ 0.9	44±2.9μ 36.22±1.88μ 1.2	60-70μ 47-58μ 1.2	35.55±1.83μ 29.23±2.86μ 1.2
Ectoaperature	8-12 x 1μ	7-12 x 1.5 μ	37-42x4-5μ	55-60x4-6μ	29-35x4-6μ
Endoaperature	2 x 4μ	4-6 x 1-2μ	9-13x10-13μ	7-10x10-15μ	4-9x15-23μ
Tectum	6-8μ, perforated, reticulate	11-20μ, perforated, reticulate	8-11μ, perforated, reticulate	8-10μ, perforated, reticulate	8-10μ, perforated, reticulate

Table 5.9. Geographical distribution of endemic tree genera and closely related genera

Poeciloneuron	Monotypic; Central and Southern Western Ghats
Stevensia	Monotypic; Souhtern Western Ghats
Mammea	47 species; Tropical Asia, Africa and America, Malesia, Madagascar and New Caledonia
Mesua	40 species; Tropical Asia, Indo-Malesia to Australia
Calophyllum	187 species; Tropical Asia and America.

Table 5.10: Character loadings from principal components analysis*

Directions	Loadings	I	II
+	0.90-1.00	34,9,12,13,15,17,26,31, 32,33,35	--
	0.80-0.90	--	--
-	0.90-1.00	16	--
	0.80-0.90	--	27,5,4,6

* Only character loadings greater than 0.8 are shown. Number under each component refer to characters outlined in Appendix i..

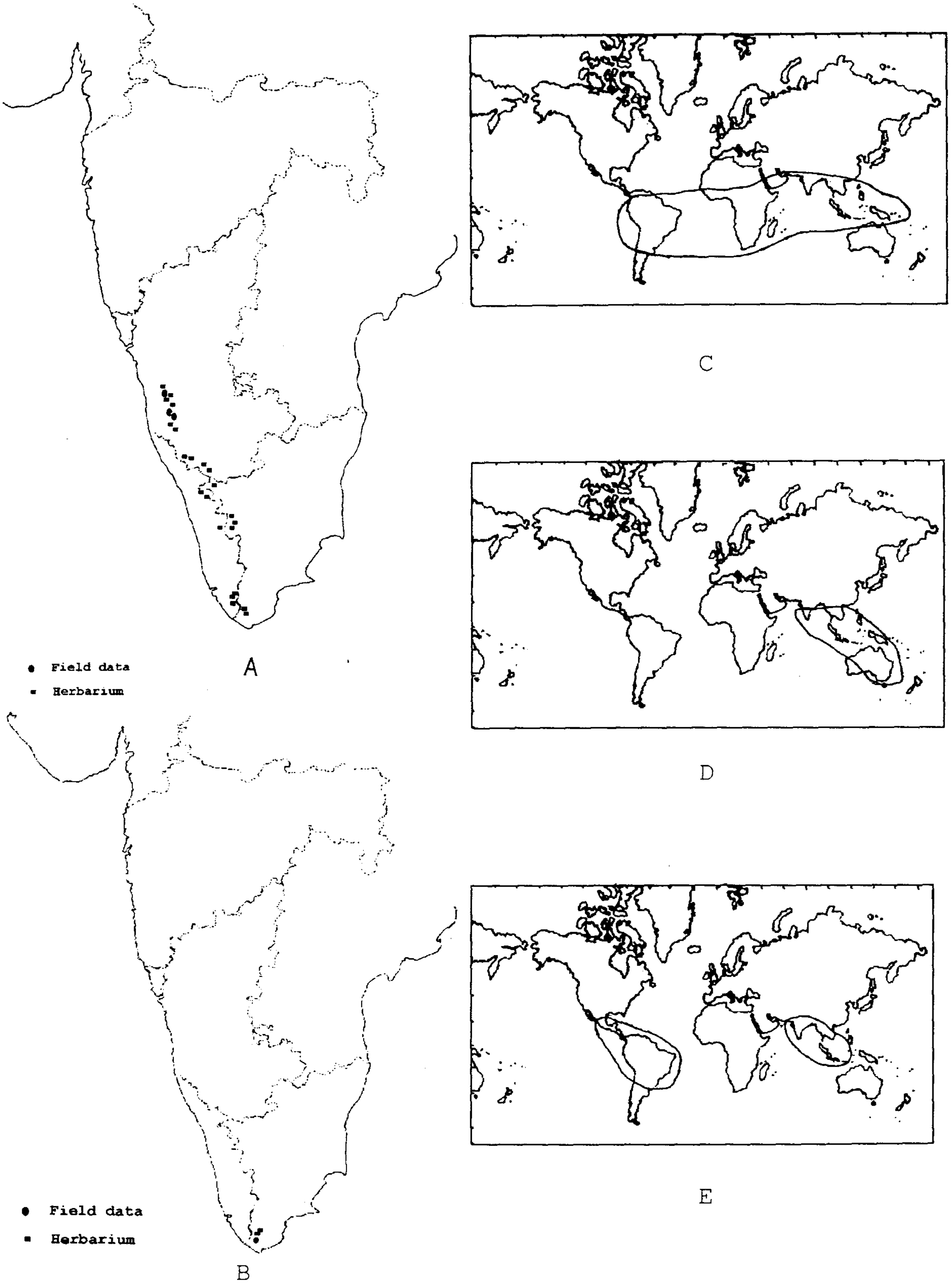


Fig. 5.3: Distribution of endemic tree genera (A.*Poeciloneuron* and B. *Agasthiyamalaia*) and closely related genera (C. *Mammea*, D. *Mesua* and E.*Calophyllum*)

Fig. 5.4 :Dendrogram using Centroid Method (Rescaled Distance) Cluster Combine

```
                    0         5        10        15        20        25
                    +---------+---------+---------+---------+---------+

CALOPHYLLUM         -+-------------+
MESUA               -+             +-------------------------------+
MAMMEA              ---------------+                               I
POECILONEURON       -----------------+-----------------------------+
AGASTHIYAMALAIA     -----------------+
```

Fig. 5.5 : Projection of first two principal components

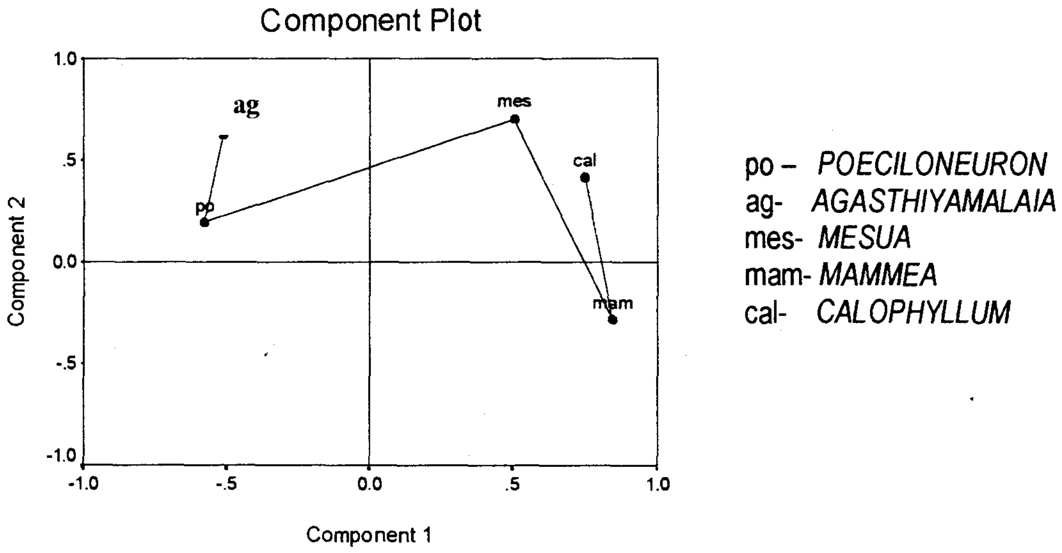
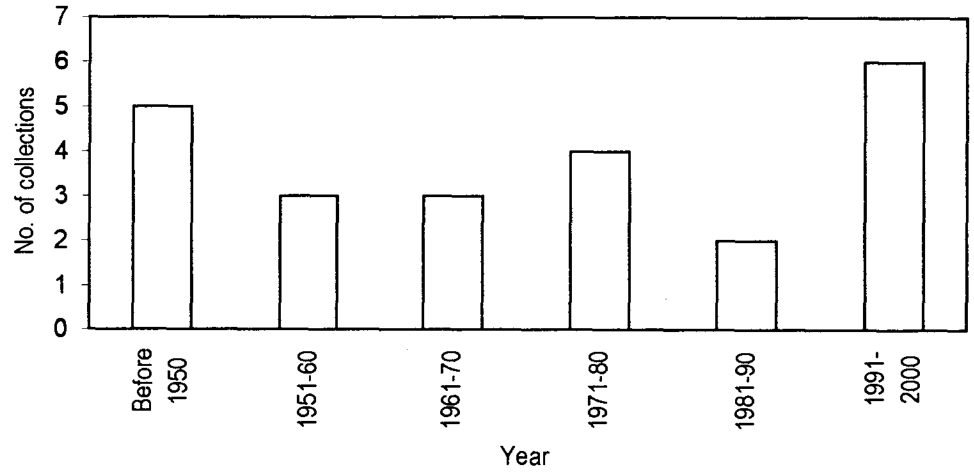


Fig. 5.6. Yearwise available collectionsof Poeciloneuron indicum in the regional herbaria



avaialable in the herbaria. The morphological characters such as lobulate anthers, indistinct stigma and the capsular drupe relate this with P. indicum, the only other species in the genus. Lack of collections and the morphological similarities made earlier workers to follow Beddome's (1869-73) treatment, under Poeciloneuron. But, in the present study, after critical evaluation, it has been raised to a distinct genus, viz. Agasthiyamalaia gen nov. It can be differentiated from the closely related genus Poeciloneuron Bedd. s. str. by the presence of solitary or paired axillary flowers, two whorled sepals and leaves with distantly parallel venation (Table 5.1).

On the basis of wood anatomy Poeciloneuron can be characterised by its aliform wood parenchyma and the presence of only simple vessel-ray pit, whereas Agasthiyamalaia by its apotracheal banded type of wood parenchyma and simple as well as bordered vessel-ray pit (Table 5.2). The wood anatomical characters are conserved and wood parenchyma varies with genus to genus (Metcalfe and Chalk 1950). Here, both the genera show different broadly categorised parenchyma types. Thus, this is another character that supports the segregation of endemic genus Agasthiyamalaia from Poeciloneuron

In Agasthiyamalaia, the upper epidermis of leaf possess resin canals whereas in Poeciloneuron only mesophyll cells contain resin canals (Table 5.3). Based on pollen morphology, the genera can be differentiated. In Poeciloenuron endoaperture is perpendicular to ectoaperture, whereas in Agasthiyamalaia it is parallel. Tectal perforations are irregular in Poeciloneuron and regular in Agasthiyamalaia. Tectal crests are smooth in Poeciloneuron whereas they are warty in Agasthiyamalaia (Table 5.4).

Comparative study with closely related genera reveals the position of these endemic genera. In cluster analysis both Poeciloneuron and Agasthiyamalaia form a separate cluster and remaining closely related genera form another (Fig. 5.4). Though both the endemic tree genera are in the same cluster the distance is more thus supporting the segregation of Poeciloneuron into two genera. Among the related genera Calophyllum, Mesua and Mammea form a separate cluster in which former two are closer.

Based on morphology, each endemic genus has its own relationship with other related genera. Poeciloneuron and Mammea related by their conspicuous fine reticulate venation. Whereas inconspicuous distant parallel venation relate Agasthiyamalaia to Mesua. The vegetative morphology shows that the genus Agasthiyamalaia is closely related to Mesua and Poeciloneuron (Table 5.5).

In the principal component analysis, the distinguishing characters between the endemic tree genera and closely related genera are external morphological as well as pollen morphological characters. As most of the characters are observed from first component, it is suggested that all the genera are distinct. The characters that are observed in the second component are leaf characters (Table 5.10). The component plot (Fig. 5.5) between principal component 1 and 2 supports the dendrogram, wherein the two endemic genera form a separate cluster. The interpolation line shows that the endemic genera are closely related to Mesua.

The flowers of Poeciloneuron are in panicles and they show relationship to Mammea and Calophyllum. Whereas in Agasthiyamalaia it is solitary (or paired) axillary and show the relationship with Mesua. The sepals of all the closely related genera and Agasthiyamalaia are in two whorls except P. indicum. The main floral characters which relate both the endemic genera are lobulate anthers and two styles with indistinct stigma. The inflorescence type, sepal and petals characters relate Agasthiyamalaia with to Mesua, whereas anthers, style and stigma characters relate it to Poeciloneuron (Table 5.5).

Wood anatomically the endemic genera show heterogeneity in their characters. The Poeciloneuron shows paratracheal aliform parenchyma whereas *Agasthiyamalaia* shows apotracheal banded parenchyma as in other related genera. Except *Mammea* all the genera show uniseriate type of rays and simple perforation plates. Presence of fibre tracheids is the character, which differentiates the endemic genera from other related genera. Wood anatomically *Agasthiyamalaia* differs from *Poeciloneuron* but closely related to *Mesua* and *Calophyllum* (Table 5.6). The genus *Mammea* shows the primitive characters such as multiseriate rays and scalariform perforations, supporting the earlier observation based on pollen morphology by Seetharam (1985) wherein early origin of the genus *Mammea* in the tribe Calophylleae was proposed. The genus *Agasthiyamalaia* shows advanced characters than *Poeciloneuron* by possessing apotracheal banded parenchyma which is common in other related genera. The characteristic vasicentric tracheids relate these endemic genera to Bonnetiaceae and *Poeciloneuron* s.l. was earlier treated under that family (Bareta-kuipers 1976). Dickison and Weitzman (1996) characterised the family Clusiaceae by the presence of resin canals in leaves. In the present study it is observed that both the genera possess resin canals in their petiole and leaf justifying their inclusion in Clusiaceae.

Leaf anatomy and petiole anatomy of the endemic genera and closely related genera show variations as the endemic genera have arc shaped vasculature with incurved ends as in *Mammea* and considered an advanced character (Schofield 1968). The genus *Calophyllum* and *Mesua* show open arc and broken arc shapes respectively. The stomata of all the genera are rubiaceous type and are sunken, as it is a family character (Metcalfe and Chalk 1950) (Table 5.7).

Pollen of all the genera show 3-zonocolporate type, as it is a family character (Seetharam 1985). The shape of pollen varies from prolate to sub-prolate. Except for pollen size and exine pattern all the genera show similar pollen morphology. The size of the pollen is smaller in *Poeciloneuron* and *Agasthiyamalaia* compared to other genera, which is an advanced character (Table 5.8).

Since no visitors were observed visiting *Poeciloneuron* during the daytime and the flowers are white, it may be considered as a nocturnally pollinated plant. Except during one season, fruiting was observed in the populations of *Poeciloneuron* during the study period. This can be attributed to complete infestation of populations with caterpillar during December 1998 which devastated the flowers.

Since most of the populations of *Poeciloneuron* are observed along the streams or steep slopes, the secondary dispersal may be through water as the dehiscence of fruits was observed during monsoon. The genus *Poeciloneuron* shows clumped and uniform pattern in S.K. border, Karnataka. Clumping of individuals of the same species may be due to inefficient mode of seed dispersal (Richards 1996) but an effective mode of dispersal through water was observed in the genus Poeciloneuron. Seedlings were abundant in around the habitat. Though saplings were not observed, they might grow into saplings wherever the canopy gap is formed. Occasional saplings or small trees were observed only along roadsides where abundant light is available simulating canopy gaps (Armesto et al. 1986; Richards 1996). This may be one of the reason for the clumped pattern of Poeciloneuron in S.K. border population.

The endemic genus Agasthiyamalaia is observed along the streams in the evergreen forests surrounded by grasslands resembling 'Shola'. Most of the populations consists of young trees, which are not more than 10 m high. Saplings were observed in the populations. The flushing of young leaves were observed in the genus which differntiates it from Poeciloneuron.

The distribution of Poeciloneuron shows that it is widely distributed in Central and Southern Western Ghats (Fig. 5.3). This plant is the main component of West Coast Evergreen forest in the Central Western Ghats (Pascal 1988). It is dominant in the upper storey in southern Western Ghats also (Manilal 1988; Ayyappan and

Parthasarathy 1999). Since the genus Poeciloneuron is abundant and distributed continuously along its range, it is considered here under 'low risk' category based on IUCN norms.

The distribution of Agasthiyamalaia is restricted to southern Western Ghats and it is considered to be narrow endemic (Fig. 5.3). So far it is known from few localities in and around Tirunelveli hills. This genus is habitat specific and found along the streams in the evergreen forests. The red data book on Indian plants reported this plant as 'Indeterminate' category (Ahmedullah and Nayar 1990) as there were no specimens available. But the present work and recent reports (Mohanan et al 1997; Gopalan and Henry 2000) shows that the plant does exist but is restricted in distribution. Since the genus Agasthiyamalaia is narrowly distributed and is habitat specific, it is considered under "endangered" category according to IUCN norms.

The endemic tree genera and their close relatives are well associated within themselves, as all of them are distributed in the Western Ghats. Though the endemic tree genera are geographically isolated, their taxonomic relatives grow together, and hence these genera may be considered 'neoendemics'.

Chapter 6

ERINOCARPUS Nimmo ex Graham

INTRODUCTION:

Erinocarpus Nimmo ex Graham is a monotypic endemic tree genus of Western Ghats of India and it belongs to the family Tiliaceae of Malvales. The number of families included in the order varies. Cronquist (1988) included Malvaceae, Bombacaceae, Sterculiaceae, Tiliaceae and Elaeocarpaceae in the order Malvales. The families such as Bixaceae, Cistaceae, Cochlospermaceae, Diegodendraceae, Dipterocarpaceae, Dirachmaceae, Huaceae, Peridiscaceae, Plagiopteraceae, Sarcolaenaceae, Scytopetalaceae, Sphaerosepalaceae and Thymelaeaceae have also been included under the order Malvales by some authors (Dahlgren 1983; Takhtajan 1987, 1997; Thorne 1992). However, authors are consistent in recognizing the families Tiliaceae, Bombacaceae, Malvaceae and Sterculiaceae in core Malvales since Linnaeus (Alverson et al., 1999). Usually, unrecognised genera of Malvales are kept under Tiliaceae (Bentham and Hooker 1862-67; Bailon 1873; Hutchinson 1967). In the order Malvales, Tiliaceae is considered to be primitive and through intermediate Sterculiaceae and Bombacaceae culminates in Malvaceae (Cronquist 1988; Takhtajan 1997; Dahlgren 1989; Thorne 1992; Judd and

Manchester 1997), but some authors kept Sterculiaceae as a basal group (Warming 1895; Venkata Rao 1952).

The recent, detailed molecular and morphological studies on the order Malvales reveal the phylogenetic and taxonomic position of the family Tiliaceae(Chase et al., 1993; Alverson et al., 1998, 1999; Bayer et al., 1999). Bayer et al. (1999) considered Tiliaceae and Sterculiaceae as polyphyletic groups and the family Malvaceae a monophyletic one in the core Malvales. The available molecular data does not support the segregation of four families in core Malvales and also does not support the combination, either Bombacaceae with Malvaceae or Sterculiaceae with Tiliaceae. Hence, they proposed nine clades in the core Malvales, and treated the order as family Malvaceae and each clade is considered in the rank of subfamily till the proposed 'phylocode' comes into effect. In another phylogentic study based on molecular data in the core Malvales (Baum et al. 1998), a rankless nomenclatural scheme has been proposed due to difficulty in recognising subgroups. In this scheme two major clades were proposed, one constituting Grewioideae and Byttnerioideae groups and the other remaining genera of core Malvales.

In Tiliaceae, the genus Erinocarpus Nimmo has been treated under the tribe Grewieae (Bentham and Hooker, 1862-67; Schumann, 1895) or Tilieae (Bailon 1873), but later it was segregated and kept under Triumfetteae based on fruit characters (Hutchinson 1967). Recent morphological studies show the position of this genus under Grewioideae (Judd and Manchester 1997; Bayer et al. 1999). Kukachka and Rees (1943) proposed nine taxonomic groups in the family Tiliaceae based on wood fibre and vessel length ratio and *Erinocarpus* comes associated with *Apeiba*, *Entelea*, *Heliocarpus*, *Triumfetta* and *Honckenya* in a separate group. Though some of the above genera are treated under different groups based on external morphology, it was argued that, distinctness of this group is the presence of unusual pith like parenchyma along with wood parenchyma (Metcalfe and Chalk 1950). Anatomy and morphology of androecium of the order Malvales shows that the genus *Erinocarpus* shows unique stelar pattern which relates it to the genus *Triumfetta* and *Heliocarpus* (Van Heel 1966). Pollen morphology of *Erinocarpus* represents its own type but related to Grewioideae group which has prolate pollen (Sharma 1969). Enormous studies carried out at various taxonomic levels within the order have still left some gaps in the understanding. According to Alverson et al., (1999) 'additional exemplars of Sterculiaceae and Tiliaceae are needed, as well as odd taxa whose tribal affiliation have always been obscure...' *Erinocarpus* is one such genus which is geographically isolated, taxonomically less understood in relation to other genera and needs to be studied in detail in order to assess its systematic position.

SYSTEMATIC TREATMENT AND OBSERVATIONS:

Erinocarpus nimmonii Graham, Cat. Bombay Pl. 21. 1839; Dalz. & Gibbs, Bombay Fl. 27. 1861; Masters in Hook. f. Fl. Brit. India 1: 394. 1874; Nairne, Fl. Pl. West India 38. 1894; Dalgado, Fl. Savantvadi 24. 1898; Cooke, Fl. Bombay 1: 146. 1901; Talbot, For. Fl. 1: 168. 1909; Blatter in J. Bombay Nat. Hist. Soc. 34(4): 889. 1931; Puri & Mahajan in Bull. Bot. Surv. India 2: 120. 1960; Vartak, Enum. Pl. Gomantak 30. 1966; Santapau, Fl. Khandala 25. 1967; Cherian & Pataskar in Bull. Bot. Surv. India 11: 385. 1969; Rao in Ind. For. 98(9): 564. 1972; Nayar in J. Econ. Tax. Bot. 1: 105. 1980; Bole & Almeida in J. Bombay Nat. Hist. Soc. 77: 462. 1981; Ramesh in Saldanha, Fl. Karnataka 1: 218. 1984; Rao, Fl. Goa 1: 52. 1985; Kulkarni, Fl. Sindhudurgh 50. 1988; Singh, Fl. Eastern Karnataka 168. 1988; Almeida, Fl. Savantwadi 1: 68. 1990; Deshpande et al., Fl. Mahabaleshwar 1: 96. 1993; Kothari & Ramamoorthy, Fl. Raigad 40. 1993; Daniel and Chandrabose in Sharma et al., Fl. India. 3:490. 1993; Almeida, Fl. Maharashtra 1: 152. 1996.

Tree, up to 10 m high, trunk crooked. Leaves simple, alternate, petiolate; petiole up to 35 cm long with ridges and furrows, pubescent; lamina up to 32 x 37 cm, orbicular, cordate at base, acutly 3-5 lobed, prominently palmately veined, dark green adaxially, pale abaxially, stellate hairy on both surfaces, glandular on margins of the cordate base; glands globose, ca. 0.2 cm long with central furrow or cavity. Inflorescence a terminal panicle, up to 40 cm long; flowers showy, yellow in color, ca. 5.5 cm across, in clusters of 2-3, subtended by 4 bracts; bracts ca. 1.5 x 0.5 cm, ovate to oblong, rusty tomentose without, acuminate at apex, covering flower buds; flower buds smoothly constricted at middle, pedicels swollen at base. Sepals 5, recurved on anthesis, up to 4.5 cm long, linear, rusty without, yellow within, abruptly acuminate at apex, apex free in bud condition. Petals 5, up to 2.8 cm x 1.6 cm, clawed, obovate, irregular along margins, yellow in color. Stamens numerous, arising from the raised disc; filaments yellow, up to 3 cm long; anthers unequally 2 celled, basifixed, greyish brown in colour, slightly twisted after dehiscence; disc 2 mm long, 5 lobed, cream in colour. Ovary superior, ca. 1.5 cm across, 3-angled, ovate in outline, spinescent, locules 6, placentation axile; style up to 4.1 cm long, yellowish white, tip yellow, stigma indistinct. Fruits indehiscent, 3-lobed, rarely flat due to suppression of one lobe, ovate in outline, up to 3.5 x 3 cm, cordate at base, 1-seeded, 1-6 seeded when young, spinescent; spine up to 1.5 cm long, pointed, green in color, mucillaginous,

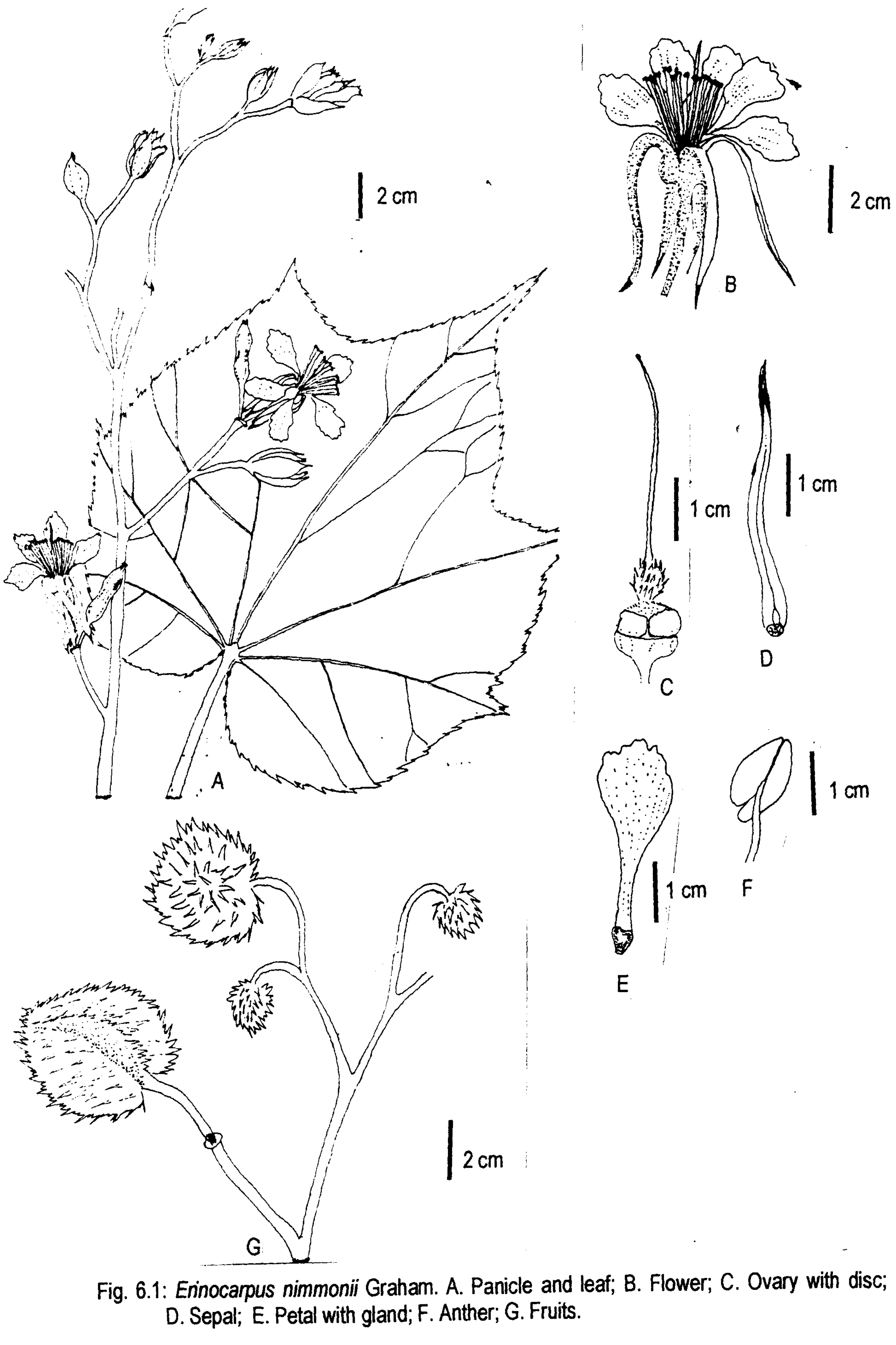


Fig. 6.1: *Erinocarpus nimmonii* Graham. A. Panicle and leaf; B. Flower; C. Ovary with disc; D. Sepal; E. Petal with gland; F. Anther; G. Fruits.

Plate 6.1 : ***Erinocarpus nimmonii*** **A.** Flowers; **B.** Tree along the stream; **C.** Fruiting branch; **D.** *Xylocopa* on the flower; **E.** Trichomes;**F.** Stomata; **G.** Immature fruits showing different numbers of seeds.

fibrous. Seeds solitary at maturity, testa very hard (Fig. 6.1; Plate 6.1A-C).

Wood Anatomy:

Wood semi ring porus. Vessels moderate in size (67μ in tangential diameter) with clusters of 2-4, 93 vessels per mm^2, mean member length 243μ (168 - 350μ), perforation simple; intervascular pitting and vessel to ray is bordered, alternate. Rays heterogenous, 2-4 cells wide, 760μ(280-1540μ) in length, lower and marginal upright cells, middle procumbent cells, gummy substances present, some times crystals present, sheath cells present, tile cells present. Wood parenchyma paratracheal, vasicentric-aliform type, crystals present, chambered crystaliferous cells present. Fibres up to 728μ in length, thick walled, pores on radial walls (Plate 6.2A-C).

Leaf anatomy:

Petiole:

Epidermis single layered, cells equal sided, mucilaginous, with cuticular thickening. Cortex two layered, outer thick walled collenchyma, inner thin walled parenchyma. Crystals solitary or grouped. Vascular bundles circular, closed, interrupted by thick medullary rays.

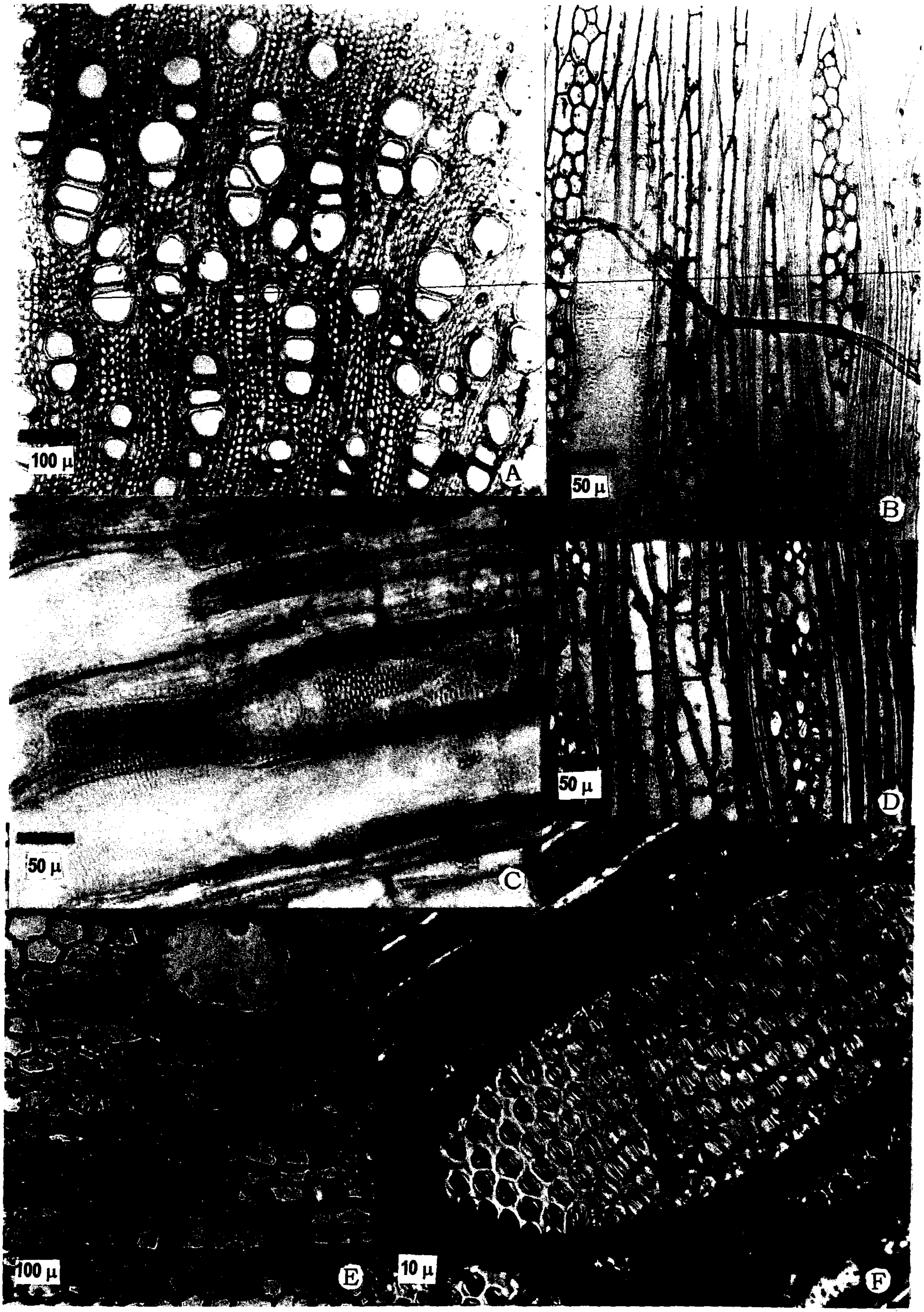


Plate 6.2: ***Erinocarpus nimmonii*** **A.**T.S. of wood; **B.** T.L.S. of wood; **C.** R.L.S. of wood showing simple perforation in vessels. ***Heliocarpus americanus*** **D.** T.L.S. of wood; **E.** T.S. of wood; **F.** Pits of vessels.

Stomata:

Anomocytic (Ranunculaceous type). Guard cells surrounded by subsidiary cells which are indistinguishable from epidermal cells; frequency 504 per mm^2; epidermal cells with parallel striations in surface view (Plate 6.1F).

Lamina:

Lamina 99µ in thickness. Upper epidermis single layered, 12µ in thickness with thin cuticle and stellate and glandular hairs. Major part of mesophyll occupied by mucilaginous palisade parenchyma of 45µ in thickness. Spongy parenchyma single layered, 15µ in thickness. Minor veins embedded in the mesophyll with phloem fibres, up to 12µ in thickness.

Trichomes:

Hairs stellate on the veins of the leaves, stem, and petiole. Glandular hairs on epidermis up to 5 celled, uniseriate with pair of cells at the tip (Plate 6.1E).

Pollen morphology:

Pollen grains prolate in shape, 3-zono colporate, polar axis 66µ and equatorial axis 40µ in length, pore 16µ in size, exine thinly reticulate.

Habitat:

Found along the streams and on the banks of the rivers in Moist deciduous forests from base of the ghats to ±700m altitude on either side of the ghats.

Phenology:

Flowering observed from the month of September to November, with peak blooming in October. Flowering is synchronous. Fruiting observed from end of September till June.

Inflorescence:

It is observed that on an average 18 flowers are produced in a single inflorescence with a range varying from 16 to 20. The blooming percentages as observed at three distant locations at different periods shows that by September end 23% and by October end 70% of the flowers had already bloomed. The remaining bloom in the first half of November. This flowering pattern remained the same across the ghats.

Anthesis:

The flower opens after the sunrise, though the time varies (between 6.00 a.m and 10.30 a.m.) depending upon the locations of the plant i.e. whether in the heavy shadow are exposed to sun. The average time taken by the flower to open is 2 min. and within 6 min. (average) of anthesis the visitors were observed. Each flower lasts for 2 days. Nectar production is comparatively high during morning.

Visitors:

The only pollinator observed was Bumblebee (Xylocopa sp.)(Plate 6.1D). Pollen stealers, mostly of Coleoptera were also noticed. The frequency of visitation was observed to be 3 times/flower/hour. The visitors stay on the flower for approximately 3 sec. Flowers which are symmetric while flowering becomes asymmetric after the visit due to the clasping of stamens by the visitor and impact of its weight on the stamens. The same pollinators were also seen visiting Vigna spp. in the close vicinity. In the study area the only other large yellow flowered species observed was Thespesia lampas, but the pollinator was never observed to be visiting it.

Fruiting:

The success rate of the flowers becoming fruit is 95%. Fruits last long in the branches till June. Fruits are indehiscent, fall at maturity with fruiting branches. Samples from immature plants from various populations show that 12% of them are single seeded, 18% 2-seeded, 32% 3-seeded, 16% 4-seeded, 12% 5-seeded and 6% 6-seeded (Fig. 6.5; Plate 6.1G).

Seedlings:

No seedlings were observed either around the plants or along downstream. But propagation through suckers was observed.

Specimens examined:

Maharashtra: Khadwals Kalyan, Thana, 7.11.1956, S.K. Jain 9398 (BSI); Khandala hill, 24.11.1957, Kumalingam 30740 (BSI); After 2nd Cave, Khandala, 31.8.1960, B.M. Wadhwa 64067 (BSI); Near-Matheran railway line 2½ mile, 4.8.1960, B.M. Wadhwa 64127 (BSI); Slopes of Bhima hill, 8.3.1962, R.S. Rao 78881(BSI); Ambavane forest on way to Kolaba, Barardev, Poona Dt., 2.2.1964, B.V. Reddi 95920 (BSI); Keraude near Dukanwad, Ratnagiri Dt., 13.11.1965, B.G. Kulkarni 106448 (BSI); Digbashi R.F., Padgha Range, 21.7.1968, K.V. Billore 116275 (BSI); Hanumantal-Ramghat, 25km from Amboli, Ratnagiri Dt., 27.5.1970, B.G. Kulkarni 120491(BSI); Phonda Ghat, Ratnagiri Dt. 4.10. 1970, B.G. Kulkarni 121440 (BSI); Nagalbet, 15km from Chandgad, Kolaphur Dt., 10.8.1971, R.S.Rao 131587 (BSI); Varandh Ghat, Mahad, 15.10.1976, M.K. Kothari 148105 (BSI); Sanegaon Forest, Roha, 27.9.1978, M.K. Kothari 155967 (BSI); K. Ghat, Koyna, 30.11.1978, R.K. Kochhar 157995 (BSI); Khambil-Chorghe ghat, Satara, 26.9.1983, S.D. Deshpande 162578 (BSI); Madgal, Savantwadi - Amboli, 24.10.1996, S. Rajkumar s.n. (GUH); Malaprabha river, 4km west of Khanaphur, Belgaum Dt., 2.10.1998 S. Rajkumar s.n. (GUH); Radhanagari - Nipani 3rd km, 3.10.1998, S. Rajkumar s.n. (GUH); Radhanagari-Kolhapur, 2nd km, 3.10.1998, S. Rajkumar s.n. (GUH)

Karnataka: Tirthahalli, Goyanum, Shimoga Dt., 23.6.1961, Sundhar Raghavan 74331(BSI); Joginath R.F. Chitradhurg Dt., 5.9.1974, N.P. Singh s.n. (BSI); Bhagvathi, North Kanara, 6.11.1976, C.J. Saldanha (JCB); Khurghi forest, Dandeli, 29.9.1978, K.P. Sreenath & K.R. Keshavamurthy KFP 3059 (JCB).

Comparative study with closely related genera:

The genus Erinocarpus was treated under the tribe Triumfettae (Hutchinson 1967). Bayer et al (1999) included it under the tribe Grewioideae. In order to assess the taxonomic distinctness and the relationship with closely related genera, the comparative study was made with few related genera namely Triumfetta, Heliocarpus and Grewia. As these genera represent more than one species, representative species (Triumfetta rhomboidea Jacq. Heliocarpus americanus L. and Grewia tilieafolia Vahl.) were studied for analysis.

External Morphology:

External morphological studies show that except Triumfetta all other genera are represented by tree species and except Grewia all other genera possess lobed leaves.

Table 6.1: External morphological differences between Erinocarpus and closely related genera

Characters	Erinocarpus	Triumfetta	Heliocarpus	Grewia
Habit	Trees	Undershrubs	Trees	Trees/Shrubs
Lamina	3-5 lobed	Lower one 3-5 lobed, upper ones entire	3-5 lobed	Not lobed
Shape	Orbicular	Ovate-orbicular	Orbicular	Ovate – orbicular
Base	Cordate	Cordate	Cordate	Cordate, unequilateral
Size (up to)	32 x 37cm	4 x 3cm	8 x 5cm	16 x 9cm
Surface	Stellatly pubescent on both sides	Stellatly pubescent (dense velvetty) on both sides	Stellatly pubescent on both sides	Stellatly pubescent above, glabrous to tomentose beneath
Gland at leaf base	Globose, sessile	Absent	Stalked	Absent
Petiole	Up to 35 cm long	Up to 2.5 cm long	Up to 10 cm long,	Up to 2 cm long
Inflorescence	Terminal panicle up to 40 cm long	Axillary clusters	Axillary as well as terminal panicles	Axillary, variable
Flower	Up to 5.5 cm across	Up to 0.5 cm across	Up to 1cm across	Up to 1.5 cm across
Bract	Ovate- oblong,1.5 x0.5 cm long, rusty tomentose	Linear, 0.1 cm long, stellatly pubescent	Absent	Linear, 0.1 cm long
Bud	Smoothly constricted at middle	Smoothly constricted at middle	Smoothly constricted at middle	Sub-globose, tomentose
Pedicel	Swollen at the base of flowers	Slender at the base of flower	Slender at the base of flower	Slender throughout
Sepal	Longer than petal, recurved during anthesis up to 4.5 cm long, rustly tomentose	Almost equal, recurved during anthesis, up to 1 cm long, stellatly hairy	Longer than petal, up to 1.2 cm long, stellatly hairy	longer than petals, recurved during anthesis
Petals	5, clawed, up to 2.8 cm long, obovate, yellow.	5, clawed, up to 1 cm long, yellow	5, clawed, up to 1 cm long, white	5, oblong, to spathulate, yellow
Glands on petals	At the base, margins ciliate	At the base, thickened	Absent	Occupying one third of petals, thickened. white villous on margins.
Stamens	Numerous; anthers unequal, basifixed, disc raised	10-15, anthers midifixed, disc raised	Numerous, anthers midifixed, disc raised	Numerous, attachment variable disc raised, ribbed.
Ovary	Globose, 3-lobed spinescent	Globose spinescent	Globose, tomentose	Globose, villous
Style	Yellowish white,;no distinct stigma	Yellowish white; no distinct stigma	White; no distinct stigma	White; stigma distinct, 5 lobed
Fruits	3-lobed or flat, ovate in outline, spinescent, woody,	Globose, spinescent, sometimes spines hooked	Compressed, plumose hairs.	Drupe globose, glabrous

Glands at leaf base are present only in Erinocarpus and Heliocarpus. The prominent bracts which cover the buds in the young stage is observed only in the genus Erinocarpus. The genus Grewia is characterised by distinct stigma as compared to other genera. The smooth fruit character differentiates Grewia from other three genera (Table 6.1).

Wood Anatomy:

Each genus studied has its own characteristic ray cells arrangement. In the genus Heliocarpus the rays are dissected into units. In Triumfetta rays are homogenous and consist of all upright cells, whereas in Grewia and Erinocarpus the rays are heterogenous with marginal upright cells and middle procumbent cells. Crystals and gummy substances were observed in the rays cells of all the four studied genera. The length and diameter of the vessels are moderate in all except Heliocarpus. Smaller bordered pit size was observed in the genus Grewia. Baring Heliocarpus wood parenchyma is paratracheal in all other genera. In Heliocarpus and Triumfetta unusual pith like parenchyma cells are present in the ground tissue of the wood (Table 6.2).

Leaf anatomy:

All the genera have atleast single layer of spongy parenchyma except Grewia where all the mesophyll cells are palisade. Stomatal types are anomocytic in all the genera.

Table 6.2: Wood anatomical features in Erinocarpus and closely related genera

Characters	Erinocarpus	Triumfetta	Heliocarpus	Grewia
Porosity	Diffuse	Diffuse	Diffuse	Diffuse
Vessels	2-4 grouped together	2-4 grouped together, rarely solitary	2-3 grouped together, sometime solitary(40%)	2-4 grouped together rarely solitary
Abundance	93 per mm^2	13 per mm^2	5 per mm^2	25 per mm^2
Length	243μ (168-350μ)	265μ (230-195μ)	448μ (350- 532)	310μ(285-340μ)
Diameter	67μ (52-74μ)	63μ(42-73μ)	147μ (130-161μ)	73μ (69-78μ)
Shape	Oval or round	Oval	Oval	Oval
Performation	Simple	Simple	Simple	Simple
Pits	Bordered, alternate	Bordered, alternate	Bordered, alternate	Bordered , alternate
Ray				
Type	Heterogenous	Homogenous,	Heterogenous,.	Heterogenous
Length	760μ(280-1540μ)	1050μ(700-1400μ)	752μ (420-1260μ)	700μ
Width	93μ (80-100μ)	120μ (110-132μ)	95μ (74 - 140μ)	92μ (85-104μ)
Tile cells	Absent	Absent	Absent	Absent
Pit size	6μ	7μ	6μ	3μ
Wood Parenchyma	Paratracheal, vasicentric-aliform	Paratracheal, confluent with diffuse apotracheal	Apotracheal, uniseriate bands	Paratracheal, vasicentric
Unusual pith like parenchyma	Absent	Present	Absent	Absent
Fibre wall	Thick	Thick	Thick	Thick

Table 6.3: Leaf anatomical features of Erinocarpus and closely related genera

Characters	Erinocarpus	Triumfetta	Heliocarpus	Grewia
Leaf thickness	99μ	168μ	62μ	192μ
Epidermis				
No. of layers	Single	Single	Single	Single
Thickness	12μ	28μ	10μ	12μ
Palisade				
No.of layers	3	4	3	4
Thickness	45μ	84μ	37μ	160μ
Spongy				
No.of layers	Single	Single	Single	Absent
Thickness	15μ	18μ	13μ	
Position of vasculatre	Embedded in mesophyll	Embedded in mesophyll	Embedded in mesophyll	Embedded in mesophyll
Petiole vasculature	continuous closed ring	continuous closed ring	continuous closed ring	continuous closed ring
Stomata				
Type	Anomocytic	Anomocytic	Anomocytic	Anomocytic
Frequency (per mm^2)	504	280	340	320
Crystals	Solitary or clustered in petiole and leaves	Solitary in petiole	Solitary in petiole and leaves	Solitary in petiole

The frequency of stomata varies, and Erinocarus shows high frequency of stomata (Table 6.3).

Pollen morphology:

Pollen is of 3- zono colporate type in all the genera. *Grewia* has sub-prolate shape when compared to prolate pollen shape of other genera. The exine ornamentation of Erinocarpus and Heliocarpus are similar with thin reticulate exine pattern, whereas Triumfetta has ornate-reticulate and Grewia retipilariate ornamentation pattern (Table 6.4).

Phytogeography:

The genera Triumfetta and Grewia are pantropical in distribution and are present in the study area also. The genus Heliocarpus is restricted to Central and South central America and Erinocarpus is endemic to Northern and Central Western Ghats (Table 6.5; Fig. 6.2).

DISCUSSION:

Erinocarpus Nimmo is a monotypic tree genus endemic to Western Ghats and belongs to the subfamily Grewioideae under Malvaceae s.l. (Bayer et al. 1999). The presence of glandular petals and numerous stamens in the genus Erinocarpus supports the inclusion of the genus under the subfamily Grewioideae by Bayer et al (1999). The dendrogram (Fig. 6.3) based on cluster analysis of morphological, anatomical and pollen morphological characters shows that

Table 6.4: Pollen morphological features of Erinocarpus and closely related genera

Characters	Erinocarpus	Triumfetta	Heliocarpus	Grewia
Type	3- zono colporate	3-zono colporate	3- zono colporate	3- zono colporate
Size				
Polar	66μ	43μ	33μ	47μ
Equatoria	40μ	29μ	24μ	38μ
Shape	Prolate	Prolate	Prolate	sub- prolate
Exine pattern	Thinly reticulate	Ornate – reticulate	Thinly reticulate	Retipilariate
Pore size	16μ	6μ	3μ	5μ
P/E value	1.65	1.48	1.38	1.24

Table 6.5: Geographical distribution of Erinocarpus and their closely related genera

Genus	Distribution
Erinocarpus	Monotypic; Endemic to Central and Northern Western Ghats
Triumfetta	100 spp; Pantropical
Heliocarpus	22 spp; Endemic to Central and Southern Central America.
Grewia	150 spp; Pantropical

Table 6.6: Character loadings from principal components analysis*

Directions	Loadings	I	II
+	0.91-0.95	31,25,27,40,26,42,44,2	1,32,19
	0.85-0.90	21,24,20	-
-	0.91-0.95	10	23
	0.85-0.90	5,22	-

* Only character loadings greater than 0.85 are shown.Number under each component refer to characters outlined in Appendix ii.

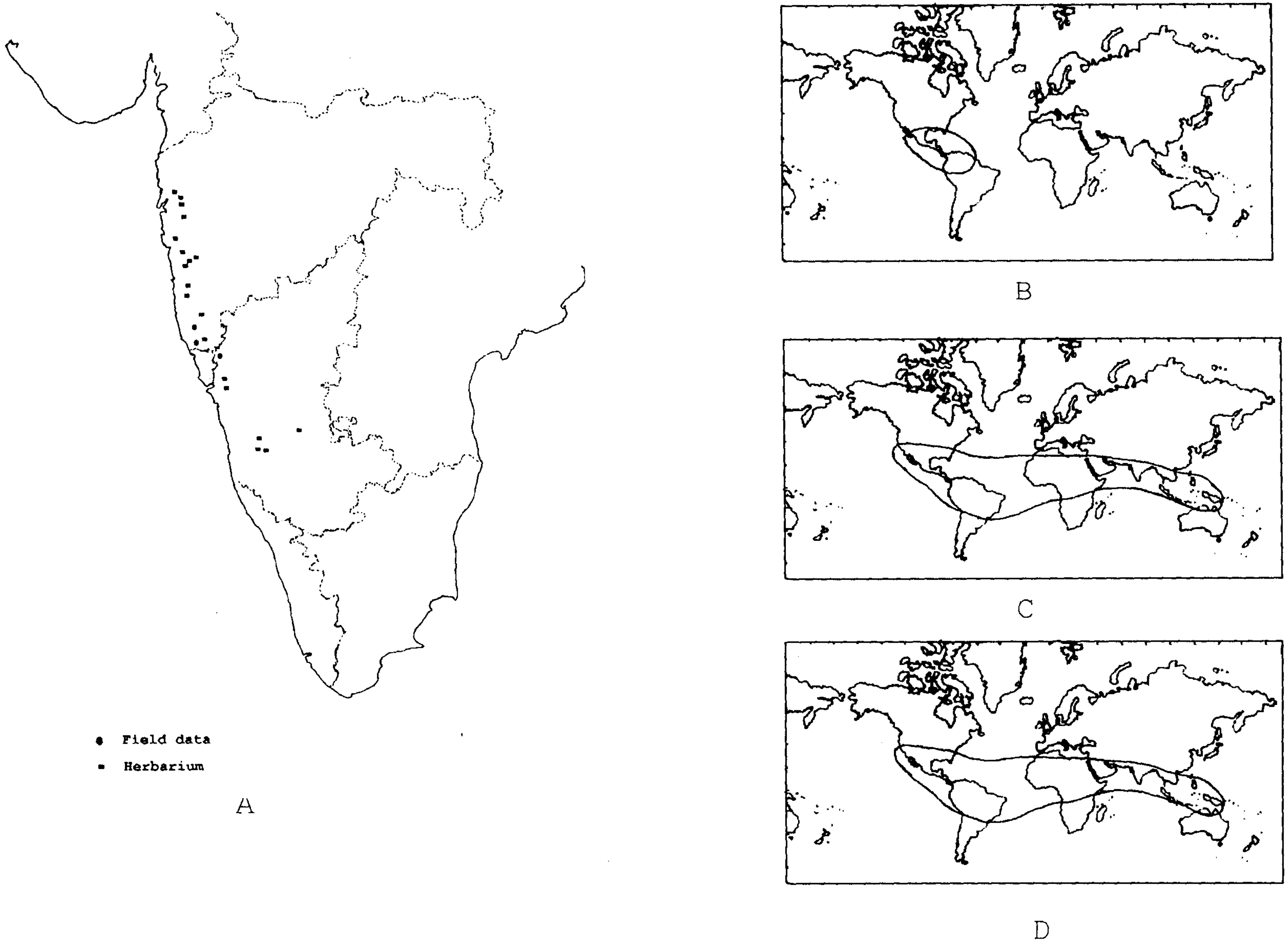


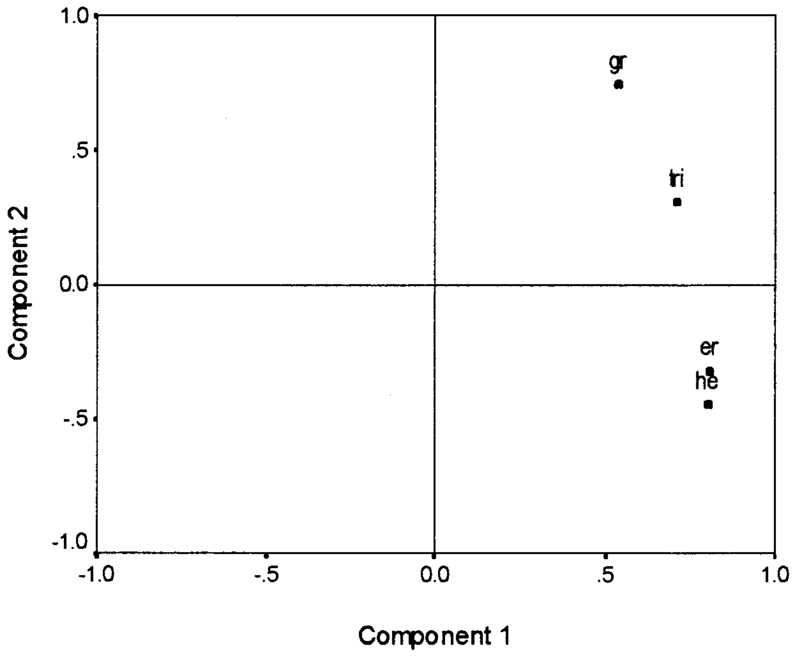
Fig. 6.2: Distribution of endemic genus *Erinocarpus* (A) and closely related genera *Heliocaprus* (B), *Triumfetta* (C) and *Grewia* (D).

Fig.6.3: Dendrogram using Centroid Method rescaled Distance Cluster Combine

```
                 0         5        10        15        20        25
                 +---------+---------+---------+---------+---------+

ERINOCARPUS   -+-----------------------------------+
HELIOCARPUS   -+                                   +-------------+
TRIUMFETTA    -------------------------------------+             I
GREWIA        ---------------------------------------------------+
```

Fig. 6.4: Projection of first two principal components.



er– *Erinocarpus*
he- *Heliocarpus*
tri- *Triumfetta*
gr- *Grewia*

Fig 6.5: Variation in the seed production in the fruits of Erinocarpus

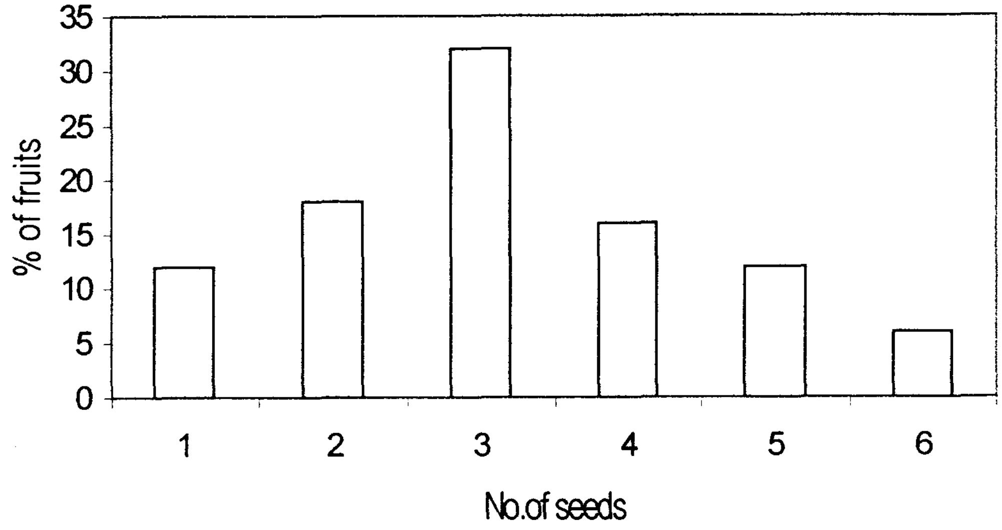
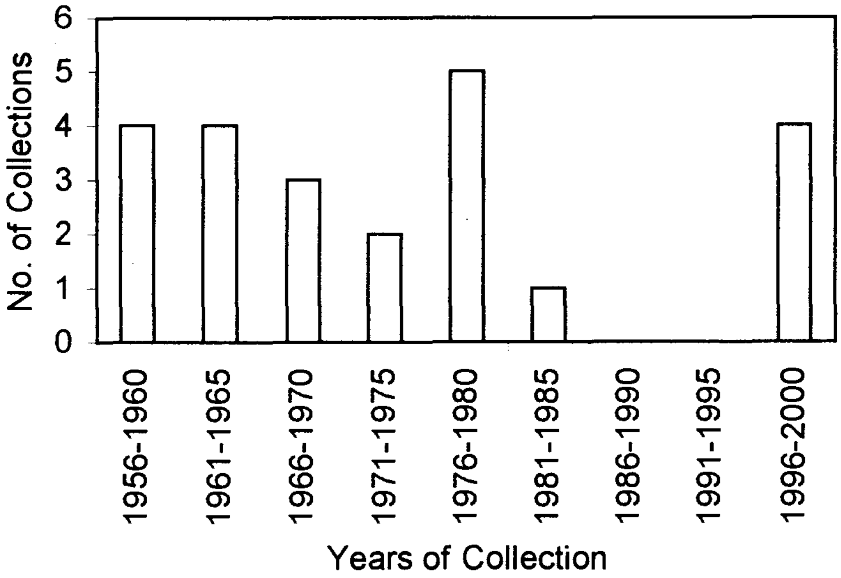


Fig. 6.6: Collections of Erinocarpus in the regional herbaria



the endemic genus is more closely related to Heliocarpus than Triumfetta. It is noted that Grewia gets segregated away from these three genera. This relationship supports the earlier classification by Hutchinson (1967) keeping them in a separate tribe. This was also confirmed by Judd and Manchester (1997) and Alverson et al. (1999) using phylogenetic analysis, where Heliocarpus and Triumfetta formed a separate clade.

The unique character which differentiates Erinocapus from the closely related genera is foliaceous bracts which cover the bud. The presence of glands at the base of lamina relates this genus to Heliocarpus and the presence of spinescent fruits to Triumfetta. In the principal components analysis the character which represent in the first components shows that fruit morphology and pollen morphology are very important to segregate the endemic genus and closely related genera (Table 6.6). The component plot (Fig. 6.4) shows close relationship between Erinocarpus and Heliocarpus supporting the cluster analysis.

Wood anatomically the genus Erinocarpus does not show relationship with other genera as each genus has unique wood anatomical characters (Table 6.2). The smaller intervessel pit diameter is the only character which differentiates Grewia from all other genera supporting the treatment based on morphology. The genus *Erinocarpus* shows advanced characters in the evolutionary trend based on Carlquist (1961). The primitive characters present are diffuse porous wood and weakly heterocellular and more than 2-seriate rays. Unusual pith like parenchyma in *Erinocarpus* (Metcalfe and Chalk 1950) was not observed in the present study, but found only in *Triumfetta* among the related genera.

Leaf anatomical studies (Table 6.3) support the morphological segregation of *Erinocarpus*, *Heliocarpus* and *Triumfetta* from *Grewia* as the latter does not show any spongy parenchyma in the mesophyll regions. Petiole anatomical characters and stomatal characters are of same type as they are characteristic to the family.

Pollen morphological studies (Table 6.4) reveal that all of them have 3-zono colporate and prolate to sub-prolate type pollen supporting the inclusion of *Erinocarpus* in the Grewioideae group (Sharma 1969). Each genus shows unique exine ornamentation pattern. But reticulate ornamentation pattern in *Erinocarpus* and *Heliocarpus* shows that they are closely related than the rest. Other studied genera are heterogenous, as they have more than one type of ornamentation.

The attractive flowers and the presence of nectar show that the flowers are pollinated by biotic agents. The solitary bee Xylocopa sp. is observed to be the main pollinator for this plant. Once the bee visited the flower, the flower become asymmetric, due to the clasping and weight. This helps the insect in avoiding the visit for second time in short span. It was observed that the early morning visiting frequency is three times per hour which comes down towards noon. Though the individuals are very far apart, according to Kapil and Dhaliwal (1969) the indian species of Xylocopa can travel as far as 20 km. Since not more than 25% of the total flowers are blooming on any day and as the population contains only few or rarely one individual, the success rate is almost 95%. This supports Cruden's (1976) suggestion that fruiting should maximise only if few numbers of flowers bloom in given time. It is also observed that in the studied habitat except Erinocarpus, no other trees were in blooming thus minimizing the competition for the pollinator, which is ruled out in evergreen forests (Devy 1998). But it was observed that Xylocopa sp. was visiting other herbaceous plants in the same area. Though 1-6 ovules are fertilized and show the signs of maturing (Plate 6.1; Fig. 6.5) only one develops into mature seed. The abortion of the rest of the ovules is essential considering the fruit morphology as the tough fibrous fruit wall makes it indehiscent and in the event of all the seeds germinating, there will be competition among siblings. The echinate morphology of fruit and distribution of tree along streams show that the dispersal may be through water. However, no seedlings were observed either underneath the tree or downstream. Absence of seedlings in the environs and failed germination in the laboratory experiments to indicate some suppressing factors are involved, though seeds are found to be viable. The mature fruits remain in the tree till the next monsoon and fall with the fruiting branch on the onset of monsoon in order to facilitate dispersal through water. The plant propagating through suckers are observed in the wild.

The distribution analysis shows that, this is the only endemic tree genus, which is distributed in Northern Western Ghats. In the northern Western Ghats, though it is found all along, it is absent from Goa southwards along the windward side, but observed in Deccan region of Western Ghats. Its absence may be due to the presence of evergreen forests from Goa southwards along the windward side, which does not support <u>Erinocarpus</u>. The range of distribution is from Chitradurgha district of Karnataka to Thane district of Maharashtra along the Western Ghats (Fig 6.2). The only population which was recorded in the Deccan region far from Western Ghats is from Chickmagalur district of Karnataka (Singh 1988). They are mostly found along the streams or riverbanks showing that they are niche specific.

The endemic tree genus *Erinocarpus* is taxonomically distinct and isolated as the closely related genus *Heliocarpus* is restricted to Central and southern central America (Table 6.5; Fig. 6.2). Since it is a tree and relictual in nature, it may be considered as paleoendemic. But the other closely related genus *Triumfetta* has pantropical distribution and the species are undershrubs.

The Red data book for Indian plants categorised this genus as "vulnerable" (Ahmedullah and Nayar 1990). But the collections available in herbaria (Fig. 6.6) show its existence in a wider area. As they occur in low land moist deciduous forest in the windward side and leeward side in the higher altitude (600-700m) and continuously distributed throughout northern Western Ghats and part of Central Western Ghats, it is cateogrised under "Low Risk".

Chapter 7

OTONEPHELIUM Radlk.

INTRODUCTION:

Otonephelium Radlk. is a monotypic endemic tree genus belonging to the family Sapindaceae. The species Otonephelium stipulaceum was first described by Beddome (1865) under the genus Nephelium. In the revisionary work on the family Sapindaceae, Radlkofer (1933) raised this species to a separate genus. The family Sapindaceae is the largest family in the order Sapindales (Cronquist 1988; APG 1998). Recently the order has been merged under Rutales (Thorne 1992). Recent molecular systematic work on the order Sapindales (Gadek et al., 1996), could not delimit order Sapindales from Rutales. In the order Sapindales, the core families Sapindaceae, Hippocastanaceae and Aceraceae form a monophyletic group (Thorne 1992). This was supported by molecular systematics (Gadek et al.,1996), cladistic analysis of morphological data (Judd et al. 1994) and wood anatomical studies (Klaassen 1999). In molecular systematics Anacardiaceae and Burseraceae joined to form a sister group of Sapindaceae (Gadek et al.1996), but not in the case of phylogenetics based on wood anatomy. The families Simaroubaceae and Meliaceae were shown very clos to Sapindaceae based on wood anatomy (Klaassen 1999) b were treated more distant from Sapindaceeae clade by Gadek et al. (1996).

The family Sapindaceae consists of 1,450 species distributed over 133 genera (Mabberley 1997). The family is divided into two subfamilies, viz. Dodonaeoideae and Sapindoideae. Under the subfamily Sapindoideae three alliances are recognized. The endemic genus *Otonephelium* belongs to the tribe Nephelieae under Cupanicae alliance (Muller and Leenhouts 1976). With *Otonephelium* there are other 10 genera forming the tribe Nephelieae. Based on macromorphological characters this tribe was catagorised into two groups, viz. *Dimocarpus* and *Pappea* group (Leenhouts 1978). Pollen morphology supported the splitting of the tribe Nephelieae into four pollen type groups (van den Berg 1978; van der Ham 1990). Klaassen (1999) recognised four groups in the family based on wood anatomy. The tribe Nephelieae is heterogenous in its wood anatomy as it represents three wood anatomical groups recognised by Klaassen (1999). However, the wood anatomy confirms the unique position of *Cubilia* and *Pometia* into a distinct group within the tribe (Klaassen 1999) as proposed earlier using pollen morphology (van der Ham 1990)

The endemic genus *Otonephelium* comes under *Dimocarpu* group based on macromorphological characters and found be closely related to the genus *Litchi* (Leenhouts 1978)

Dimocarpus (Leenhouts 1971). Pollen morphology of *Otonephelium* represents *Litchi* pollen type, which is believed to be derived from *Dimocarpus* pollen type (van der Berg 1978). Reduction in petals, number of stamens and development of stipules show that *Litchi* and *Otonephelium* (Leenhouts 1978) have taken different evolutionary routes from *Dimocarpus*. In the tribe Nephelieae, the genus *Otonephelium* represents type IV wood anatomy group along with *Litchi*, *Dimocarpus* and *Xerospermum*. A close relationship among these genera was established using minute vessel pit characters (Klaassen 1999).

Though several independent studies were carried out at family level, no critical studies with particular reference to *Otonephelium* with regard to its systematics and phytogeography have been carried out.

SYSTEMATIC TREATMENT AND OBSERVATIONS:

Otonephelium stipulaceum (Bedd.) Radlk. Spindac. Holl. Ind. 71. 1879; Gandhi in Saldanha & Nicolson Fl. Hassan 368. 1976; Chitra in Nair & Henry Fl. Tamil Nadu 1: 85. 1983; Ramachandran & Nair, Fl. Cannanore 183. 1988; Saldanha in Saldanha & Nicolson in Fl. Karnataka 1: 369. 1978; Keshavamurthy & Yoganarashimhan, Fl. Coorg, 120. 1990. *Nephelium stipulaceum* Bedd. in Trans. Linn. Soc. London 25: 212. 1865 & Ic. t. 103. 1868-1874; Hiern in Hook.

Fl. Brit. India 1: 690. 1875; Gamble, Fl. Madras 1: 180. 1957 (repr.ed.).

Trees, up to 15 m high; branches smooth. Leaves compound, alternate; rachis terete, up to 25 cm long; leaflets 2-3 pairs, opposite; petiolules up to 0.5 cm long, terete, glabrous; lamina ovate-oblong, acute at base, entire along margins, acute to obtuse at apex, dark green and glabrous adaxially, greyish tomentose abaxially, naked glands on lower side of leaflets along their nerve axils; lower leaflets reduced to form pseudostipules, ca. 3 x 2 cm, unequally reniform. Inflorescence an axillary as well as a terminal panicle, equal to or shorter than leaves; peduncle terete, pubescent. Flowers greenish yellow, hirsute, pedicellate, bracteate; pedicels slender, ca. 0.4 cm long; bracts leafy, ca. 0.3 cm long, glabrous; bracteoles triangular, ca. 0.2 cm long. Calyx 5-6 lobed; lobes triangular, acute at apex, hairy throughout, greenish yellow. Petals absent. Stamens 6-8, filaments longer than calyx, slender. Disk rounded, glabrous. Ovary globose, 2-lobed, hirsute; ovules 2, placentation axile; stigma sub-sessile, 2-lobed, flat, hairy. Fruit a capsule, ovoid, ca. 3 x 1.5 cm, spinescent, single seeded, arillate, aril white fleshy (Fig. 7.1; Plate 7.1A&B).

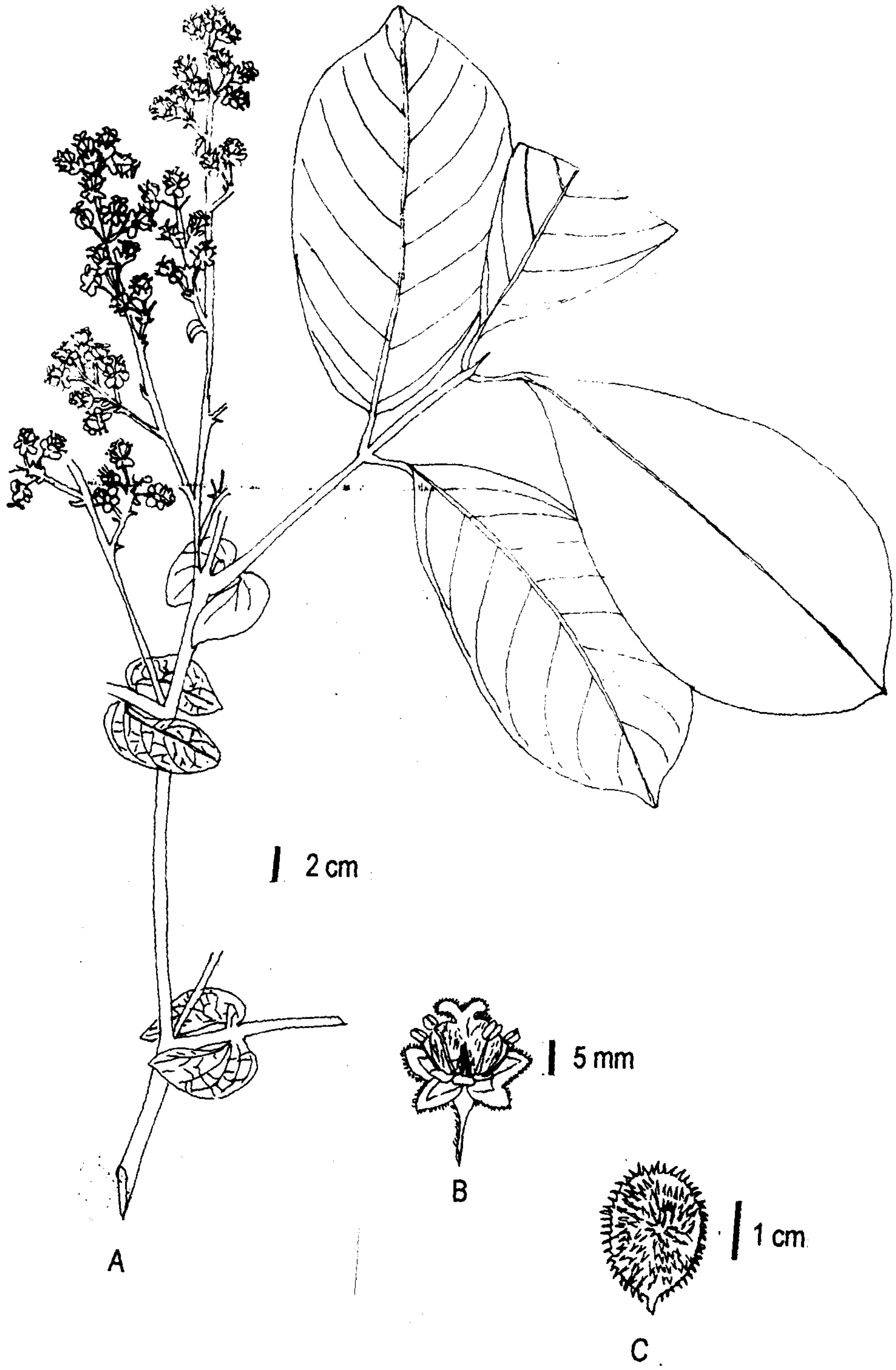


Fig 7.1: *Otonephelium stipulaceum* (Bedd.) Radlk. A.Flowering twig; B. Flower; C. Fruit.

Plate 7.1: ***Otonephelium stipulaceum*** **A.** Branches with pseudostipules; **B.** Fruits; **C.** T.L.S. of wood; **D.** Vessel; **E.** T.S. of wood; **F.** SEM of T.S. of wood.

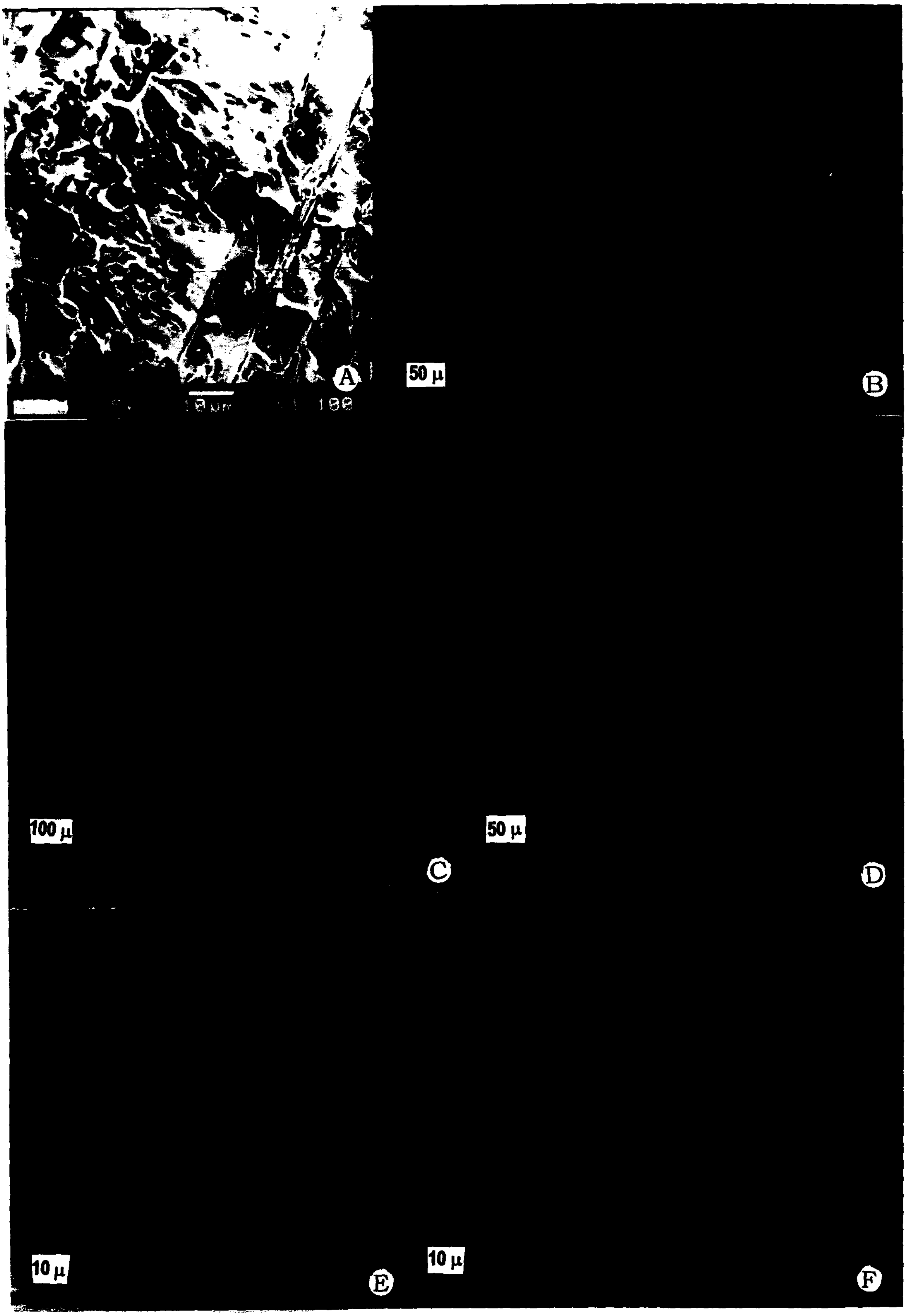


Plate 7.2: ***Otonephelium stipulaceum*** **A.** Vessel pits; **F.** Epidermal projections. ***Litchi chinensis*** **B.** T.L.S. of wood; **C.** T.S. of wood; **D.** Vessels; **E.** Epidermal projection.

Wood anatomy:

Wood diffuse porous; vessels grouped (36%) as well as solitary (64%); grouped ones are 3-4 cells together, ovate irregular in outline; tangential vessel diameter 73μ (56-98μ), 21 - 23 per mm^2, mean member length 358μ (280 - 420μ), perforation simple; intervascular pitting alternate, rounded; parenchyma scanty paratracheal to vasicentric and confluent with 6 cells width; rays uniseriate, heterogenous, up to 21 cells high and 196 μ (126 μ- 350μ), 54 per mm^2, crystals present; rays to vessels pitting are simple, alternate; fibres thin walled, septate, 700μ in length, some times reaches 1 mm (Plate 7.1 C-F)

Leaf anatomy:

Petiole and Petiolules:

Epidermis single layered, elongated radially with thick cuticle; cortex collenchymatous, 9-layered; vasculature continuous, cirucular.

Lamina:

Lamina ca. 195μ in thickness. Upper epidermis ca. 12μ in thickness with cuticle, single layered. Palisade 2-layered. Lower epidermis ca. 9μ in thickness with cuticular projections; minor veins transcurrent (Plate 7.1F).

Pollen morphology:

Pollen grain spherical, P/E 0.98, equatorial outline circular to rounded-triangular, tricolporate, polar axis ca. 18 μ, equatorial axis ca. 20μ; ectoaperature ca. 14μ; endoaperatures circular/elliptical, meridionally elongated, diameter ca.2μ. Thickness of exine 1.6 μ in mesocolpia. Sole 0.8 μ, columellae 0.2 μ, tectum 0.6μ. Tectum striate.

Phenology:

Flowering and fruiting was observed from February to May. The flowering phenology varies from population to population. Occasional stray flowers were observed in the population.

Ecology:

Mostly distributed in the evergreen forests above 500m altitude in the central and southern Western Ghats. It is associated with *Myristica* sp., *Eleaocarpus* sp., *Syzygium* sp., *Poeciloneuron indicum* *Blepharistemma serratum* and *Meteoromyrtus wynadensis*. No seedlings were observed in the vicinity of the plant.

Specimens examined:

Karnataka: Kerike Road, Bagamandala, 15.5.1959, R.K. Arora 55214 (BSI); Kagenari Forest, Shirodi ghat, 21.6.1972, D.H. Nicolson, T.P. Ramamoorthy and K.N. Gandhi HFP 2849 (JCB);

Wotekolli - Irutti, Coorg Dt., 21.3.2000, Rajkumar s.n. (GUH).

Tamil Nadu: Anamallais, 1871, R.H. Beddome 11782 (MH); Carcon ghat, Nilgiri Dt., 1886, J.S. Gamble 11781 (MH); Vallera Malley, 12.11.1890, J.S. Gamble 11797 (MH); Kannikatty, 20.9.1921, Jacob 85367 (MH); Yanaikunde shola, 29.1.1962, J. Joseph 13817 (MH); Shanthi Estate Shola, Ouchetloney valley, Nilgiri 29.1.1971, J.E. Ellis 37752 (MH); Way to Power House, Nadugani, Nilgiris 24.5.1971, J.E.Ellis 38511 (MH); Rockwood R.F. Nilgiris, 28.2. 1973, E. Vajravelu 43776 (MH).

Kerala: Theerthundimalai, Chandanathode, 14.2.1965, J.E. Ellis 25237 (MH); Aryathukavala Nilakkal, Anilkumar 502 (MH); Kulamavu, Idukki Dt., 19.8.1977, K. Vivekananthan 50424 (MH); Machiston Estate, Kalla, Trivandrum, 5. 3. 1980, s.l., 66109 (MH); Painavu, Idukki Dt., 18.2.1983, s.l. 76233 (MH); Ayyappan koil Forest, Pamba, Sabarimala R.F. 25.4.1984, E. Vajravelu 80594 (MH); Chandanthode, Wynaad Dt., S.Rajkumar, 17.5.1997, s.n.; 15.3.1999, s.n. (GUH).

Comparative study with closely related genera:

The tribe Nephelieae is represented by 11 genera including Otonephelium. Based on morphology the genus Otonephelium was grouped along with Dimocarpus, Litchi and Pometia. In the present study, in order to assess the systematics of this rare taxon, representative species of closely related genera, viz. Dimocarpus (D. longan) and Litchi (L. chinenesis)were taken up for analysis. The genus Dimocarpus represents 5 species and distributed in Southeast Asia and Australia (Leenhouts 1971; Klaassen 1999). The genus Litchi is native of China and now found in cultivation up to Western Malesia (Leenhouts 1978).

External Morphology:

Based on external morphology the endemic genus Otonephelium can be differentiated from other genera by its pseudostipules. Lamina of Dimocarpus and Litchi are oblong and acuminate, whereas in Otonephelium it is ovate-oblong with obtuse-acute apex. In the genus Dimocarpus the petals are pentamerous and they have tuberculate hairs, whereas in Otonephelium and Litchi the petals are absent (Table 7.1)

Wood Anatomy:

The growth rings are distinct in the genus Otonephelium where as in Dimocarpus and Litchi either they are indistinct or absent. Pit diameter is larger in Otonephelium as compared to closely related genera. All the studied genera possess scanty parenchyma and in addition to this the genus Otonephelium has paratracheal confluent type and Litchi has paratracheal aliform type. Crystals are present in ray cells of all genera. In Litchi and

Table 7.1: External morphological features of Otonephelium and closely related genera.

Characters	Otonephelium	Dimocarpus	Litchi
Habit	Tree	Tree	Tree
Leaves	2-5jugate, leaflets opposite	up to 7-jugate, leaflets alternate	2-5 jugate, leaflets alternate
Stipule	Lower leaflets modified into stipules	Absent	Absent
Lamina	Ovate-oblong, apex obtuse - acute	Oblong, apex acuminate	Oblong, apex acuminate
Surface	Greyish abaxially	Greyish abaxially	Greyish abaxially
Gland	Naked glands on nerve axils	Naked glands on nerve axils	Naked glands on nerve axils
Inflorescence	Cymose panicle, terminal	Cymose panicle, terminal	Cymose panicle, terminal
Sepals	5,fused, rusty tomentose	5, fused, rusty tomentose	4- 5 , hairy
Petals	Absent	5, smaller than sepals, tomentose	Absent
Stamens	5-6, filaments slender	6-10, filaments filiform	6-10, filaments filiform, hairy
Ovary	Cordate, 2-celled, hairs tuberculate	Cordate, 2-3 celled, hairs tuberculate	Cordate 2-3 celled, hairs tuberculate
Stigma	Sub-sessile, bilobed, spreading	Stalked, bilobed, spreading	Stalked, bilobed, spreading
Fruits	Globular, spinescent	Globular, granular, nearly smooth	Globular, granular
Seeds	Arillate	Arillate	Arillate

Table 7.2: Wood anatomical features of Otonephelium and closely related genera.

Characters	Otonephelium	Dimocarpus	Litchi
Porosity	Diffuse, growth ring indistinct	Diffuse, growth ring distinct or absent.	Diffuse,growth ring distinct or absent.
Vessel			
Solitary	64%	15-70%	10-50%
Grouped	36%	30-85%	50-90%
V-frequency	21-23/mm^2	5-18/mm^2	17/mm^2
V-diameter	70-112μ	80-150μ	70-84μ
V-length	280-420μ	450-600μ	280-392μ
Perforation	Simple	Simple	Simple
V– ray pit	Alternate, rounded	Alternate, rounded	Alternate, rounded
Pit diameter	5μ	2μ	3μ
Ray type	Uniseriate	Uniseriate	Uniseriate
Length	126-350μ	200-400μ	120-225μ
Frequency	54/mm^2	10-20/mm^2	58/mm^2
Contents	crystals	crystals	crystals
Parenchyma	scanty,paratracheal confluent (6 cells width)	scanty	scanty,paratracheal aliform
Fibres	Septate, 700-1000μ long	Septate, 780-1050μ long, crystal present	Sepatate, up to 1000μ long, crystal present

Table 7.3: Leaf anatomical features of *Otonephelium* and closely related genera.

Characters	Otonephelium	Dimocarpus	Litchi
Leaf thickness	196μ	180μ	195μ
UppperEpidermis			
Layers	Single	Single	Single
Thickness	12μ	15μ	12μ
Position of minor veins	Transcurrent	Transcurrent	Transcurrent
Lower Epidermis			
Layers	Single	Single	Single
Thickness	6μ	9μ	9μ
Cuticular projection	18μ	15μ	16μ
Stomatal Type	Anisocytic	Anisocytic	Anisocytic
Petiole vasculature	Continuous, circular	Continuous, circular	Continuous, circular

Table 7.4: Pollen morphological features of Otonephelium and closely related genera.

Characters	Otonephelium	Dimocarpus	Litchi
Pollen type	3-zono colporate	3- zono colporate	3-zonocolporate
Polar axis	18μ	17μ	19μ
Equatorial axis	20μ	22μ	25μ
P/E ratio	0.98	0.77	0.83
Ectoaperature	14μ	-	16μ
Endoaperature	2μ	-	2μ
Tectum	Striate, 0.6μ thick	Striate, perforate, psilate, finely reticulate	Striate, 0.4μ thick
Columella	0.2μ	-	0.2μ

Table 7.5: Geographical distribution of endemic genus and closely related genera

Genus	Distribution
Otonephelium	Central and Southern Western Ghats.
Dimocarpus	Southeast Asia and Australia
Litchi	Originally China, later culitvated up to Malesesia.

Table 7.6: Character loadings from principal components analysis*

Directions	Loadings	I	II
+	0.95-1.00	27,24,16,21,19,2,15,12, 7,18,8,9,10	
-	0.95-1.00	25,3,22,28	5

* Only character loadings greater than 0.95 are shown. Number under each component refer to characters outlined in Appendix iii.

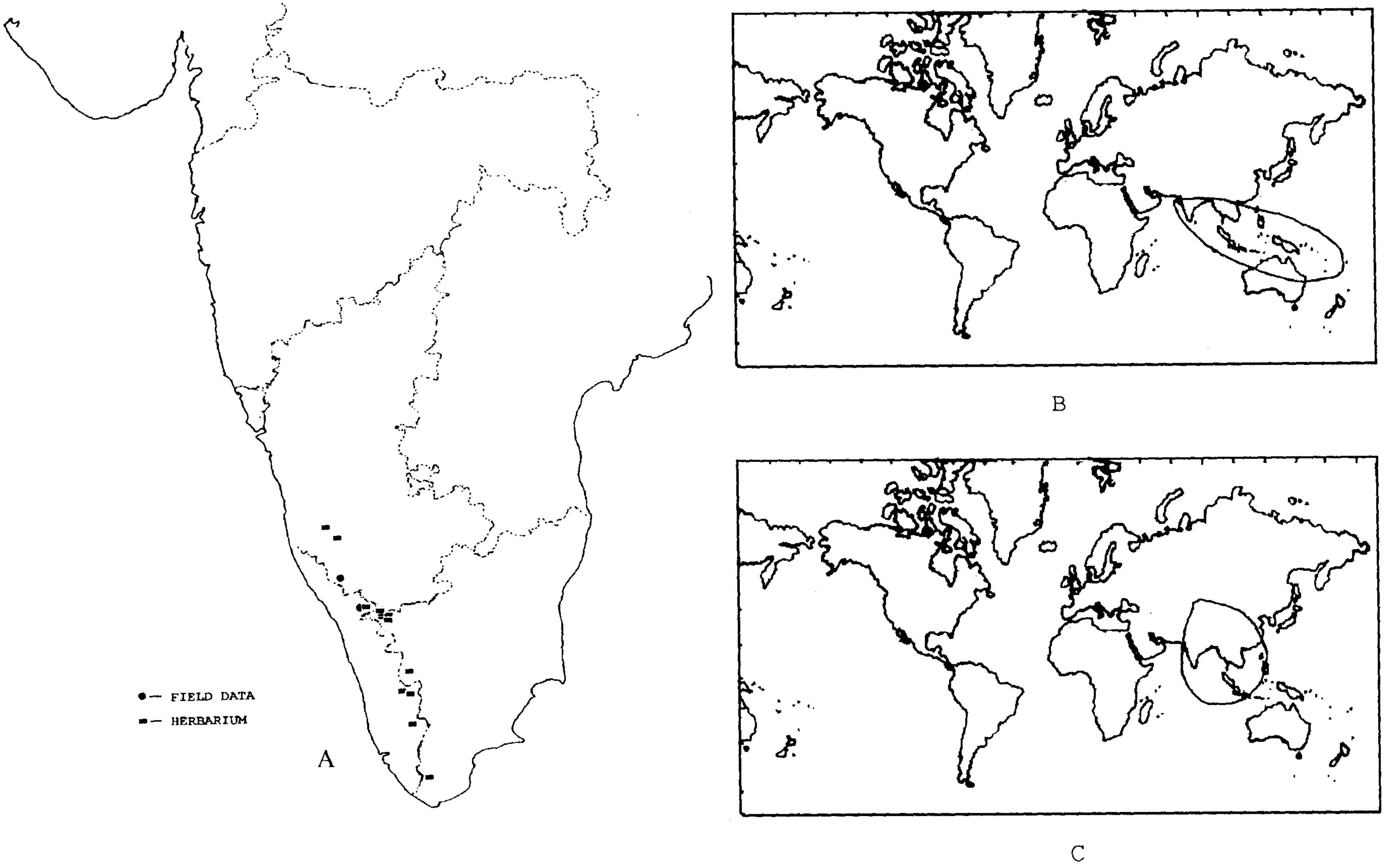


Fig. 7.2 : Distribution endemic genus *Otonephelium*_(A) and closely related genera *Dimocarpus* (B) and *Litchi* (C)

Fig.7.3:Dendrogram using Average Linkage (Between Groups) rescaled distance cluster combine

```
                   0         5        10        15        20        25
                   +---------+---------+---------+---------+---------+

DIMOCARPUS         -+-----------------------------------------------+
LITCHI             -+                                               I
OTONEPHELIUM       -------------------------------------------------+
```

Fig.7.4 : Projection of first two principal components

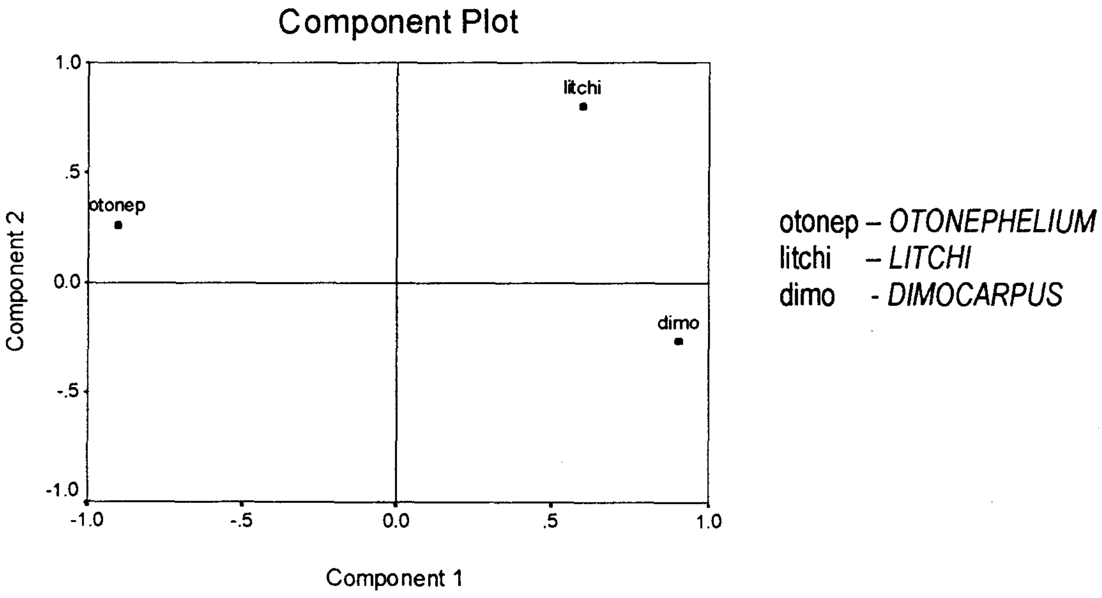
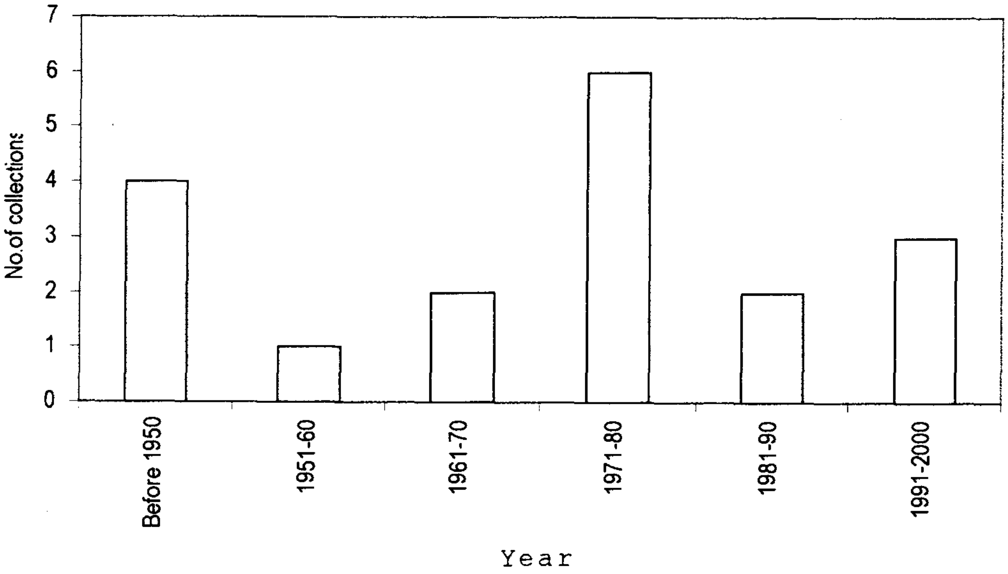


Fig. 7.5: Collections of <u>Otonephelium stipulaceum</u> from the regional herbaria



Dimocarpus crystals are present in the fibrous elements also (Table 7.2)

Leaf anatomy:

All the genera show circular continuous vasculature in the petiole. Palisade cells are transversly septate and spongy cells are with larger intercellular spaces in *Otonephelium* (Table 7.3)

Pollen morphology:

Otonephelium and *Litchi* form a separate pollen type based on tectum pattern. The pollen morphology of *Dimocarpus* is heterogenous (Table 7.4).

Numerical Analysis:

The dendrogram (Fig 7.3) based on cluster analysis using binary scoring of morphological and anatomical characters (Appendix iii) shows that *Litchi* and *Dimocarpus* form a distinct cluster and the *Otonephelium* a separate one.

In Principal component analysis most of the characters are represented in the first principal component and majority of them are anatomical characters (Table 7.6). The component plot between two principal component shows that all the three genera are distinct (Fig. 7.4)

DISCUSSION:

The endemic genus *Otonephelium* Radlk. stands as a distinct genus as it differs from the closely related genera in a number of morphological characters (Table 7.1). Development of pseudostipules is one of the main character that differentiates the endemic genus from the closely related ones. Pometia, the only other genus which shows development of pseudostipules, is not considered as a close relative, since it differs in several other characters (Leenhouts 1978). The other important character which differentiates this endemic genus from other closely related genera is its spinescent fruits.

Out of three genera in Dimocarpus group, Otonephelium is closely related to the genus Litchi. The absence of petals and 2-5 jugate leaves shows that the Otonephlium is closely related to Litchi than to Dimocarpus contrary to the earlier report (Leenhouts 1971). But both the genera share other characters with the genus Dimocarpus, confirming it as a basal group (Leenhouts 1978).

Based on wood anatomy the endemic genus can be put under the Type II of Klaassen (1999) classification, though he has not placed Otonephelium in any of his groups. Pit diameter (5μ), vasicentric - aliform type of wood parenchyma and presence of crystals only in ray cells are the chracters which differentiate this genus from Litchi and Dimocarpus (Table 7.2). These latter two genera were positioned under the Type IVb type (Klaassen 1999), which shows the pit diameter in the range of 3-6μ and scanty parenchyma and presence of crystals in rays, woody parenchyma and fibres. Though Litchi shows confluent-aliform type of parenchyma, other characters relate this genus to Type IVb (Klaassen 1999).

Klaassen's (1999) classification based on wood anatomy puts Otonephelium in Type II and Litchi and Dimocarpus under Type IVb separating them altogether. Whereas, his cluster analysis based on wood anatomy shows all the related genera clustering together supporting the morphological tribal classification.

Pollen morphological studies reveal that the genus Otonephlium is closely related to Litchi and they together form a Litchi pollen type. The pollen type of Dimocarpus is heterogenous with more than one pollen type (Muller and Leenhouts 1976). Based on the evolutionary trend of pollen morphology in the tribe Nephelieae, van dan Berg (1978) postulated that the genus Otonephelium to be primitive than its close relative Litchi. They show small pollen, striate tectum and long colpi (Table 7.4). The Litchi pollen type is believed to have evolved from Dimocarpus type (van den Berg 1978).

In the cluster analysis, the genus Otonephelium forms a separate group and the closely related genera, viz. Dimocarpus and Litchi forming another group. The principal component analysis plot shows that all the three genera are distinct (Fig 7.4). The character loadings also show that the anatomical characters are very important in differentiating these genera (Table 7.7). Moreover, the morphological characters such as pseudostipules ,and number of stamens are also important in segregating these genera and Leenhouts (1978) found these characters are evolutionarily significant in the tribe Nephelieae.

The phenological pattern of the endemic genus coincides with the general flowering pattern of the habitat but in some localities stray flowering and fruiting were observed. The spinescent fruits and the habitat suggests that the dispersal is through water. However, no seedling were observed in the vicinity. The presence of suckers shows that they are vegetatively propagating plants.

The endemic genus Otonephelium is restricted to ever green forests of Western Ghats. They are often observed adjacent to the streams which is considered to be favourable niche for the relict species (Ahmedullah and Nayar 1986). This endemic genus is distributed in central and southern Western Ghats and is continuous along its range (Fig. 7.2).

As the plants are present in wide continuous range of area, it falls under 'Low Risk' category based on the IUCN norms. Moreover, as the habitats are well protected, there is no immediate threat to this endemic genus. But according to Ashton (1988) the loss of reproductive capacity and the vegetative propagation leads to the natural extinction of tree species.

The genus Otonephelium is restricted to the evergreen forests of southern and central Western Ghats and the distribution is continuous. The closely related genus Litchi was said to be cultivated in the central China and later it was introduced up to Malaysia (Leenhouts 1978). Dimocarpus, another closely related genus is distributed in Southeast Asia and Australia, and is represented in the study area by a single species, viz. D. longan. The characters which relate genus Dimocarpus with Otonephelium are present in D. fumatus, D. foveolatus and D. gardeneri. However, these species are not distributed along with Otonephelium. This shows that the endemic genus is taxonomically and geographically isolated and relictual in nature.

Chapter 8

BLEPHARISTEMMA Wall. ex Benth.

INTRODUCTION:

The genus Blepharistemma Wall. ex Benth. is a monotypic endemic genus described by Bentham (1858)based on Heyne's collection supplied by Wallich in 1832. This belongs to the mangrove family Rhizophoraceae. Out of 15 genera recognised in the family, only four genera with 16 species live exclusively in mangrove habitats (Tobe and Raven 1988).

Taxonomically the family Rhizophoraceae has been placed in different orders by various authors. The family was either treated under Myrtales (Takhtajan 1980; Dahlgren 1988) or Cornales (Cronquist 1968; Thorne 1968). The family is said to be closely related to Combretaceae, Elaeocarpaceae, Rubiaceae and Tiliaceae (Airy Shaw 1966) or Erythroxylaceae (Behnke 1982; 1988; Dahlgren 1988). Recent taxonomic treatments placed Rhizophoraceae under separate order Rhizophorales (Cronquist 1981; Thorne 1992). Based on molecular studies, it has been proposed to place the family under Malphigiales with Erythroxylaceae as its sister group (Schwarzbach and Ricklefs 2000), which supports earlier investigation on this family (Behnke 1982; Dahlgren 1988).

Within the family Rhizophoraceae the tribe Anisophylleae (Bentham and Hooker 1862-67), was elevated to subfamily of Rhizophoraceae (Takhtajan 1997) and later raised to a separate family Anisophylleaceae (Behnke 1982; Dahlgren 1988; Keating and Randrianasolo 1988; Tobb and Raven 1988). The relationship between these two families is well studied and some authors proposed Anisophylleaceae to be closely related to Rhizophoraceae (Van Vliet 1976; Van Vliet and Bass 1984) and some authors related this family to Rosales (Cronquist 1981; Tobe and Raven 1988; Thorne 1992). Recent molecular studies show that the family Anisophyllaceae has most affinity towards the order Cucurbitales (Schwarzbach and Ricklefs 2000).

Apart from the tribe Anisophylleae, two more tribes, viz. Rhizophoreae and Legnotidae were recognised (Bentham and Hooker 1858) in the family Rhizophoraceae. The treatment of these tribes by different authors is given in Table 8.1. The tribe Rhizophoreae was always kept as a distinct group, as it contains mangroves with distinct characters. But Schimper (1898) divided the family based on floral characters and placed the mangrove genera in two different subtribes which also included inland genera. Based on wood anatomy, Marco (1935) segregated the family into four groups. The inland genera of the family Rhizophoraceae was kept in a single tribe Gynotrocheae based on morphological, anatomical and embryological features (Geh and Keng 1974). Detailed morphological

Table 8.1: Classification of family Rhizophoraceae by different authors.

Bentham and Hooker (1865)	Schimper (1898)	Marco (1935)	Metcalfe and Chalk (1950)	Tobe and Raven (1988) Takhtajan (1997)	Juncosa and Tomlinson (1988) Schwarzbach and Ricklefs (2000)
Rhizophoreae	**Rhizophorideae**	**Group I**	**Rhizophoreae**	**Rhizophoreae**	**Rhizophoreae**
	Gynotracheae				
Rhizophora		*Rhizophora*	*Rhizophora*	*Rhizophora*	*Rhizophora*
Ceriops	**Gynotrochinae**	*Ceriops*	*Ceriops*	*Ceriops*	*Ceriops*
Kandelia		*Kandelia*	*Kandelia*	*Kandelia*	*Kandelia*
Bruguiera	*Crosostylis*	*Bruguiera*	*Bruguiera*	*Bruguiera*	*Bruguiera*
	Gyrotroches				
Legnotideae	*Ceriops*	**Group II**	**Gynotracheae**	**Gynotracheae**	**Gynotracheae**
	Kandelia				
Carallia	*Rhizophora*	*Anisophyllea*	*Anisophyllea*	*Carallia*	*Carallia*
Crossostylis		*Carallia*	*Carallia*	*Gynotroches*	*Crossostylis*
Gynotroches	**Carallinae**	*Combretocarpus*	*Combretocarpus*	*Pellacalyx*	*Gynotroches*
Pellacalyx		*Crossostylis*	*Crossostylis*		*Pellacalyx*
Haplopetalum	*Carallia*	*Gynotroches*	*Gynotroches*	**Crossostylideae**	
Pleasiantha	*Pellacalyx*				**Macarisieae**
Weihea	*Bruguiera*	**GroupIII**	**Macarisieae**	*Crossostylis*	
Macarisia					*Anopyxis*
Blepharistemma	**Macarisieae**	*Anopyxis*	*Anopyxis*	**Macarisieae**	*Macarisia*
Dactylopetalum		*Blepharistemma*	*Blepharistemma*		*Blepharistemma*
Cassipourea	*Blepharistemma*	*Cassipourea*	*Cassipourea*	**Macarisinae**	*Comiphyton*
	Cassipourea	*Macarisia*	*Macarisia*		*Dactylopetalum*
	Dactylopetalum	*Sterigmopetalum*	*Sterigmopetalum*	*Anopyxis*	*Cassipourea*
	Macarisa			*Macarisia*	*Sterigmopetalum*
	Weihea	**Group IV**		*Streigmpetalum*	
		Pellacalyx		**Cassipourinae**	
		Poga			
				Cassipourea	
				Blepharistemma	
				Comiphyton	

studies suggest that the tribe Macarisieae and Gynotrocheae are paraphyletic (Juncosa and Tomlinson 1988). On the basis of seed morphology and anatomy Tobe and Raven (1988) segregated a monogeneric tribe Crossostylideae from the tribe Gynotracheae and divided the tribe Macarisieae into two subtribes, viz. Cassipourinae and Macarisinae, based on arillate and winged seed characters respectively. Based on floral characters a new tribe Hypogyneae (illegitmate name) comprising Cassipourea and Sterigmopetalum, has been carved out of the tribe Macariseae (Steyermark and Liesner 1983). This was supported by Keating and Randrianasolo (1988) based on leaf venation pattern. The recent molecular studies support the traditional subdivision of the family into three tribes, viz. Macarisieae, Gynotrocheae and Rhizophoreae (Schwarzbach and Ricklefs 2000).

The genus Blepharistemma along with Cassipourea constantly remained in tribe Macarisieae, throughout the infrafamilial classification. Based on seed morphology and anatomy the Blepharistemma was treated under the subtribe Cassipourinae along with Cassipourea and Comiphyton (Tobe and Raven 1988). Based on phenetic analysis of pollen morphology of the family, the genus Blepharistemma has been positioned under the tribe Macariseae with connection to tribe Rhizophoreae (Vezey et al. 1988). Independent pollen morphological studies on the genus Blepharistemma shows that it is closely related to Cassipourea (Murthy 1992).

This endemic genus was earlier reported to occur from South Kanara to Travancore lowlands (Bentham and Hooker 1862-67). After nine decades it was relocated in the Kollam district of Kerala (Nair and Mohanan 1981) and subsequently reported by others(Keshavamurthy and Yoganarasimhan 1990; Sasidharan and Sivarajan 1996). It was recorded mainly in sacred groves of Kerala and Karnataka as a rare species. The closely related genus Cassipourea (including Weihea and Dactylopetalum) represented by 62 species is distributed in tropical America, South Africa, Madagascar, Srilanka and India (Mabberley 1997).

Though enormous studies were carried out in this family as well as tribe Macariseae, the biological and systematic aspects of this endemic genus was always obscure. Since this genus is geographically isolated, it is essential to ascertain the systematic position and biology.

SYSTEMATIC TREATMENT AND OBSERVATIONS:

Blepharistemma serratum (Dennst.) Suresh in Nicolson et al., Intepr. van Rheede's Hort. Malab. 214. 1988; Sasidharan & Sivarajan, Fl. Thrissur 174. 1996. Rodschiedia serrata Dennst. Schluss. 16. 24, 31. 1818. Blepharistemma corymbosum Wall. ex Benth. in J. Linn. Soc. Bot. 3: 65. 1858; Henslow in Hook. f. Fl. Brit. India 2: 441. 1878; Bourd., For. Trees of Travancore 172. 1908; Gamble, Fl.

Madras 3: 460. 1919. Blepharistemma membranifolia (Miq.) Ding Hou. Fl. Males. ser. 1, 5(4): 489. 1958; Nair & Mohanan in J. Econ. Tax. Bot. 2: 233. 1981; Ramachandran and Nair, Fl. Cannanore 175. 1988; Keshavamurthy & Yoganarasimhan, Fl. Coorg 183. 1990. Gynotroches membranifolia Miq. Anal. pt. 3. 7. 1852. Dryptopetalum membranaceum Miq. in Pl. Hohenack. 713. 1847 (nom. nud.).

Shrubs to trees, up to 10 m high, bole clear; branches 1-4 from almost a point, horizontal; bark reddish, smell of tamarind when injured. Leaves simple, opposite, stipulate; stipules interpetiolar, ca. 0.5 cm long, lanceolate, acuminate at apex, ciliate along the margins, light green, caducous; petiole up to 1 cm long, glabrous, flat on upper surface; lamina up to 17 x 7 cm, elliptic to oblong to ovate, acute and slightly unequal at base, entire or crenate along margins, acute at apex, membranous, glabrous or hairy. Infloresцense an axillary cyme, peduncules dichotomously branched; peduncle up to 1.5 cm long, glabrous. Flowers ca. 1 cm across, white, turning yellow, pedicellate; pedicel up to 0.3 cm long, glabrous. Calyx tube 0.4 cm long, pubescent without; lobes 5, triangular, acuminate at apex, green in color. Petals 5, ca. 0.6 cm long, linear, lacerated at apex with 5-8 lobes, pubescent within, lacerated lobes incurved in bud condition. Stamens 8; filaments ca. 0.4 cm long, stout, white, ciliate;

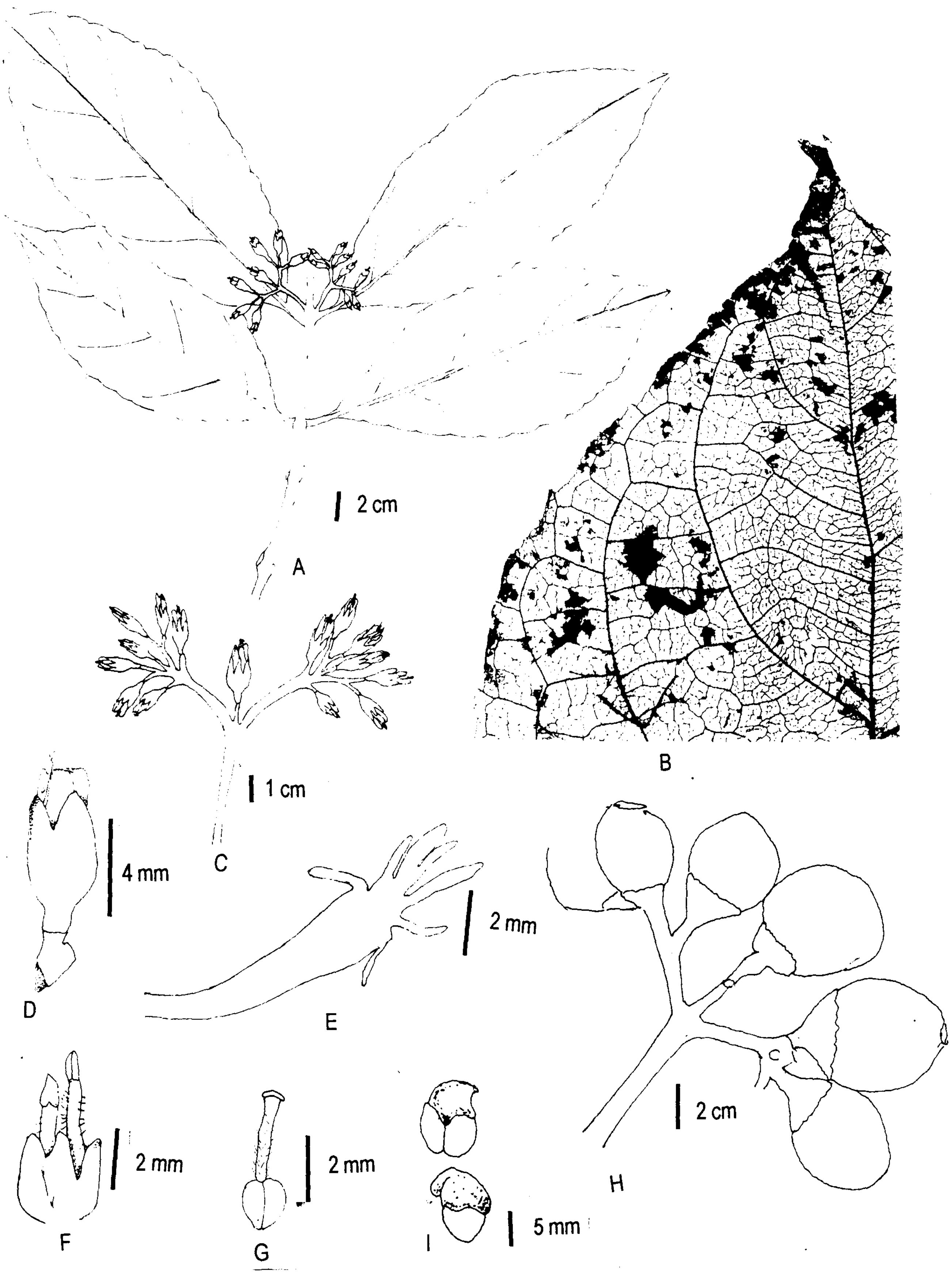


Fig 8.1: *Blepharistemma serratum* (Dennst.) Suresh. A. Flowering twig; B. leaf venation; C. Inflorescence; D. Flower bud; E. Lacerate petal; F. Stamens; G. Pistil H. Infructascence I. Arillate seeds.

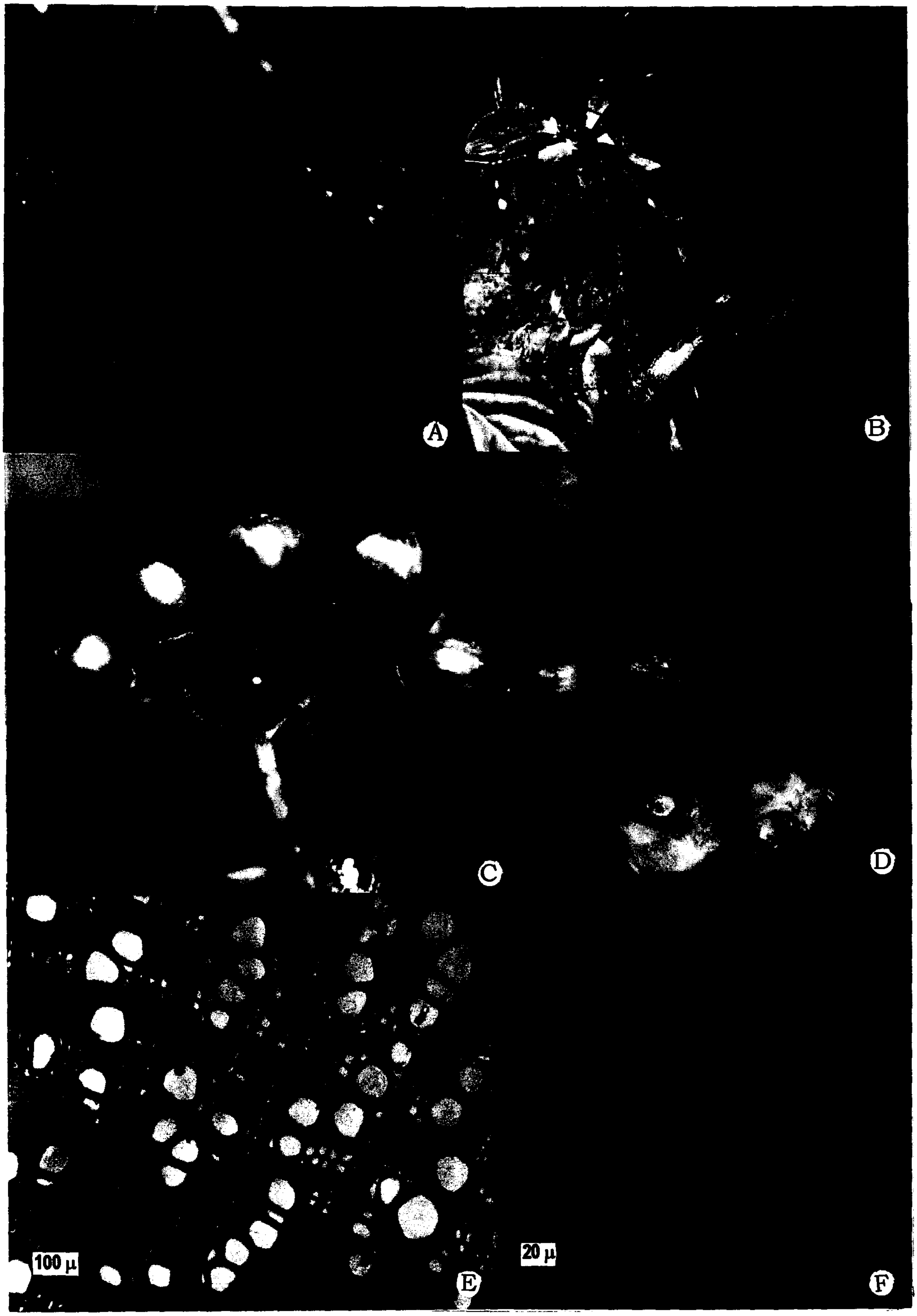


Plate 8.1: ***Blepharistemma serratum*** **A.** Flowering branch; **B.** Suckers; **C.** Fruits; **D.** Arillate seeds ; **E.** T.S. of wood; **F.** T.L.S. of wood.

anthers conical, basifixed, green. Ovary 0.3 cm in diameter, globose, reddish in color; style 0.4 cm long, with long white hairs; stigma capitate, greenish white. Fruit a capsule with persistent calyx, rounded, 3-seeded, one aborted. Seeds arillate; aril half covered, yellow (Fig. 8.1; Plate 8.1A-D).

Wood anatomy:

Diffuse porous wood. Vessels solitary, as well as clustered, 63µ (45 - 75µ) in diameter, mean member length 686µ (518- 840µ), rounded in outline, 20 vessels in mm^2, perforation simple as well as scalariform, pit 2µ in diameter, tailed, intervascular and vessel-ray pitting rounded and alternate. Wood parenchyma apotracheal, uniseriate. Rays homogenous with crystals, 2-3 cell wide, 40- 50 cells high, up to 700µ, 8 rays per mm^2. Fibres up to 1.3 mm long, thick walled, with distinct bordered pits (Plate 8.1E&F; Plate 8.2A&B).

Leaf anatomy:

Petiole:

Epidermis single layered with anticlinal cells, crystals solitary. Cortex parenchymatous, crystals solitary. Vascular bundles crescent shaped, ends incurved towards centre.

Plate 8.2: ***Blepharistemma serratum*** **A.** Perforation in vessel; **B.** Vessel pits; **C.** Stomata; **G.** Pollen. ***Cassipourea zeylanica*** **D.** T.S. of wood; **E.** T.L.S. of wood; **F.** Perforation in vessel; **H.** Stomata.

Venation:

The straight primary veins is attached to the Eucamptodromous secondaries in uniform wide-acute or acute angle. Occasional simple intersecondaries are present and forked. Tertiary veins are sinuously percurrent, often forked, forming polygonal domains with intersecondaries. Tertiary angles of origin are variable, but the tertiaries tend to be oblique to the primary vein. They originate mostly orthogonal to the secondaries but may be exmedially acute. Quarternaries and quinternaries form irregular orthogonal domains. Teeth are shallow, strongly asymmetric, and curved inward to a small concave sinus. An asymmetrical turbinate gland having a superficial columnar epidermis protrudes from the apex parallel to the margin or incurved toward the sinus. Just inside the margin, tertiary and quarternary veins branch off from the tooth vein and become part of looped marginal venation (Fig 8.1).

Lamina:

Lamina 85μ in thickness. Upper epidermis single layered 8μ in thickness with polygonal cells. Mesophyll with two palisade layers and three spongy layers of 52μ in thickness. Lower epidermis with oblique cells.

Crystals and Trichomes:

Prismatic crystals are present, concentrated along the veins. Trichomes solitary, very few along the veins.

Stomata:

Anisocytic type, guard cells are surrounded by cells distinct from epidermis, out of 3 subsidary cells one is distinctly smaller than the other two (Cruciferous unequal type) (Plate 8.2C).

Pollen morphology:

Pollen 3 - zonocolporate, prolate; equatorial axis 18µ (±1.1) and polar axis 19µ (±1.6) in length; endoaperature ca. 4µ in length, fused; exine punctate, rugulate; tectum ca. 0.27µ in thickness, columella 0.9µ x 10µ, endexine 0.07µ in thickness (Plate 8.2G).

Seed anatomy:

The seed coat 200-220µ in thickness, comprising testa with 135-142µ in thickness and tegment ca. 50µ in thickness. The exotestal forms the seed coat.

Habitat:

Found along the slopes of evergreen forests, in sacred groves of lowland evergreen forests, coconut groves, rubber plantations and disturbed coastal forests.

Pollination:

Plants observed in full bloom in the month of March. Flower nectariferous and fragrant. The flowers are visited by solitary bees, flies and other small insects. When in full bloom the trees were seen buzzing with variety of insects.

Population ecology (Fig. 8.2):

Population 1:

The population in sacred groves of Bilman, South Kanara District is represented by a single tree of 10 m high. The leaves are comparatively small, entire along margins and glabrous. Small individuals of suckers origin were noted adjacent to the tree. The associated plants in the sacred groves are *Diospyros* spp. *Knema attenuata* and *Garcinia xanthochymus* etc.

Population 2:

The population in KFRI campus, Peechi, Kerala is represented by three individuals and all of them are trees. They are found to be deciduous and shed their leaves during the months of December and January. Flowers come with the flushing of leaves in the month of March. Leaves are larger than those found in South Kanara. Interestingly flowers are observed to be caducous and fruits are never set.

Population 3:

This population is seen along the road side of Aickad grove, Koduman, Pathanamthitta (earlier part of Quilon) District of Kerala. Only five individuals could be located and all of them are shrubs of <3 m in high. Leaves show a distinct variation compared to the earlier populations. Leaves are large, with strong crenation and the abaxial

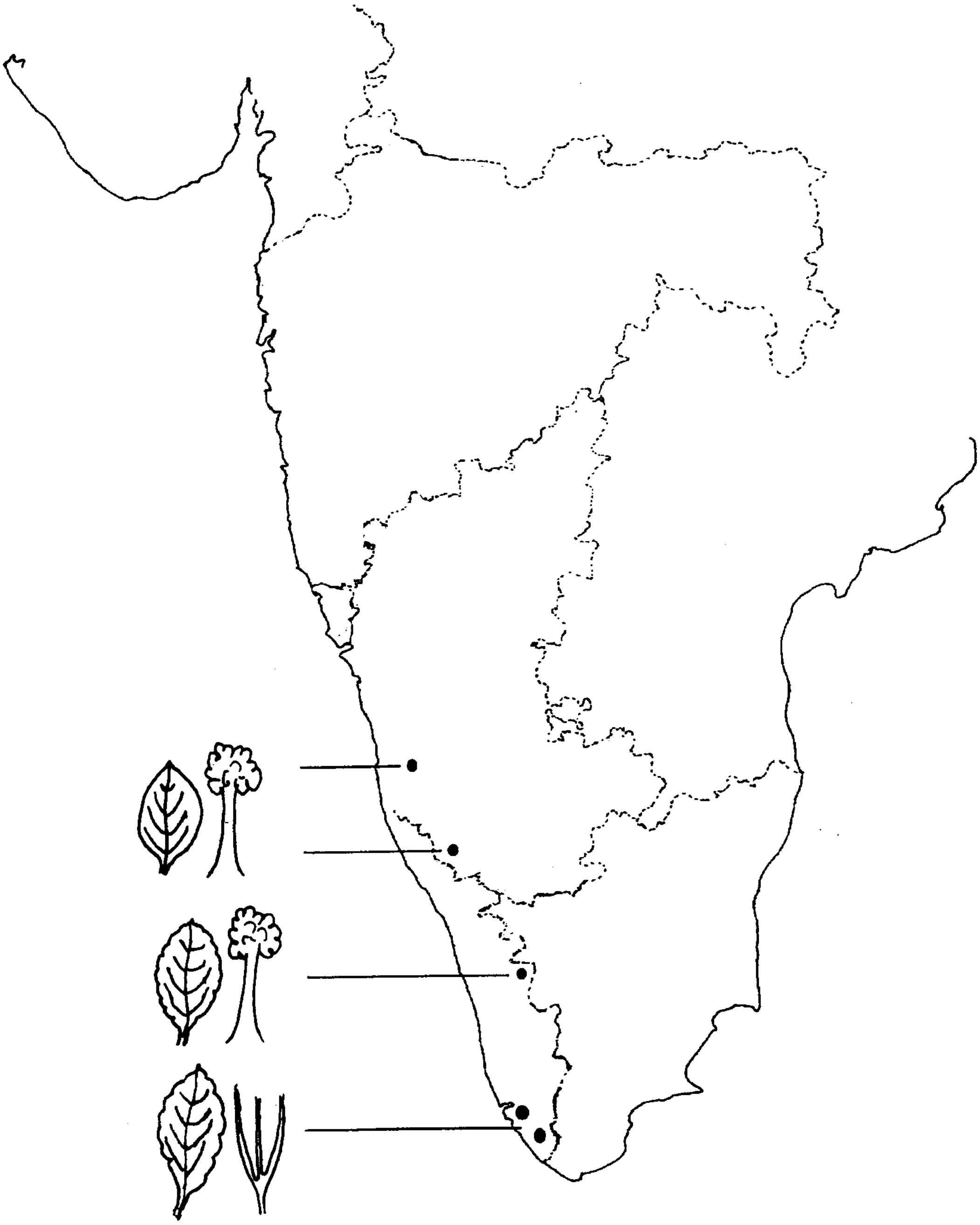


Fig.8.2 : Morphological variation in the population of Blepharistemma along Western Ghats

side of the leaves are densly puberulent. Plants are found to be propagating through suckers.

Population 4:

This population is found along the roadside cuttings on the way to Trivandrum at about 2.5 km from Kottarakara. All the individuals are shrubby, and the variations are as seen in Koduman population.

Population 5:

This population is found in Wotekolli forest in Kodagu (Coorg) District, This is the only population found at 450 -500 m altitude. The individuals are found in margins and slopes of the evergreen forests. The leaves are glabrous and their crenations are inconspicuous.

IUCN category:

Based on IUCN norms it is here categorized as Vulnerable. The following are the norms by which it qualifies the vulnerable category:

B. Area of occupance is estimted to be less than 5,000 km^2.

B1. Severely fragmented or known to exist at no more than ten locations.

B2c. Quality of habitat: threat to sacred groves and disturbed coastal forests.

D2. Population is charcterised by an acute restriction in its area of occupancy. Some population represented by single individual.

Specimens examined:

Karnataka: Karkala, Canara Dt., 17.3.1915, s.l. acc. no. 11985 (MH); Pilarkan, Bilman, South Kanara, 22.3.1997, Rajkumar s.n. (GUH); Wotekolli - Irutti, Coorg Dt., 21.3.2000, S. Rajkumar s.n. (GUH).

Kerala: Dharmadam, Telichery, Cannanore Dt., R. Suryanarayanan s.n. (MH); Travancore, s.l. acc. no.19872 (MH); Telicherry, Cannanore Dt., s.l. acc. no. 19875 (MH); Colatoopolay, 27.2.1894, T.F. Bourdillon 163(MH); Kodumon, 30.3.1978, C.N. Mohanan 116695 (MH); Punalur-Kulathupuzha, 11.8.1978, C.N. Mohanan 116699(MH); Aickad Groove, kodumon, 14.12.1979, C.N. Mohanan 116678 (MH); Nalukodi, Changanacherry, 5.3.1984, V.T. Antony 327 (MH); Ernakulam - Thowara 12.2.1986, P.C. Binay 242 (TBGT); Attayar-Thiruvananthapuram, 8608 (TBGT); KFRI campus, Peechi, 3.5.1999 S. Rajkumar s.n. (GUH); Aickad groove, Kodumon, 4.5.1999, S. Rajkumar s.n. (GUH); Kottarakara-Thiruvananthapuram, 4.5.1999, Rajkumar s.n. (GUH).

Comparative study with closely related genus:

The tribe Macariseae is represented by 6 genera. Out of these, Blepharistemma is considered closely related to Cassipourea (Schwarzach pers. comm.) and Comiphyton. Cassipourea is a widely distributed genus whereas Comiphyton is restricted to West Africa. The comparative

Table 8.2: Morphological features of Blepharistemma and Cassipourea

Characters	Blepharistemma	Cassipourea
Habit	Tree or Shrub	Tree or Shrub
Phyllotaxy	Simple, opposite, stipulate	Simple, opposite, stipulate
Lamina shape	Elliptic oblong to ovate.	Oblong
Lamina margins	Entire or crenate	Entire
Inflorescence	Axillary cyme	Axillary solitary or fasicled
Bracteole	Absent	Present,forming a cup in bud condition
Calyx	Lobes 5, valvate, pubescent	Lobes 5, valvate,
Petals	5, linear-spathulate, lacerate	5, spathulate, lacerate
Number of stamens	8	16-30
Filaments	Stout, at two levels	Slender
Anthers	Basifixed	Basifixed
Ovary & Ovule	Ovary 3 celled; 2 ovules per locule	Ovary 3 celled; 2 ovules per locule
Style	Stout, hairy at base	Filiform, long
Stigma	Capitate, shortly lobed	Shortly 2-4 lobed
Capsule	With persistent calyx	With persistent calyx
Seed	Arillate, cotyledons flat	Arillate, cotyledons flat

Table 8.3: Comparative Wood anatomical features of Blepharistemma and Cassiopourea

Characters	Blepharistemma	Cassipourea
Vessel arrangement	Solitary or clustered	Solitary or clustered
Abundance	23 per mm2	12 per mm2
Pore outline	Round	Round
Diameter	63µ (45 – 75µ)	73µ
Length	686µ (518- 840µ)	980µ
Perforation	Simple and scalariform	Simple
Pit to ray cell	Rounded, alternate	Rounded, alternate
Wood Parenchyma	Apotracheal, uniseriate	Apotracheal, uniseriate, some times diffused
Rays	Homogenous	Heterogenous
Ray length	700µ (40-50 cells)	464µ (30-34 cells)
Ray width	56µ (2-3 cells)	60µ (3-4 cells)
Abundance of rays	20 per mm2	19 per mm2
Fibre	Thick walled, 1400µ in length	Thick walled, 1260µ in length

study was made with the genus Cassipourea represented by C. zeylanica in Western Ghats.

External Morphology:

The endemic genus is closely related to Cassipourea. But the former is characterised by cymose inflorescence, ebracteolate flowers and few stout filaments arranged at two levels, whereas Cassipourea is differing by its solitary or fascicled and bracteolate flowers and slender stamens which are >16 and arranged in single level (Table 8.2).

Wood anatomy:

The perforation plate in the vessels of Blepharistemma show both scalariform as well as simple plates, whereas in Cassipourea it is simple. The wood parenchyma of Cassipourea is apotracheal, uniseriate as well as diffuse type, but in Blepharistemma it is only apotracheal uniseriate type. Ray cells show heterogenous condition in case of Cassipourea whereas it is homogenous in Blepharistemma (Table 8.3).

Leaf anatomy:

Most of the characters of leaf anatomy are common for both the genera, except that the minor veins lack sclerenchymatous tissues in the case of Blepahristemma. Stomata is anisocytic in the case of Blepharistemma and anomocytic in the case of Cassipourea (Table 8.4).

Table 8.4: Comparative leaf anatomical features of Blepharistemma and Cassipourea

Characters	Blepharistemma	Cassipourea
Leaf thickness	85μ	92μ
Epidermis	single layered,	single layered,
Lower epidermal cells	Sinuous	Polygonal
Palisade	2 layered	2-layered
Spongy	3 layered	5 layered
Crystals	present	present
Venation type	Basally eucamptodromous and distally brochidiodromous	Brochidodromous
Areole shape	Polygonal	Irregular
Trichomes	Few	absent or common
Petiole vasculature	Crescent shaped with incurved margins	Crescent shaped with incurved margins
Stomata	Anisocytic (unequal cell type)	Anomocytic

Table 8.5: Comparative Pollen morphological features of Blepharistemma and Cassipourea

Characters	Blepharistemma	Cassipourea
Pollen Type	3-zono colporate	3- zono colporate
Size		
Polar axis	18μ (±1.1)	15μ (±1.3)
Equatorial axis	19μ (±1.6)	20μ (±1.7)
P/E ratio	107	133
Aperture size	4μ	3μ
Exine pattern	Punctate and Rugulate	Punctate
Columella size	0.09μx0.10μ	0.11μx0.12μ

Table. 8.6:Comparative seed morphology and anatomical features of Blepharistemma and Cassipourea

Characters	Blepharistemma	Cassipourea
Fruit	Capsular	Capsular
Ovules per carpel	2	2
Seeds per fruit	6	4-8
Seed form	Arillate	Arillate
Thickness of integument cell layers		
outer	3-4	3-6
inner	4-5	5-8
Thickness of seed coat	0.20-0.22mm	0.16-0.22mm

Table.8.7: Geographical distribution of Blepharistemma and Cassipourea

Blepharistemma	Monotypic,Central and Southern Western Ghats
Cassipourea	Africa, India, Srilanka and South America

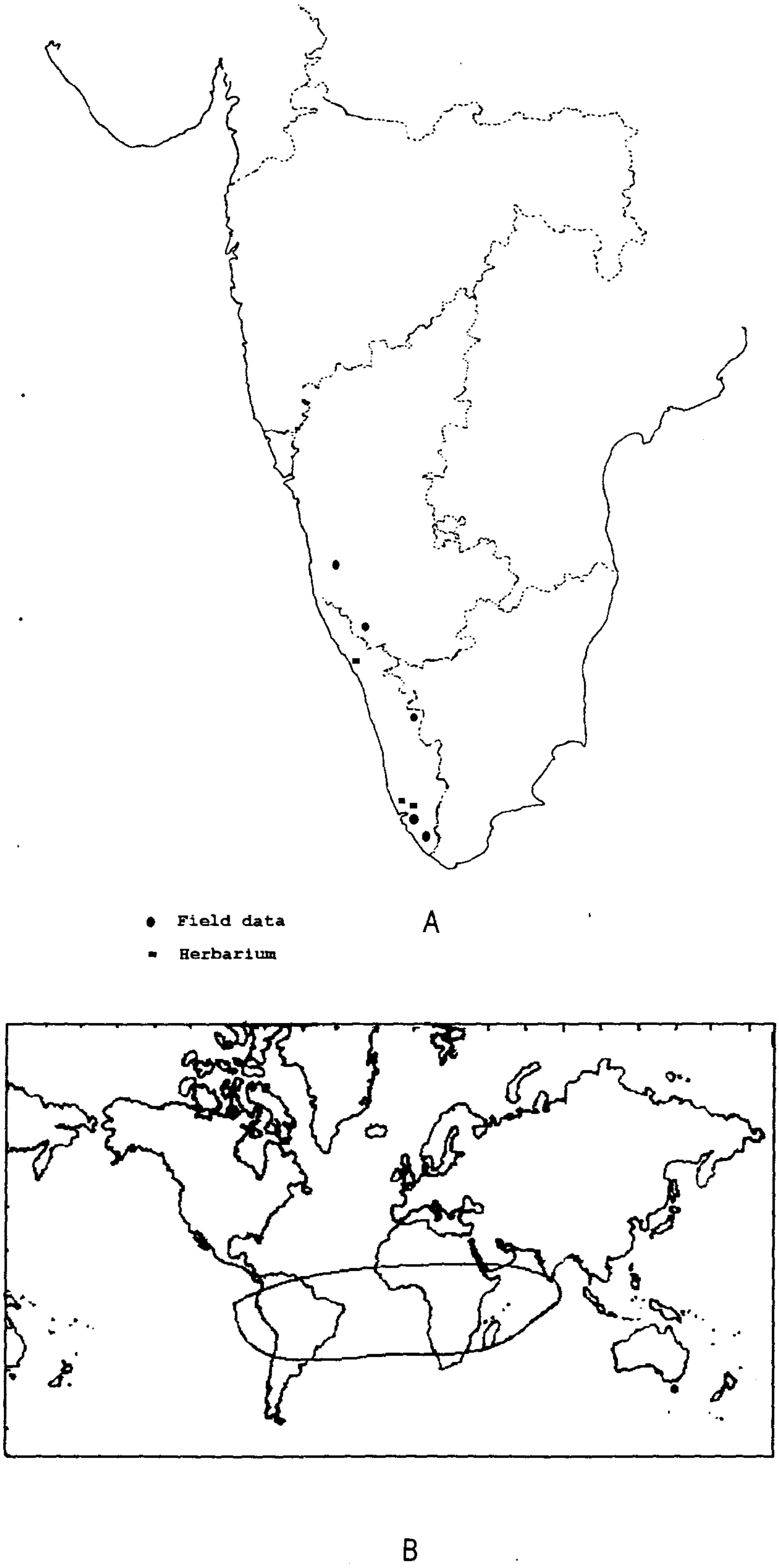


Fig. 8.3: Distribution of endemic tree genus *Blepharistemma* (A) and closely related genus *Cassipourea* (B)

Leaf Venation:

The genus Blepharistemma shows basally Eucamptodromous and distally Brochidiodromous and the closely related genus Cassipourea Brochidiodromous venation pattern. The tertiary veins are forked in Blepahristemma and obtuse in Cassipourea. Glands were observed in the shallow teeth of leaf margin in the endemic tree genera which are not present in Cassipourea. Trichome along the veins present in some populations of Blepharistemma were present, but totally absent in Cassipourea (Table 8.4).

Pollen morphology:

The exine pattern of Blepharistemma is both punctate as well as rugulate where as Cassipourea shows only punctate exine pattern. In Blepharistemma pollen mesocolpeal region shows granulations as compared to Cassipourea (Table 8.5)

DISCUSSION:

Blepharistemma is an inland monotypic endemic tree genus of Rhizophoraceae. The present study reveals that this genus is taxonomically distinct. Earlier phylogenetic studies based on floral and fruit morphology treated Cassipourea as closely related genus to Blepharistemma. These two genera come under the tribe Macariseae which is considered a distinct tribe in the family Rhizophoreaceae (Tobe and Raven 1988; Juncosa and Tomlinson 1988). The genus Cassipourea can be differentiated from Blepharistemma by its different leaf morphology and presence of bracteoles.

The floral morphological characters support the positioning of this endemic genus in the tribe Macariseae (Tobe and Raven 1988). In Macariseae the genus Blepharistemma was reported to be having polygamodioecious flowers (Juncosa and Tomlinson 1988), but in the present study it is observed that all the flowers are bisexual in nature. In Blepharistemma the ovary is superior and considered to be plesiomorphous which is shared by all genera in Macariseae except Crossostylis (Tobe and Raven 1988). Though the floral morphology of the tribe Macariseae varies very little (Juncosa and Tomlinson 1988), the endemic tree genus shows distinct differences with its closely related genus (Table 8.2). Another main character which differentiates these two genera is androecium type. It is diplostemonous type in Blepharistemma and polyandrous type in Cassipourea. This polyandrous type is considered as homoplasy by Juncosa and Tomlinson (1988) as one genus from each tribe has polyandrous type of flowers. The capsular fruit, arillate seeds and thick seed coat of Blepharistemma differentiate this genus along with Cassipourea and Comiphyton from other remaining genera of the tribe Macariseae which have winged seeds.

The morphological characters of the genus

Blepharistemma supports the infrafamilial classification by Tobe and Raven (1988) dividing the tribe Macariseae into two subtribes based on seed appendages. Both the subtribes are considered to be paraphyletic which was not clarified by the molecular studies (Schwarzbach and Ricklefs 2000). The genus Blepharistemma which shares all plesiomorphous characters with other genera in the tribe Macariseae (Tobe and Raven 1988) and considered to be advanced group in the family.

The wood anatomical characters within the family Rhizophoraceae varies widely (Marco 1935; Van Vliet 1976). Since, the ecological factors also influence the variations in wood internal morphology particularly in mangroves, it is very difficult to use wood anatomical characters for systematics of this family (Keating and Randrianasolo 1988). The wood anatomical characters of Blepharistemma are primitive in nature. The diameter and length of the vessel is small compared to the closely related genus Cassipourea. The endemic genus shows primitive characters such as simple and scalariform type of perforations and elongated vessel to ray pits (Table 8.3). However, the wood parenchyma shows apotracheal uniseriate type which is considered to be advanced.

Both brochidodromy and eucamptodromy venation pattern are closely related as intermediate forms are quite common

(Keating and Randrianasolo 1988). Based on that Blepharistemma and Cassipourea are considered to be closely related. The areoles in Blepharistemma are considered to be well developed compared to Cassipourea since they show polygonal shape(Table 8.4). The marginal teeth are well developed in some populations of Blepharistemma with the gland at the furrows. This was correlated with eucamptrodromous venation pattern and considered as an advanced character (Hickey and Wolfe 1975).

The pollen morphology of Blepharistemma and Cassipourea do not reveal much difference (Table 8.5). However, it is observed that these genera bleonging to Macariseae show pollen characters of both Rhizophoreae and Gynotracheae (Vezey et al. 1988) indicating their relationship. It is also most similar to Anisophylleaceae contradicting earlier observation by Tobe and Raven (1988).

Based on the floral characters and seed characters of Cassipourea and Comiphyton, Tobe and Raven (1988) related the family Rhizophoraceae with Celastraceae and Elaeocarpaceae which also have arillate seeds, lacerate petals and leaf venation pattern. In the present study it is found that Blepharistemma also shares the same morphological characters and is considered an ancestral character in the family Rhizophoraceae. Based on molecular studies (Schwarzbach and Ricklefs 2000) rejected this idea and considered Erythroxylaceae a close relative.

In the present study, no seedlings were observed underneath the tree and in the vicinity. Geh and Keng (1974) observed that this character is common to inland genera of Rhizophoraceae. The observation of suckers in the field and failure of seeds to germinate in labarotory condition prove that it propagates vegetatively. Ridley (1930) proposed that general trend of arillate seed dispersal is by the means of birds or ants. The same mode was attributed to the genus Blepharistemma by Tobe and Raven (1988). But the present field observations do not support the theory in relation to Blepharistemma as neither birds nor ants were seen involved in dispersal.

The distribution of this endemic genus is along the windward side of the western Ghats and lowland evergreen forests. The population analysis along the geographic range shows that there is a change from trees to shrubs, entire leaf margin to crenate margin and glabrous lamina to pubescent ones. The trees are observed in either lowland disturbed coastal forests or evergreen forest in 450- 500 m altitude. The shrubs are observed in disturbed forests or near groves. The shrubby habit is associated with crenate pubescent leaves and trees with entire, glabrous leaves (Fig. 8.2). These variations might be one of the reasons for more number of synonym for this genus as evident from Keating and Radrianasolo (1988), where he mentioned the plant with entire leaf as B. membranifolia and plant with crenate margin as B. corymbosa. The populations which are present in disturbed coastal forests show crenation pattern. It confirms Givinish's (1979) statement that deciduous leaves are toothed more frequently than evergreen leaves. As suggested by Ashton (1988), the pattern of morphological variations got fragmented with the discontinuous distribution.

The genus Blepharistemma is distributed discontinuously along the Western Ghats (Fig. 8.3). The closely related genus Cassipourea is widely distributed and only one species is present in the southern most part of the Western Ghats, that too only on leeward side. This shows that the endemic genus is isolated taxonomically and geographically and it may be considered as paleoendemic. The genus Blepharistemma is discontinuously distributed in varied habitats and fall under 'vulnerable' category according to IUCN norms. Two of the populations are found in sacred groves. According to Gadgil and Vartak (1974) these habitats are immune to human interference and is important to protect these habitats in order to conserve the rare plants.

Chapter 9

METEOROMYRTUS Gamble

INTRODUCTION:

Meteoromyrtus Gamble is a monotypic endemic tree genus belonging to the family Myrtaceae. The family Myrtaceae along with monogeneric Heteropyxidaceae and Psiloxylaceae form a Myrtacean group in the order Myrtales (Johnson and Briggs 1984). Earlier the family Heteropyxidaceae and Psiloxylaceae were treated as subfamilies of Myrtaceae (Briggs and Johnson 1979), and this was supported by Schmid (1980) based on floral anatomy.

The family Myrtaceae is divided into two subfamilies, viz. Leptospermoideae and Myrtoideae (Briggs and Johnson 1979) and later based on cladistics (Johnson and Briggs 1984) the family was divided into several groups. Andrews (1913) and Beadle (1981) treated Myrtoideae as a base group of the family but later it was contested by Johnson and Briggs (1984).

The genus Meteoromyrtus comes under the group Myrtoideae sensu stricto along with Eugenia, Austromyrtus, Fenzelia, Myrcia, Myrtella, Myrtus, Pilothecium, Psidium, Sterocaryum, Uromyrtus and Xanthomyrtus. But the genus Syzygium which was thought to be closely related to Eugenia was segregated into a separate group (Acmena group) along with Acmena (Johnson and Briggs 1984). In the group

Myrtoideae the genus Meteoromyrtus seems to belong to Eugenia alliance (Briggs and Johnson 1979). Meteoromyrtus wynadensis (=Eugenia wynadensis) was described by Beddome (1864) under the genus Eugenia, though he was' not sure about its position under the genus as evidenced by the question mark after the generic names in the protologue. Duthie (1879) also kept it as a doubtful species, as the generic relative was not found. Later, Gamble (1918) raised it to a separate genus in order to position it in his Flora. After the type collection from Devalicottah, Wyanad, Kerala, it was relocated after almost a century with a finding that the population did not set fruits (Ramachandran et al. 1983). Later, the fruit was described for the first time from the collection from Idukki District, Kerala (Pandurangan et al. 1984). Subsequently it was recorded from Shimoga District, Karnataka (Rao and Yoganarashiman 1986) and Madurai District in Tamil Nadu (Ravikumar 1993).

Since the collections were meager and the taxon is very rare, there were no taxonomic works on this genus. Earlier works were based on protologue, which does not give much information about the genus. Thus, evaluation of taxonomic position of this genus is very much essential.

SYSTEMATIC TREATMENT AND OBSERVATIONS:

Meteoromyrtus wynadensis (Bedd.) Gamble in Kew Bull. 1918: 241. 1918 & Fl. Madras 1: 343. 1967 (repr. ed.) "wynaadensis"; Ramachandran et al. in J. Bombay Nat. Hist. Soc. 79 (2): 461. 1982; Pandurangam et al in J. Econ. Tax. Bot. 5(5): 1186. 1984; Rao & Yoganarasimhan in Curr. Sci. 55(4):188. 1986. Eugenia wynadensis Bedd. in J. Sci. ser. 3(1): 47. 1864. et. Fl. Sylv. Part. 16: 115. 1872. et Ic. Pl. Ind. Or. t. 161. 1868-1874; Duthie in Hook. f. Fl. Brit. India 2: 506. 1879.

Shrubs or trees up to 12 m high, bark greyish with white patches; branches irregular, glabrous, young one rusty tomentose. Leaves simple, opposite, petiolate; petiole ca. 2 cm long, glabrous, young ones rusty tomentose; lamina up to 13 x 6 cm, oblong, acute and slightly unequal at base, entire along the margins with intramarginal venation, acuminate at apex. Flowers solitary, extra axillary, occassionally with pair of subopposite flowers, 1.2 cm across, white in color; pedicels slender, up to 1.5 cm long, rusty tomentose. Sepals 4, linear, incurved, rusty tomentose outside. Petals 4, white, membranous, ciliate at tip. Stamens numerous; filaments white; anthers greenish. Ovary inferior; ovules pendulous. Fruit up to 6 x 3.5 cm, pear shaped, fleshy when mature, greenish, glandular hairy when young, calyx and

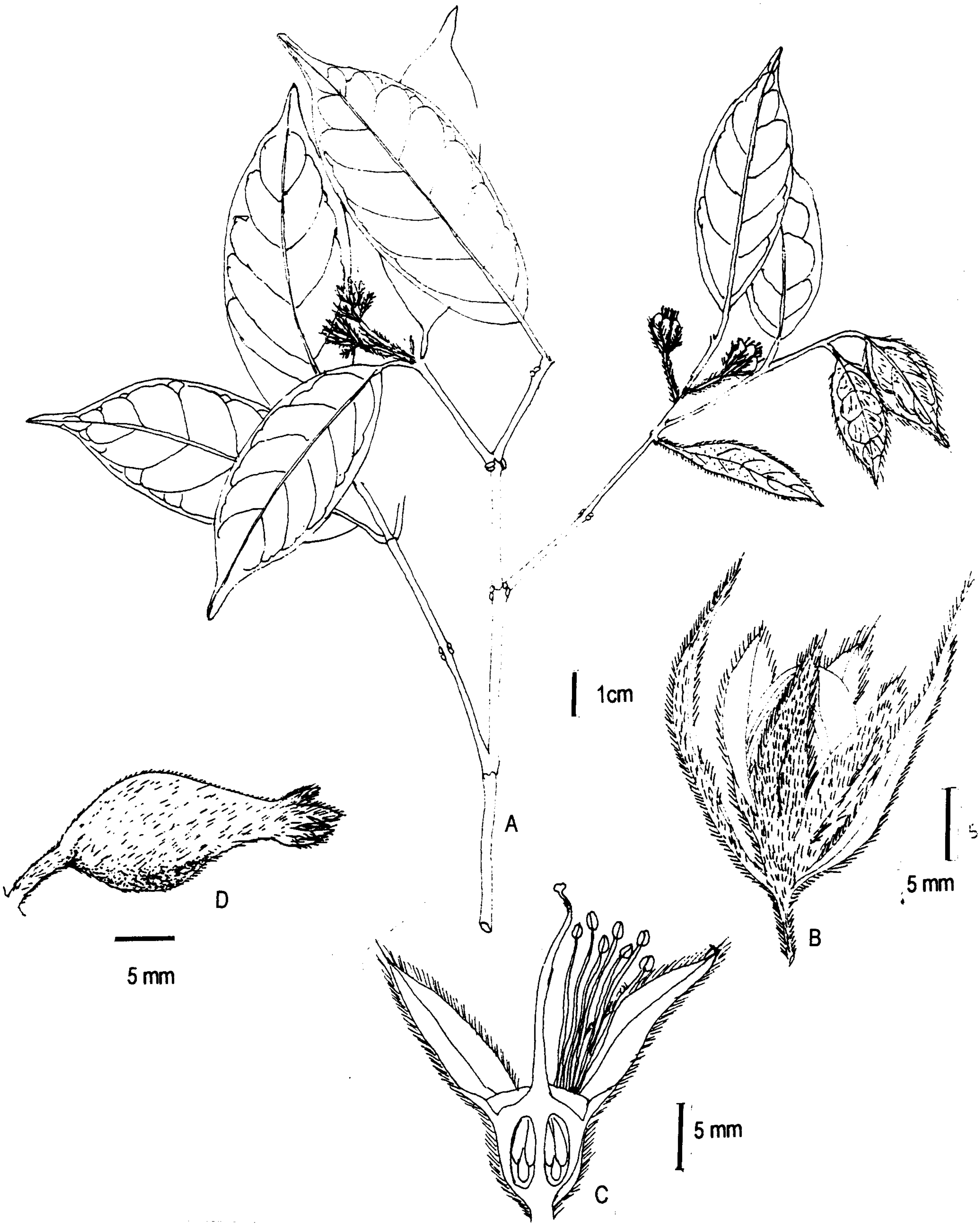


Fig. 9.1: *Meteoromyrtus wynadensis* (Bedd.) Gamble. A. Flowering twig; B. Flower; C. V.S. of Flower; D. Young fruit.

Plate 9.1: ***Meteoromyrtus wynadensis*** **A.** Flowering branch; **B.** Habitat; **C-E.** Extra axillary flowers; **F.** Young fruit; **G.** L.S. of young fruit showing pendulous ovule.

stylar base persistent. Seeds solitary, variegated when young (Fig. 9.1; Plate 9.1A-G).

Wood anatomy:

Vessels solitary, evenly distributed, 42 - 56 μ in diameter, 19 per mm^2, perforation simple, mean member length 575μ (434 - 790 μ), bordered pits sparse, alternate. Ray - vessels half bordered, pits alternate. Rays 1-2 seriate, heterogenous with rows of upright cells, average length 260 μ (455 - 156 μ), up to 15 cells high. Vasicentric tracheids present. Wood parenchyma paratracheal aliform-confluent, mostly uniseriate. Fibres thick walled, 680 - 1200μ (Plate 9.2A-D).

Leaf anatomy:

Petiole:

Epidermis single layerd with thick cuticle; cortex collenchymatous, 7-layered with oil ducts; canals 84μ in diameter. Vasculature crescent shaped.

Lamina:

Dorsiventral type, total thickness up to 189μ, upper epidermis single layered, ca. 12 μ in thickness, covered with thick cuticle of ca. 12 μ in thickness. Palisade parenchyma single layered, ca. 30 μ in thickness. Spongy mesophyll 7-layered, ca. 130 μ in thickness, lower

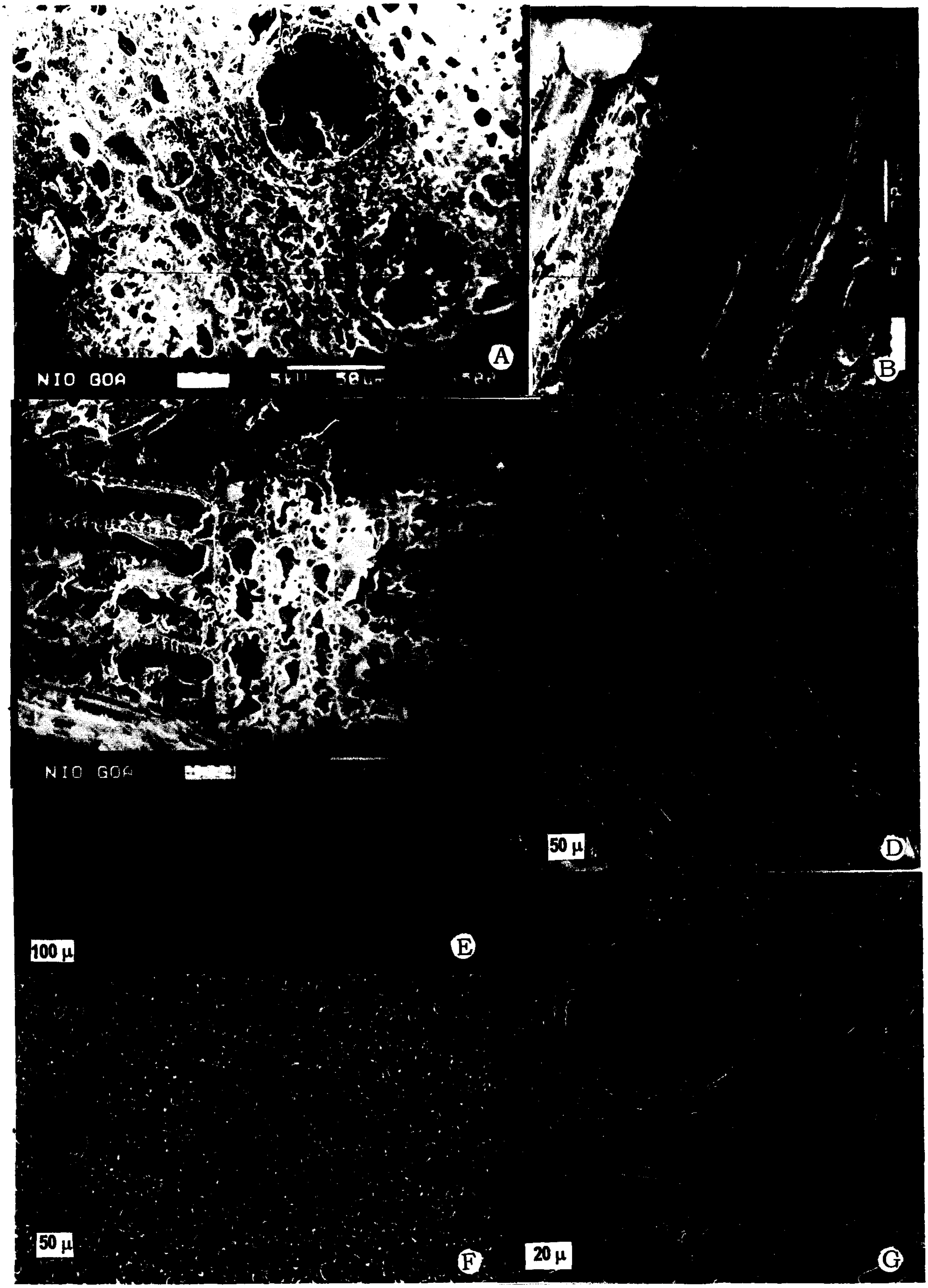


Plate 9.2 : ***Meteoromyrtus wynadensis*** **A.** SEM of T.S. of wood; **B.** Vessel pits; **C.** Vessel – ray pits; **D.** T.L.S. of wood; **E.** T.S. of leaf; **F.** Stomata; **G.** Resin ducts in leaf.

epidermis ca. 9 μ in thickness, cells horizontally expanded. Secretory canals just below the upper epidermis, ca. 66 μ in diameter, covered by single layered linear parenchyma cells. Crystalliferous cells present both in palisade as well as spongy parenchyma, either solitary or grouped (Plate 9.2E&G)

Stomata:

Anomocytic type (Ranunculaceous), Frequency 266 per mm^2 (Plate 9.2F).

Phenology and Pollination:

The flowering and fruiting were observed in the month of March and April. The flower does not produce nectar. No visitors were observed during the day time.

Habitat:

The endemic genus found growing along the streams in the evergreen forests. This tree occupies lower storey in the evergreen forest. Some individuals are found growing amidst bolders along the small streams.

Ecology:

Seedlings and saplings were observed close to the tree in the habitat. Saplings to the height of 2m were observed in the population. The endemic genus is associated with Otonephelium stipulaceum, Syzygium spp. and Diospyros spp.

Specimens examined:

Tamil Nadu: Sengaltheri - Naterikal, Vajravelu 77702 (MH); Estate in Pachakamatchi hills, Madurai, Highway Mountains, Madurai, s.d., K. Ravikumar 3095 (MH).

Kerala: On way to Theerthundimalai, Chandanathode, Cannanore Dt., 4.2.1979, V.S. Ramachandran 61362 (MH); Theerthundimalai, Cannanore Dt., 20.3.1980, V.S. Ramachandran 66834 (MH); Meenmutty - Kulamavu, Idukki Dt., 25.2.1984, A.G. Pandurangan, 78084 (MH); Kulamavu, Idukki Dt., 28.2.1984, A.G. Pandurangan 80750 (MH); Meenmutty, Idukki Dt., 26.4. 1989, C.N. Mohanan 81622 (MH); Kulamavu, Idukki Dt., C.N. Mohanan, 79944 (MH); Kulamavu, 10.10.1987, C.N. Mohanan 74535 (MH); Theerthundimalai, Chandanthode, Wyanad Dt., 15.3. 1999, S. Rajkumar s.n. (GUH); Chandanathode, Wyanad Dt., 19.3.2000, S. Rajkumar s.n. (GUH).

Comparative study with closely related genera:

Morphology:

The genus differs from other closely related genera by its extra axillary flowers and pendulous ovules, and it is resembling Syzygium in its calyx lobes producing beyond ovary and absence of staminal disc (Table 9.1).

Wood anatomy:

The genus Meteromyrtus resembles Eugenia as well as Syzygium in its wood anatomical details. Solitary vessels

Table 9.1. Comparative exomorphological characters of Meteoromyrtus and closely related genera

Characters	Meteoromyrtus	Eugenia	Syzygium
Habit	Trees or Shrubs	Trees or Shrubs	Trees or Shrubs
Leaves	Opposite, entire, gland dotted	Opposite, entire, gland dotted	Opposite or alternate, gland dotted
Flowers	Solitary or paired; extra axillary	Solitary, fasicle or short cyme; axillary or terminal	Terminal, axillary or lateral cyme, usually corymbose
Calyx	Tube short, lobes 4, linear incurved, tomentose	Tube globose, lobes not produced beyond ovary	Tube turbinate or funnel shaped, 4-5 lobed, lobes produced beyond ovary
Staminal disk	Absent	Present	Absent
Ovary	Globose, 2- celled	Globose, 2- celled with false placentation	Globose, 2- celled with false placentation
Ovule	4, pendulous	Numerous, axile	Numeorus, axile
Fruit	Berry, glandular hairy when young, crowned by persistant calyx	Globose berry, crowned by calyx	Globose berry crowned by calyx
Seed	Single, variegated when young	1-2 large	1-2

Table 9. 2: Comparative wood anatomical characters of Meteoromyrtus and closely related genera.

Characters	Meteoromyrtus	Eugenia	Syzygium
Porosity	Diffuse, solitary	Diffuse, solitary	Diffuse, solitary or grouped
Vessesls			
diameter	42-56μ	75-90μ	100-200μ
length	437-790μ	440-720μ	650-1090μ
frequency	19per mm^2		20per mm^2
pore	Vestured, 7μ	Vestured, 5μ	Vestured, 8-12μ
perforation	Simple	Simple	Simple
Rays			
Type	1-2 seriate	1-3 seriate	1-5 seriate
Height	heterogenous up to 15 cells	heterogenous up to 20 cells	heterogenous 20-50 cells
Parenchyma	Paratracheal, vasicentric – aliform, uniseriate	apotracheal	paratracheal, vasicentric – aliform
Fibres	Thick walled with numerous bordered pits, 680 -1200μ long	Thick walled with numerous bordered pits, 680 -1200μ long	Thick walled with numerous bordered pits, 800-1270μ long
Vasicentric trachieds	Present	Present	Absent
Crystals in rays & parenchyma	Present	Present	Present

Table 9.3. Geographical distribution of Meteoromyrtus and closely related genera

Genus	Distribution
Meteoromyrtus	Southern and central Western Ghats
Eugenia	South America, South east Asia and Australia
Syzygium	South east Asia, Australia, South Africa and South America

Fig. 9.3 :Dendrogram using Centroid Method rescaled Distance Cluster Combine

```
            0         5        10        15        20        25
            +---------+---------+---------+---------+---------+

EUGENIA         -+-----------------------------------------------+
MATEOROMYRTUS   -+                                               I
SYZYGIUM        -------------------------------------------------+
```

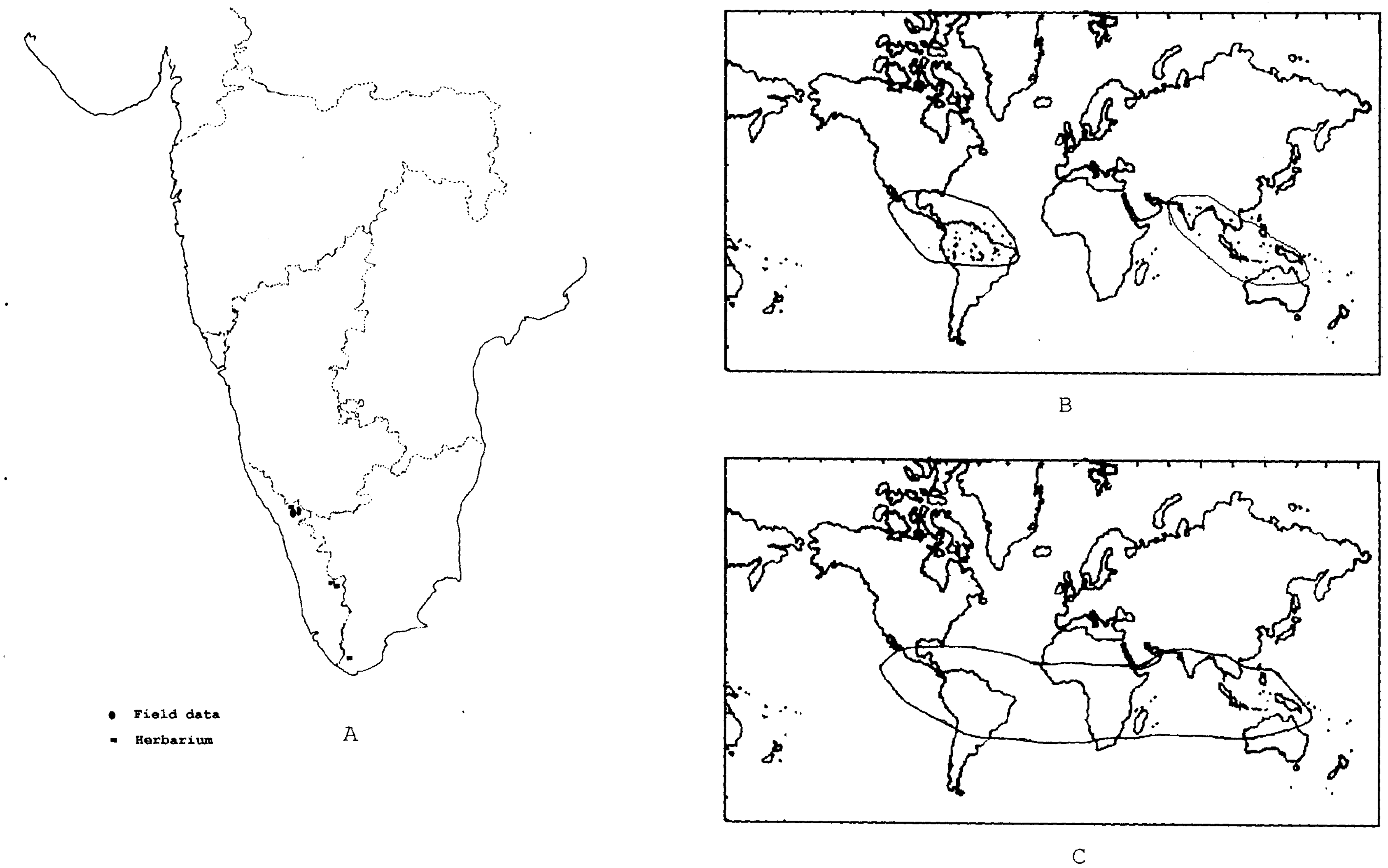


Fig.9.2: Distribution of endemic tree genus (A. *Meteoromyrtus*) and closely related genera (B. *Eugenia* and C. *Syzygium*)

and presence of vasicentric trachieds are similar to that of Eugenia and paratracheal aliform parenchyma resembles that of Syzygium (Table 9.2).

Phytogeography:

The endemic genus is discontinuously distributed in southern and central Western Ghats. The closely related genus Eugenia is concentrated in South America and also distributed in Africa, Southeast Asia and Australia. The other closely related genus Syzygium is distributed mainly in Southeast Asia and Australia and also represented in South Africa and South America (Fig. 9.2; Table 9.3).

IUCN category:

Based on IUCN norms it is here categorized as 'endangered' (EN). The following are the norms by which it qualifies the vulnerable category

B1. Severly fragmented known to exist only in two populaitons.

B2c. Area of occupancy is very less

B2d. Quality of habitat: near submergible area and near cardamom estate which is prone for destructions.

DISCUSSION:

Meteoromyrtus Gamble is a monotypic endemic genus of the subfamily Myrtoideae s. str. of Myrtaceae (Briggs and Johnson 1979). However, they recognised this genus with particular doubt. Earlier it was treated under Eugenia alliance of the subfamily Myrtoideae s. l. The present study reveals that the endemic genus stands as a distinct genus and it is closely related to Eugenia.

The pendulous ovule is a unique character, which differentiates Meteoromyrtus from the closely related genera. Based on the pendulous ovule the genus derived its name (Briggs and Johnson 1979). As they have not seen the fruit the affinity was 'uncertain' to them. This endemic genus is similar to Eugenia in its infloresense type which is axillary, solitary or paired and to Syzygium in its calyx lobes which are produced beyond the ovary and in absence of staminal disc (Table 9.1). The pendulous ovule is also present in Pimenta, which comes under Myrtus alliance, differs in number of other morphological characters from Meteoromyrtus, to which Kausel (1957) referred this genus. The dendrogram based on cluster analysis shows that the genus Meteoromyrtus is closely related to Eugenia compared to Syzygium. The genus Syzygium forms a separate cluster and Eugenia and Meteoromyrtus cluster together (Fig. 9.3).

The extra axillary, solitary (or paired) flowers and opposite leaves suggest that the genus Meteoromyrtus is primitive as the characters resemble that of the hypothetical primitive genus Protomyrtacea (Johnson and Briggs 1984). The monad type infloresense is related to

Eugenia where Monad and Triad types are represented. But in Syzygium, the inflorescence is from Monad to Panicle. In the present study it is observed that Meteoromyrtus has more or less uniform ring of stamens even in the primordial condition which is not common but a primitive character in Myrtoideae s. str.

Syzygium is considered another closely related genus of Meteoromyrtus (Schmid pers. comm.) but the inflorescence type and androecium characters do not show any affinity to Syzygium. This supports the earlier argument against Schmid (1972) on Syzygium-Eugenia relationship by Tobe and Raven (1983) using embryological characters. Johnson and Briggs (1984) using cladistic analysis have shown that the Syzygium is closely related to Kjellbergiodendron which comes under Acmena alliance than Myrtoideae group where Eugenia alliance belongs. They doubtfully included Meteoromyrtus under Eugenia alliance due to paucity of material.

Wood anatomically, the genus Meteoromyrtus is related to Eugenia by the solitary vessels, presence of vasicentric tracheids and distinct bordered pits in fibres. The character which differentiates Eugenia from endemic genus is the presence of apotracheal parenchyma which also differentiates Eugenia from Syzygium (Table 9.2). This character affinity between Syzygium and Meterormyrtus shows that the taxonomic position of *Meteoromyrtus* in *Eugenia* alliance is questionable, as the *Eugenia* s.l. was divided into *Engenia* A(*Eugenia*) and *Eugenia* B(*Syzygium*) based on wood anatomy (Ingle and Dadswell 1953). The genus *Meteoromyrtus* shows phylogenetically primitive characters such as solitary vessels, paratracheal wood parenchyma and long heterogenous rays which support the relictual nature of this endemic genus.

Leaf anatomically the endemic genus shows relationship with *Eugenia*. The characters which are shared by *Eugenia* and endemic genus are anomocytic stomata, presence of oil canals and crystalliferous cells. Petiole vasculature of both the genera is crescent shaped. Though the genus *Eugenia* share characters with the endemic genus, other stomatal types (Anisocytic, Paracytic) and petiole vasculature (U-shaped, shallow arc) are also common to *Syzygium* group (Table 9.3), but the combination of characters keep *Eugenia* and *Meteoromyrtus* separately from *Syzygium*.

Since the endemic genus has white flowers and do not produce nectar during daytime it may be considered as self pollinated or nocturnally pollinated plant. For the first time fruiting was observed in Wyanad populations, as earlier they were reported to be sterile by Ramachandran et al. (1983). The success rate of the endemic genus may be considered high as the seedlings and saplings were abundant in the surrounding areas. This endemic genus is restricted to evergreen forests mostly along the streams and rocky slopes and shows that it is niche specific.

The description of specimen reported from Kigga forest, Sringeri of Shimoga Dt., of Karnataka (Rao and Yoganarasimhan 1986) does not match as their description mentions about whorled leaves and flowers in cymes which is not the case with Meteoromyrtus.

Since there was no collection available prior to 1983, it was included in the rare and threatened plants of southern India (Henry et al. 1979). After the relocation (Ramachandran et al. 1983), the Red data book on Indian plants considered this genus under 'Endangered' category (Ahmedullah 1990). This genus is considered a narrow endemic as it is distributed in only four small populations. The isolated populations are restricted to Central and Southern Western Ghats. The population in the Highwavy Mountain of Madurai Dt. of Tamil Nadu is distributed near the cardamom estate (Ravikumar 1993). The other two populations are in evergreen forests of Wyanad and submergible area in Kulamavu of Idukki district of Kerala. Since the genus is habitat specific, the populations are very far from each other and the habitats are prone to destruction it is considered here under "endangered" category based on IUCN norms.

The closely related genus *Eugenia* is concentrated in South America, especially new World tropics. It is represented in the old World tropics in south east asia and Australia. In view of the occurrence of several main lines and several endemic myrtoid genera in Australia, Johnson and Briggs (1984) suggested the early diversification of family Myrtaceae is east Gondwana region. The presence of *Meteoromyrtus* in peninsular Indian part of Gondwana land shows its primitiveness and early evolution. In Western Ghats there are number of *Eugenia* species and seven of them are endemic (Nayar 1996). Except these three genera (*Meteoromyrtus*, *Eugenia* and *Syzygium*) no other genus of family Myrtaceae is represented in the Western Ghats. Hence, the endemic genus is considered here as a relict.

Chapter 10

PSEUDOGLOCHIDION Gamble

INTRODUCTION:

Pseudoglochidion Gamble is a monotypic endemic tree genus and belongs to the family Euphorbiaceae. The family Euphorbiaceae consists of 300 genera and 7,000 species (Webster 1967) and has undergone lot of infrafamilial classification by several authors based on morphology (Bailon 1858; Bentham 1880; Hutchinson (1969). Based on anatomy, Metcalfe and Chalk (1950) classified the family in to two subfamilies, viz. Phyllanthoideae and Crotonoideae. The phylogenetic relationship of Euphorbiaceae has always been controversial. Cronquist (1981) suggested a close relationship with Celastrales based on ovary character and presence of nectary disc. Webster (1967) suggested that the family Euphorbiaceae evolved from rosalean plexus and considered Geraniales as close relatives. Takhtajan (1980) and Thorne (1976) considered Violales and Malvales as close relatives particularly the primitive families such as Flacourtiaceae and Sterculiaceae. Airy Shaw (1965; 1973) and Hutchinson (1969) considered Euphorbiaceae as polyphyletic.

The endemic genus Pseudoglochidion comes under Phyllanthoideae subfamily. The subfamily Phyllanthoideae is considered primitive as many of its members have petaliferous flowers (Levin 1986). Based on Wood anatomy the subfamily is divided into i) Aporusa type and ii) Glochidion type (Metcalfe and Chalk 1950).

The endemic genus, showing intermediate characters between Glochidion and Phyllanthus was first described by Gamble (1925). Recently, Webster (1994) treated Pseudoglochidion as congeneric to Phyllanthus.

According to Ahmedullah and Nayar (1990) there were no collections available in the herbaria other than type collection. Hence, it is very essential to assess the taxonomy of this plant as well as the status of the plant in the wild.

SYSTEMATIC TREATMENT AND OBSERVATIONS:

In the present study, after the critical evaluation of external and internal morphology the endemic genus Pseudogochidion is considered congeneric to Phyllanthus following Webster (1994).

Phyllanthus anamalayanus (Gamb.) Webster in J. Arn. Arbor. 81: 45. 1994. Pseudoglochidion anamalayanum Gamble in Kew Bull. 1925: 329-330. 1925 et in Fl. Madras 2(7): 1285. 1925; Chandrabose in Henry et al. Fl. Tamil Nadu 3: 239. 1987.

A small tree or erect shrub up to 10 m in high; branches slender, irregular. Leaves 4-9 x 1.5-3 cm, lanceolate, chartaceous, biseriate, attenuate at base, acute at apex, glabrous above, glaucous beneath, primary lateral nerves regular on both sides, 8-12; stipule minute, subulate, caducous; petiole short, nearly 3 mm long. Flowers axillary, few flowered clusters, cream coloured. Male flower: pedicel filiform, ca. 5 mm long. Calyx lobes 6, ovate-lanceolate, erect, 2- 3 mm long. Disc glandular, 6, conspicuous, apex fimbriate. Stamens 3, erect; anthers lanceolate, apiculate, extrorse, longitudinal dehiscence. Female flower: flowers small. Calyx lobes 6, 1-2 mm long. Disc annular, toothed. Ovary 3 locular, ovules 2 in each locule, style cylindrical; stigma 6-toothed, united. Capsules 3-4 lobed, 7-8mm in diameter, globose, glabrous, depressed apex. Seeds dorsally curved, 3-4 mm, dotted (Plate 10.1 A-C).

Wood anatomy:

Wood diffuse porous, vessels grouped, 3-4 together, 40-60μ in tangential diameter, mean member length 346-415μ, perforation simple as well as scalariform; vessel to ray pitting simple, large, elongated, vessel to vessel simple as well as bordered pits. Rays heterogenous, 1-3 seriate, 1485 - 1834μ long, crystals present, mostly upright cells. Parenchyma absent. Fibres up to 980μ, septate, bordered pits on radial walls(Plate 10.1 D-F).

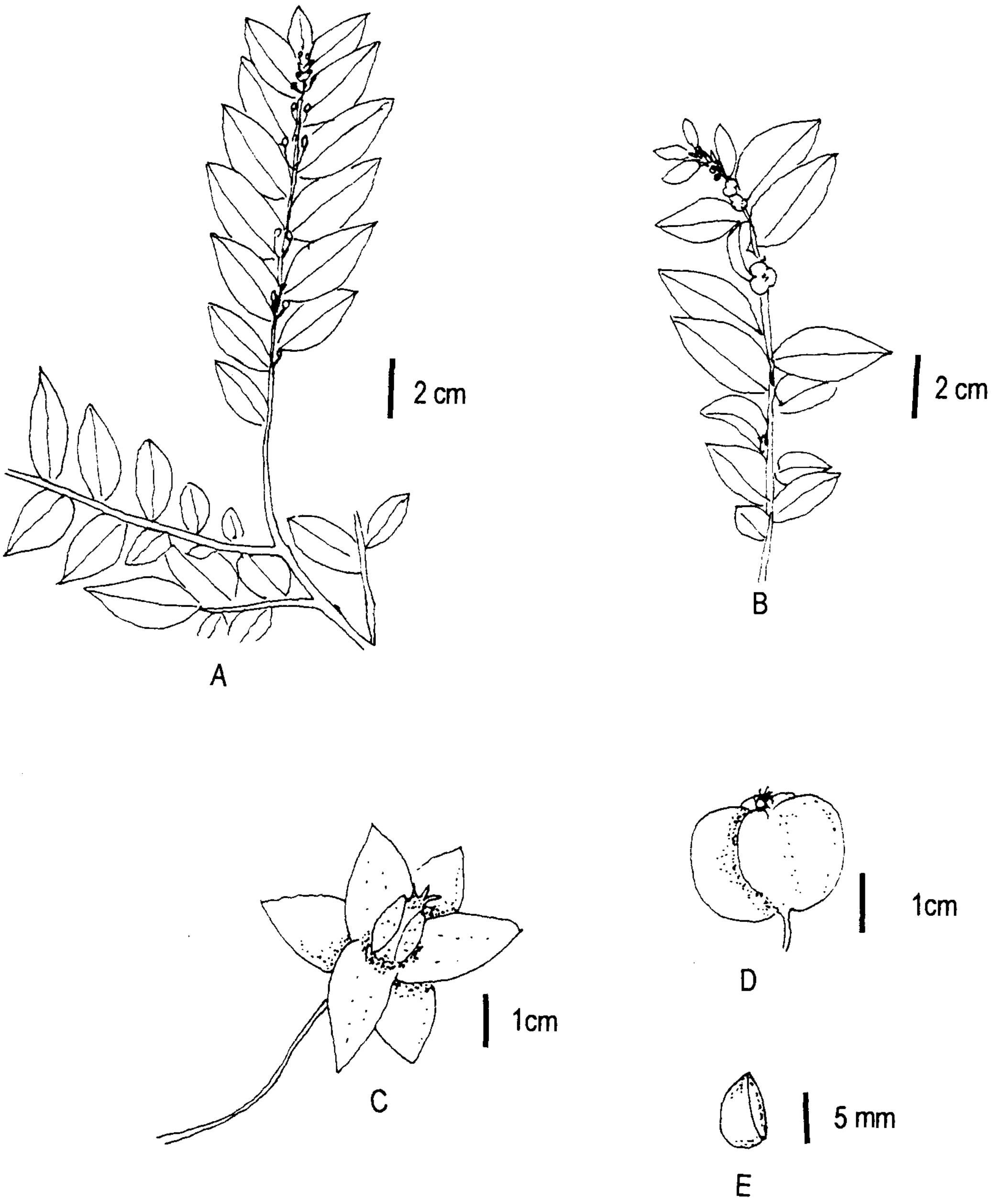


Fig. 10.1: *Phyllanthus anamalyanus* (Gamb.) Webster (=*Pseudoglochidion anamalayanum*). A. Twig with male flowers; B. Twig with female flowers; C. Male flower; D. Fruit; E. Seed.

Plate 10.1: ***Phyllanthus anamalayanus* (=*Pseudoglochidion anamalayanum*)** **A.** Habit; **B.** Flowering branch; **C.** Branches with flowers and fruits; **D.** SEM T.L.S. of wood; **E.** SEM of T.S. of wood; **F.** Pits of vessels.

Ecology:

Found in evergreen forests at an altitude of 1400m. It is associated with *Artocarpus* sp., *Ficus* sp., *Clerodendon* sp., and *Erycibe* sp. Flowering and fruiting were observed in the month of May. Seedlings and saplings were observed around the trees along the slopes. This endemic species is distributed only in the Anamalai hills of Coimbatore District, Tamil Nadu and is locally abundant.

IUCN category:

Based on the following IUCN norms it is considered under 'Endangered'(EN)category.

B. Extent of occurrence estimated to be less than 5000km^2 or area of ocupancy estimated to be less than 500km^s

B1. Known to exit at no more than five locations.

B2. Quality of habitat: surrounded by tea estate and near submergible area.

Specimens examined:

Tamil Nadu:

Iyerpadi, Anamalais, Coimbatore Dt., 19.4.1903, C.A. Barber 5417 (MH); Gynoon, Anamllays, Coimbatore, s.d. R.H. Beddome, Acc. no. 47570(MH); Kavarakal, Anamalais, 24.1.1963, J. Joseph 15600(MH); Forest near Iyerpadi, Coimbatore, 20.4.1963, J. Joseph 16231(MH); Sholaiyar submergible area, 25.12.1963, J. Joseph 35170(MH); Kavarakal-Attakatti, 22.7.1978, Chandrabose 57244(MH); Lower Nisar, Italiar forest, 6.9.1983, s.l. 78408(MH);

Iyerpadi- Kavarakal, 37th hairpin bend, 6.5.1999, S.Rajkumar s.n. (GUH).

Comparative study with closely related genera:

According to Gamble (1925) this genus is intermediate between *Glochidion* and *Phyllanthus*. Comparative studies were carried out between endemic tree genus and closely related genera.

Morphology:

Lobed disc in male flowers and annular disc in female flowers relate *Pseudoglochidion* to *Phyllanthus* and differentiate it from the other closely related genus *Glochidion*.

Wood anatomy:

The endemic genus *Pseudoglochidion* shows similarity to *Phyllanthus* in a number of wood anatomical characters. They differ from other closely related genus *Glochidion* by their 1-3 seriate rays, large vessel-ray pore, smaller vessel diameter, whereas in *Glochidion* the rays are 3-4 seriate, minute vessel-ray pore and moderate vessel diameter.

DISCUSSION:

The present study shows no distinct exomorphological differences between the endemic genus and *Phyllanthus*. Synandrium was considered distinct character for the endemic tree genus (Gamble 1925), but it is also observed to be characteristic of *Phyllanthus* (Webster 1956). The

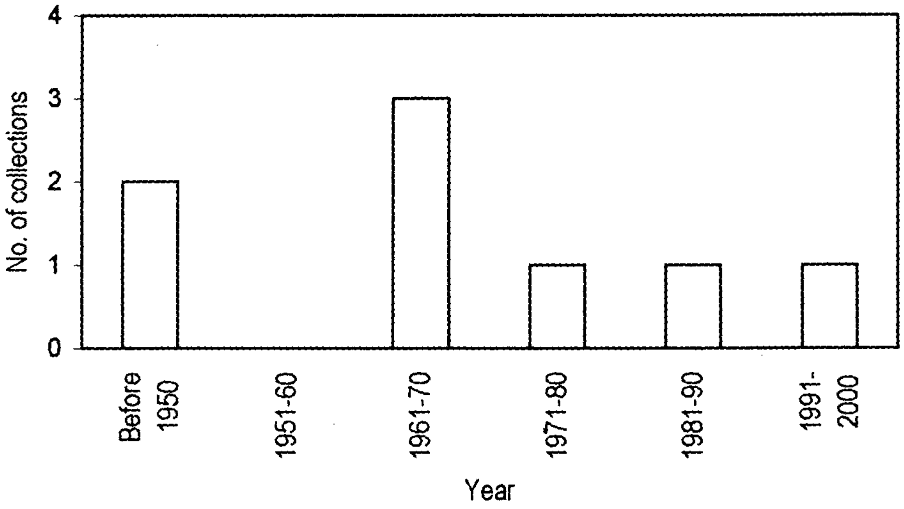
Table 10.1: Morphological features of endemic tree genus and closely related genera

Characters	Pseudoglochidion	Phyllanthus	Glochidion
Habit	Shrubs or Trees	Herbs, Shrubs or Trees	Trees
Leaf venation	Lateral nerves 8-12	Lateral nerves few	Lateral nerves 7-8
Stipule	Minute, caducous	Narrow or absent	Narrow
Flower	Few flowered axillary clusters	solitary or axillary clusters	Axillary clusters
Sepals	6, biseriate	4-6, biseriate	6, biseriate
Male disc	6, conspicuous	4-6, conspicuous or absent,	Absent
Female disc	Annular	Annular	Absent
stamen	3, filaments united	3-5, filaments free to connate	3-8, filaments free.
ovary	3 locular, 2 ovules per locule	3-locular, 2 ovules per locule	3-15 celled, 2 ovules per locule
Style & Stigma	Slender, style 3-lobed, stigma 6	Slender, style 3-lobed, stigma 6	Style connate, lobed
Fruit	Capsular, 3-4 lobed, globose	Capsule, berry or a drupe.	Capsule, 3 cocci, globose or depressed
Seed	3- gonous, rounded on dorsal side, pitted	3-gonous, crustaceous or fleshy cotyledonous	3-gonous, laterally compressed

Table10. 2: Wood anatomical characters of endemic tree genus and closely related genera.

Characters	Pseudoglochidion	Phyllanthus	Glochidion
Porosity	Diffuse	Diffuse	Diffuse
Vessels Diameter Length Pore	Grouped 40-60μ 346-415μ Simple, elongated, 10μ	Grouped 50μ 670μ Simple. elongated, 8μ	Grouped 100-200μ 840μ Simple, 4μ
Rays Length Width	Heterogenous 1485-1834μ 1-3 cells	Heterogenous 1400μ 1-3 cells	Heterogenous 1280μ 4-11cells
Parenchyma	Absent	Absent	Absent
Fibres	Septate, 980μ	Septate, 1040μ	Septate, 1020μ

Fig. 10. 3: Collections of Phyllanthus anamalayanus (=Pseudoglochidion anamalayanum in regional herbaria of



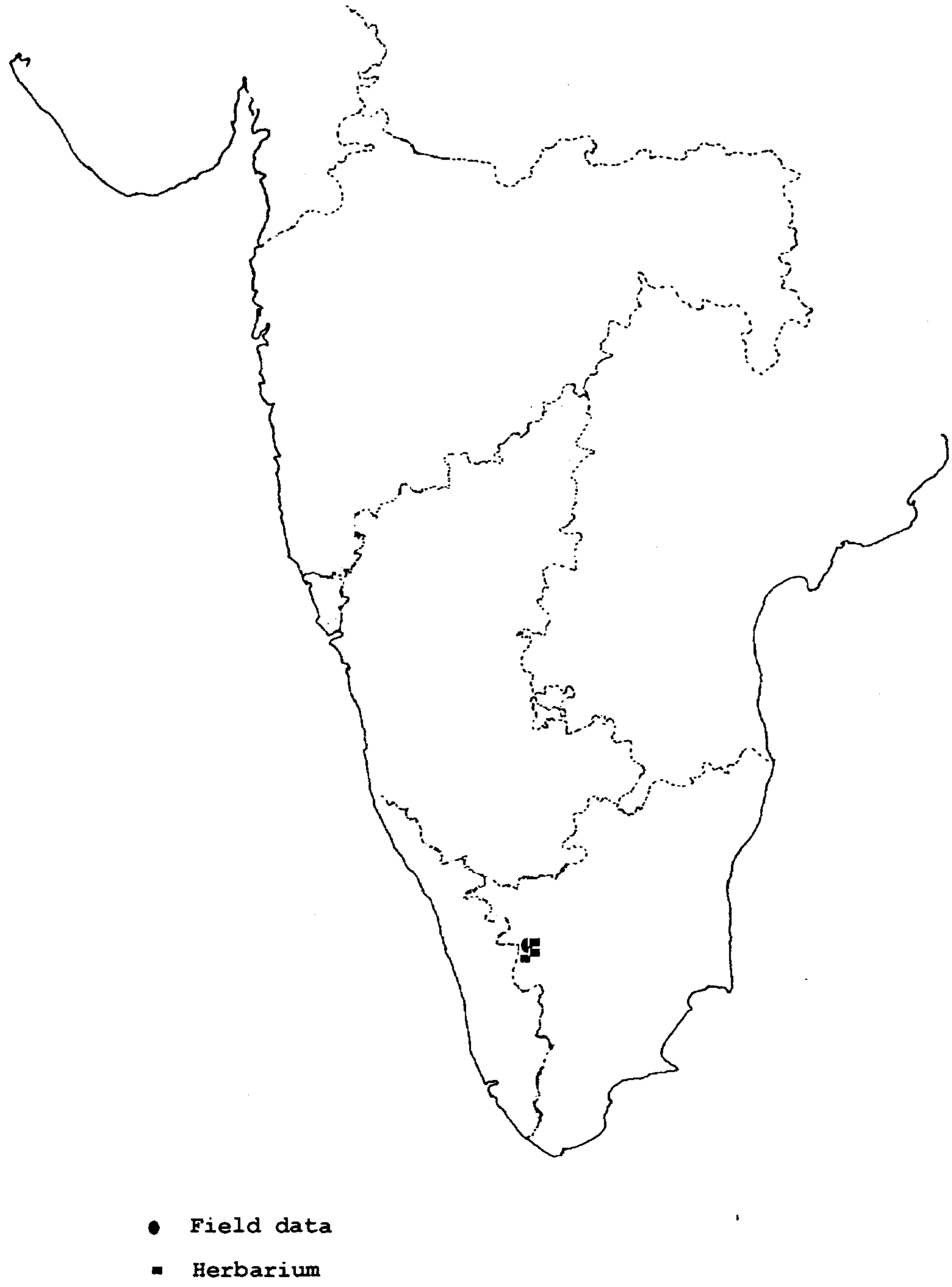


Fig.10.2:Distribution of *Phyllanthus anamalayanus* (=*Pseudoglochidion anamalayanum*) along the Western Ghats.

glandular disc in the male flowers is the character which differentiates it from the genus *Glochidion* wherein the disc is absent. The genus *Phyllanthus* shows the disc in both male and female flowers where male discs are lobed and female ones are annular (Webster 1956) which is similar to that of *Pseudoglochidion*.

The endemic tree genus and closely related genera (*Phyllanthus* and *Glochidion*) are sharing wood anatomical characters such as absence of parenchyma and septate fibres as they all belong to the *Glochidion* type (Metcalfe and Chalk 1950). The characters common to *Phyllanthus* and *Pseudoglochidion* are the bigger vessel pore size, smaller vessel diameter and 1-3 seriate heterogenous rays (Table 10.2). Whereas in *Glochidion* the pore size is smaller and the vessel diameter is moderate in size and the rays are multiseriate. The sclariform pitting, multiseriate rays and the arborescent nature of the genus *Glochidion* shows the primitive nature of the genus than *Phyllanthus,* where the plants are mostly herbaceous and wood anatomical characters are advanced.

Based on above analysis it is concluded here that the endemic genus *Pseudoglochidion* is congeneric to the genus *Phyllanthus,* supporting Webster's (1994) treatment merging this endemic genus under *Phyllanthus*. *Phyllanthus anamalayanus (=Pseudoglochidion anamalayanum)* is considered close relative to P. baeobotryoides which is distributed in Eastern Himalyas up to Myanmar (Balakrishnan pers. comm.).

Kruckeberg and Rabinowitz (1985) state that the potential subjectivity of taxonomic status of rarities may express itself in ambiguities at various levels of the taxonomic hierarchy. In the case of Pseudoglochidion as a genus it is considered rare, monotypic genus and after the merger with the genus Phyllanthus, the status of rarity at the generic level is lost.

They produced flowers and fruits almost throughout the year. The fruits are dehiscent capsules. Moreover, the plants are distributed along the streams which is favourable for distribution of seeds. The seedling and saplings are observed in the population. From the above observation, it is considered that the population is reproductively viable.

The distribution of Phyllanthus anamalayanus (=Pseudoglochidion anamalayanum) is restricted to Anamalai hills of Western Ghats. In Red data book on Indian plants it is treated under 'Indeterminate' (Ahmedullah and Nayar 1990). But on the contrary several collections are available in MH collected since 1963 (Fig. 10.2). But all the above collections are from a narrow region from Anaimalais. In the present study they are found along evergreen forests, along the streams above 1400m near the tea estates. The earlier collections were also from submergible areas of Anamalais. This suggests that this is a narrow endemic and the threat to the plant is high, as the area is prone to human destruction. Hence, it is categorized here under "endangered" based on IUCN norms. The distribution of closely related species *P. baeobotryoides* in Eastern Himalayas suggests that the endemic species is a relict as it is taxonomically isolated.

Chapter 11

GENERAL DISCUSSION

TAXONOMY AND PHYLOGENY:

The studies on endemic tree genera of Western Ghats reveal that out of six endemic tree genera recognised earlier (Ahmedullah and Nayar 1986; Nayar 1996) five remain distinct. The present study on systematics reveals that Pseudoglochidion does not stand as a separate genus. Webster (1994) considered this congeneric to Phyllanthus and the present study based on anatomical characters supports this view. Poeciloneuron was considered the only endemic tree genus of Western Ghats represented by two species. In the present study P. pauciflorum has been elevated to the rank of a new genus Agasthiyamalaia, based on morphology and anatomical characters.

All the endemic tree genera of Western Ghats are polypetalous families of Bentham and Hooker (1862-67) and positioned under Archichlamydeae of Engler and Prantl (1887-1915). The endemic genera are equally distributed between subclass Strobioloideae and Cotyloideae of Bessey (1915). The genera Erinocarpus, Poeciloneuron and Agasthiyamalaia coming under Strobiloideae are primitive in the line. The remaining genera figuring under Cotyloideae occupy intermediate position in the line. The endemic genera coming under Strobiloideae and Cotyloideae come under Dilleniidae and Rosidae of Cronquist (1981). None of these genera are coming under the most primitive subclass Magnoliidae of Cronquist (1981), thus supporting the idea that the primitive families are poorly represented in this part of Gondwana land (Ahmedullah and Nayar 1986).

MORPHOLOGICAL CHARACTERS:

All the endemic tree genera show primitive morphological characters. The simple leaf, a primitive character, is present in all endemic genera except Otonephelium. The solitary flowers and the panicle among inflorescence types are considered primitive (Parkin 1914; Pilger 1922) and all the endemic tree genera show either solitary flowers or panicle inflorescence. The primitive characters such as the hypogynous flowers and numerous stamens are generally present in all endemic genera, except Meteoromyrtus, wherein the flowers are epigynous and Clusiaceous genera where the stamens are definite. The morphology of fruits indicates their dispersal pattern. The observations in the field show that capsular drupe of Poeciloneuron and Agasthiyamalaia and echinate, indehiscent fruits of Erinocarpus and Otonephelium are distributed secondarily by means of water. However, no animals were seen associated with the dispersal of arillate seeds in the capsule of Blepharistemma and Otonephelium and berries of Meteoromyrtus.

According to Frost (1930; 1931) Kribs (1935; 1937) and Metcalfe and Chalk (1950), scalariform perforation, multiseriate rays, apotracheal parenchyma, diffuse porous wood, longer vessel member, thick fibre walls with bordered pits are primitive characters. These are seen in the endemic genera. However, the advanced characters such as simple perforation, paratracheal parenchyma and uniseriate rays are also represented in the endemic tree genera.

REPRODUCTIVE BIOLOGY:

The phenological pattern of the endemic tree genera varies with the habitat in which they are present. The only genus that is present exclusively in moist deciduous forests is Erinocarpus. The flowering period of this genus is during September to November and this is not correlating with the general flowering pattern of the habitat (Appanah 1993), thus invariably bringing down the competition for the visitors. The other endemic tree genera are found in evergreen forests and their flowering season coincides with the general flowering pattern of their habitats. Two peak flowering periods were observed in evergreen forests of southern Western Ghats (Devy 1998). Appanah (1993) observed that short flowering period of about 2-3 months and flowering of trees during general flowering period increases the competition for the pollinators. General pollinators visit the flowers with nectar and pollen as reward (Momose et al 1998). Erinocarpus and Blepharistemma fall under this category.

The regeneration capacity of the endemic tree genera is very poor. Except Poeciloneuron, Agasthiyamalaia and Meteoromyrtus other genera do not produce seedlings. The success rate of the seedling in these genera is variable. Meteoromyrtus shows abundant seedlings and saplings, whereas Poeciloneuron produces abundant seedlings but the recruitment ratio is very less as only very few saplings were observed. The genus Agasthiyamalaia produced very few seedlings and saplings. Propagation of Erinocarpus, Blepharistemma and Otonephelium reveals that the reproductive capacity through seeds is almost lost in these genera.

HABITAT AND DISTRIBUTION:

All the genera except Erinocarpus are distributed in evergreen forests and the latter in moist deciduous forests. All these genera except Blepharistemma are restricted to streams or river banks in their respective habitats. As the relict species are restricted only to their favourable habitat (Ahmedullah and Nayar 1986) these endemic genera may also be considered relicts. Moreover, the fruit morphology and dispersal mechanism through water are well adapted for this habitat. The only genus, which is present in wide range of habitats is Blepharistemma. It is observed in disturbed lowland coastal forests, sacred groves and evergreen forests.

Except Poeciloneuron and Agasthiyamalaia all other genera are isolated from their close relatives. The close relative of the genus Erinocarpus is restricted to central and south central America. This taxonomic isolation makes it a relict.

Erinocarpus is the only endemic tree genus distributed in the northern Western Ghats. Other genera are in central and southern Western Ghats. As the duration of dry period is long (6-8 months) towards northern western Ghats the capacity to maintain moisture for the formation of evergreen forests is less (Pascal 1988), hence other habitat specific endemic genera are not found in northern Western Ghats. The genera Otonephelium, Poeciloneuron and Erinocarpus are distributed continuously along their range, whereas Meteoromyrtus and Blepharistemma are dicontinuously distributed. The genus Agasthiyamalaia is restricted to the southern end of Western Ghats. The habitat destruction and/or the relict nature of these endemic tree genera may be the reason for their narrow discontinuous distribution.

Since Erinocarpus is exclusively present in moist deciduous forest, there is no possibility for other endemic tree genera get associated with this. As the genera Poeciloneuron and Otonephelium are distributed throughout the evergreen forest range, the chances of their association with other endemic tree genera are more. The only locality where the discontinuously distributed Blepharistemma present in evergreen forests is in Coorg along with Otonephelium and Poeciloneuron. The distribution pattern of endemic tree genera shows that out of six endemic genera, four are represented in Wynaad-Coorg area. This part of Western Ghats is part of Nilgiri-Wynaad-Coorg second most hotspot in Western Ghats (Nayar 1996) which harbours ~150 strict endemic species. Though the "hottest hotspot" Agasthyamalai has more than 150 species of endemic plants, only three of six endemic tree genera are present. However, Gopalan and Henry (2000) recorded 125 strict endemics to Agasthiyamalai in which only Agasthiyamalaia (=Poeciloneuron pauciflorum) figures.

THREAT STATUS:

The evergreen forests is one of the main habitat which harbours most number of endemics (Ramesh and Pascal 1991), and destruction of this habitat leads to the extinction of species. Most of the endemic tree genera are present in evergreen forests and the two of them viz. Meteoromyrtus and Agasthiyamalaia are 'endangered'. The genus Blepharistemma is discontinuously distributed in varied habitats and fall under 'vulnerable' category of IUCN due to the population size. Two of the habitats of this genus are sacred groves. According to Gadgil and Vartak (1974) the sacred groves represent original forests in number of cases, remained immune to human interference and they emphasized survey to understand their role in conservation. The presence of *Blepharistemma* in the groves underlines the importance of conserving these groves and in turn protection given by these groves to this tree genus.

Analysis of the earlier collections available in various herbaria also shows the status of these genera. The critically endangered *Meteoromyrtus* was recollected almost a century after type collection. The genus *Agasthiyamalaia* was represented by few collections after type. Other genera are represented by fairly good number of collections in herbaria.

Most of the endemic tree genera are represented in the evergreen forests and they are well protected by existing laws and provisions. Moreover, these plants produce either suckers or seedlings. This will be helpful in artificial regeneration in the arboreta for latter introduction into the wild area.

Chapter 12

SUMMARY AND CONCLUSIONS

- Out of six previously known endemic tree genera, five are treated taxonomically distinct and the genus Pseudoglochidion Gamble is treated congeneric with Phyllanthus.

- A new monotypic genus Agasthiyamalaia S. Rajkumar gen. nov has been carved out of Poeciloneuron Bedd.

- For the first time wood anatomical studies have been carried out for Meteoromyrtus Gamble and Pseudoglochidion Gamble.

- Echinate fruits in Erinocarpus Nimmo ex Graham and Otonephelium Radlk. and dehiscent capsular drupe of Poeciloneuron s. str. Bedd. and Agasthiyamalaia S. Rajkumar facilitate dispersal through water. Arillate seed of Blepharistemma Wall. ex Benth. and drupe of Meteoromyrtus Gamble suggest the dispersal through biotic agents but none was observed.

- For the first time fruiting was observed in the Wynad population of Meteoromyrtus Gamble, as earlier it was thought to be sterile.

- The close relative of Erinocarpus Nimmo ex Graham is Heliocarpus L. which is distributed in central and south central America. The close relatives of Blepharistemma and Otonephelium are Cassipourea and Litchi respectively, which are also distributed in Western Ghats. The close relative Poeciloneuron and Agasthiyamalaia are Mesua and Mammea, which are also distributed in Western Ghats. The close relative of Meteoromyrtus is Eugenia, which is concentrated in South America but distributed in Western Ghats also.

- Though Poeciloneuron Bedd. produces abundant seedlings, the recruitment ratio is very low.

- Though seeds of all genera are viable, Blepharistemma Wall. ex Benth., Erinocarpus Nimmo ex Graham and Otonephelium Radlk. neither produce seedlings in the wild nor germinate in laboratory conditions.

- The genera Blepharistemma Wall. ex Benth., Erinocarpus Nimmo and Otonephelium Radlk. propagate vegetatively through suckers.

- [illegible] of [illegible] Wall. ex Benth. show [illegible]

- All the endemic tree genera except Blepharistemma Wall. ex Benth. are found along the rivers. Except Erinocarpus Nimmo ex Graham and Blepharistemma Wall. ex Benth., all other genera are exclusively distributed in evergreen forests.

- Erinocarpus is the only endemic tree genus distributed in the northern Western Ghats. Other genera are restricted to southern and central Western Ghats.

- Coorg-Wynaad area is identified as 'hotspot' for endemic tree genera as they harbour four out of six endemic tree genera.

- The threat categories assigned to endemic tree genera are lowrisk (Erinocarpus Nimmo ex Graham, Otonephelium Radlk. and Poeciloneuron Bedd.), vulnerable (Blepharistemma Wall. ex Benth.) and endangered (Meteoromyrtus Gamble and Agasthiyamalaia S. Rajkumar).

- As the present study altered the taxonomic and threat status of few genera, similar studies on other endemic species are suggested to consolidate the real status of endemic plants in Western Ghats.

- As stated in objectives, the reassessment of taxonomic status of all endemic tree genera have been accomplished, which resulted in creation of a new genus (viz. Agasthiyamalaia) and support for the merger of genus Pseudoglochidion with Phyllanthus. The studies also resulted in new knowledge on systematics, phytogeography and threat status (using IUCN norms) of all these taxa and biology (pollination, population, seed viability, seed germination and seedling performance) of selected taxa. This knowledge provides base for future studies on breading pattern and genetic diversity of these important endemic taxa and their conservation.

BIBLIOGRAPHY

Ahmedullah, M. and M.P. Nayar. 1986. *Endemic plants of the Indian region* Vol. 1. Peninsular India. BSI.

Ahmedullah, M. 1990. *Meteoromyrtus wynaadensis* (Bedd.) Gamble. In: M.P. Nayar and A.R.K. Sastry (eds.) *Red data book on Indian plants.* 3: 189.

Ahmedullah, M. and M.P. Nayar. 1990. *Erinocarpus nimmonii* Graham. In: M.P. Nayar and A.R.K. Sastry (eds.) *Red data book on Indian plants.* 3: 33.

Ahemdullah, M. and M.P. Nayar. 1990. *Poeciloneuron pauciflorum.* In: M.P. Nayar and A.R.K.Sastry (eds). *Red data book of Indian plants.* 3: 87.

Ahmedullah, M. and M.P. Nayar. 1990. *Pseudoglochidion anamalayanum* Gamble In: M.P. Nayar and A.R.K. Sastry (eds.) *Red data book of Indian plants* 3: 126.

Airy Shaw, H.K. 1965. Diagnoses of new families, new names, etc., for the seventh edition of Willis's "Dictionary". *Kew Bull.* 18: 249-273.

Airy Shaw, H.K. 1966. *J.C. Willis: a dictionary of the flowering plants and ferns,* 7th ed. Cambridge press, Cambridge, UK.

Alverson, W.S., K.G. Karol, D.A. Baum, M.W. Chase, S.M. Swensen, R. McCourt, and K.J. Systma. 1998. Circumscription of the Malvales and relationships to other rosidae: evidence from rbcL sequence data. *Amer. J. Bot.* 85: 876-887.

Alverson, W.S., B.A. Whitlock, R. Nyffeler, C. Bayer and D.A. Baum. 1999. Phylogeny of the core Malvales: evidence from ndhF sequence data. *Amer. J. Bot.* 86: 1474-1486.

Andrews, E.C. 1913. The development of the natural order Myrtaceae. *Proc. Linn. Soc. New South Wales* 38: 529-568.

Angiosperm Phylogeny Group (APG). 1998. An ordinal classification for the families of flowering plants. *Ann. Missouri Bot. Gard.* 85: 531-553.

Appanah, S. 1993. Mass flowering of Dipterocarp forests in the aseasonal tropics. *J. Biosciences.* 18: 457-474.

Armesto, J.J., J.D. Mitchell and C. Villagran 1986. A comparison of spatial pattern of trees in some tropical and temperate forests. *Biotropica* 18: 1-11.

Arnott, H.J. 1959. Leaf clearings. *Turtox News* 37: 192-194.

Ashton, P.S. 1988. Systematics and Ecology of Rain Forest Trees. *Taxon* 37(3): 622-679.

Ayyappan, N. and N. Parthasarathy. 1999. Biodiversity inventory of trees in a large-scale permanent plot of tropical evergreen forest at Varagalaiar, Anamalais, Western Ghats, India. *Biodiversity and Conservation* 8: 1533-1554.

Bailon, H. 1858. *Etude Generale du Groupe des Euphorbiacees.* Victor Masson, Paris.

Bailon, H. 1873. *Histoire des plantes.* vol.4. Paris.

Baretta-Kuipers, T. 1976. Comparative wood anatomy of Bonnetiaceae, Theaceae and Guttiferae. *Leiden Bot. Ser.* 3: 76-101.

Baum, D.A., W.S. Alverson and R. Nyffeler. 1998. A durian by any other name: Taxonomy and nomenclature of the core Malvales. *Harvard Papers in Botany* 3(2): 315-330.

Bayer, C., M.F. Fay, A.Y. De Bruijn, V. Savolainen, C.M. Morton, K. Kubitzki, W.S. Alverson and M.W. Chase. 1999. Support for an expanded family concept of Malvaceae within a recircumscribed order Malvales: a combined analysis of plastid atpB and rbcL DNA sequences. *Bot. J. Linn. Soc.* 129: 267-303.

Beadle, N.C.W. 1981. *The vegetation of Australia.* Gustav Fischer Verlag. Stuttgart and New York.

Beddome, R.H. 1864. *Madras J. Sci.* ser. 3, 1: 47.

Beddome, R.H. 1865. On a new genus of Ternstroemiaceae: *Poeciloneuron* from Nilgiris. *J. Linn. Soc.* 8: 267.

Beddome, R.H. 1865. *Trans. Linn. Soc. London.* 25: 212.

Beddome, R.H. 1869 - 1874. *Flora Sylvatica South India* Vols. 1 & 2. Madras.

Behnke, H.D. 1982. Sieve-element plastids of Cyrillaceae, Erythroxylaceae and Rhizophoraceae: description and significance of subtype PV plastids. *Plant Syst. Evol.* 141: 31-39.

Behnke, H.D. 1988. Sieve-element plastids and systematic relationships of Rhizophoraceae, Anisophylleaceae and allied groups. *Ann. Missouri Bot. Gard.* 75: 1387-1409.

Bentham, G. 1858. Synopsis of Legnotideae, a tribe of Rhizophoraceae. *J. Proc. Linn. Soc. Bot.* 3: 65–80.

Bentham, G. 1880. Euphorbiaceae. In G. Bentham and J.D. Hooker. *Genera Plantarum* 3: 239-340. L. Reeve & Co., London.

Bentham, G. and J.D. Hooker. 1862-67. *Genera Plantarum* Reeve, London.

Berg, R.G. van den. 1978. Pollen morphology of the genera *Pometia, Cubilia, Otonephelium* and *Litchi* (Sapindaceae -Nephelieae). *Blumea* 24: 369-394.

Bessy, C.E. 1915. The phylogenetic taxonomy of flowering plants. *Ann. Missouri. Bot. Gard.* 2: 109-164.

Blasco, F. 1970. Aspect of the flora and ecology of savannas of the South Indian hills. *J. Bombay. Nat. Hist. Soc.* 67(3): 522-534.

Bourdillon, T.F. 1908. *The forest trees of Travancore.* Trivandrum.

Briggs, B.G. and L.A.S. Johnson. 1979. Evolution in the Myrtaceae-evidence from inflorescence structure. *Proc. Linn. Soc. new South Wales.* Ser.2, 102: 157-256.

Cain, S.A. 1944. *Foundations of Plant geography.* New York.

Carlquist, S. 1961. *Comparative Plant Anatomy.* Rinehar & Winston, New York.

Carlquist, S. 1965. *"Island Life": A natural history of islands of the world.* New York.

Chase, M.W., D.E. Soltis, R.G. Olmstead, D. Morgan, D.H. Les, B.D. Mishler, M.R. Duvall, R.A. price, H.G. Hills, Y.L. Qiu, K.A. kron, J.H. Rettig, E. Conti, J.D. palmer, J.R. Manhart, K.J. Systma, H.J. Michaels, W.J. Kress, K.G. karol, W.D. Clark, M. hedren, B.S. Gaut, R.K. janen, K.J. Kim, C.F. Wimpee, J.F. Smith, G.R. Furnier, S.H. Strauss, Q.Y. Xiang, G.M. Plumkett, P.S. Soltis, S.M. Swensen, S.E. Williams, P.A. Gadek, C.J.

Quinn, L.E. Equiarte, E. Golenberg, G.H. Learn, S.W. Graham, S.C.H. Barrett, S. Dayanandan and V.A. Albert. 1993. Phylogenetics of seed plants - an analysis of nucleotide sequences from the plastid gene rbcL. *Ann. Missouri Bot. Gard.* 80: 528-580.

Chatterjee, D. 1940. Studies on the endemic Flora of India and Burma. *J. Asiat. Soc. Bengal.* 5: 19-67.

Clarke, C.B. 1898. On the soil sub-areas of British India. *J. Linn. Soc. London.* 34: 1-146.

Cooke, T. 1901- 1908. *The Flora of the Presidency of Bombay.* London. (3 vols.).

Cronquist, A. 1968. *The evolution and classification of flowering plants.* Houghton Mifflin, Boston, Massachusetts, USA.

Cronquist, A. 1981. *An integrated system of classification of flowering plants.* Columbia University Press, New York, New York, USA.

Cronquist, A. 1988. *The evolution and classification of flowering plants.* 2nd ed. New York: The New York Botanical Garden.

Cruden, R.W. 1976. Fecundity as a function of nectar production and pollen-ovule ratios. pp. 171-178. In: J. Burley and B.T. Styles (eds.) *Tropical Trees: Variation, Breeding and Conservation.* Academic press. London.

Dahlgren, R. 1980. A revised system of classification of the Angiosperms. *Bot. J. Linn. Soc. London* 80(2): 91-124.

Dahlgren, R. 1983. General aspects of angiosperm evolution and macrosystematics. *Nord. J. Bot.* 3: 119-149.

Dahlgren, R.. 1988. Rhizophoraceae and Anisophylleaceae: summary statement, relationships. *Ann. Missouri Bot. Gard.* 75: 1259-1277.

Dahlgren, G. 1989. The last Dahlgrenogram: system of classification of the dictoyledons. In: K. Tan, R.R. Mill, and T.S. Elias (eds.). *Plant taxonomy, phytogeography and related subjects.* 249-260. Edinburgh University, Edinburgh.

Dalzell, N.A. and Gibson, A. 1861. *The Bombay Flora.* Bombay.

De Candolle, A. 1855. *Geographie Botanique Raisonnee.* vols. 1,2. Paris.

Devy, M.S. 1998. *Pollination of canopy and sub-canopy trees by social bees in a wet evergreen forest of south Western Ghats, India.* Ph.D thesis submitted to Madras University.

Dickson, W.C. and A.L. Weitzman 1996. Comparative anatomy of the young stem, node and leaf of Bonnetiaceae, including observations on a foliar endodermis. *Amer. J. Bot.* 83(4): 405-418.

Drury, W.H. 1974. Rare species. *Bio. Conserv.* 6: 162-169.

Drury, W. H. 1980. Rare species of plants. *Rhodora.* 82(829): 3-48.

Duthie, 1879. Myrtaceae. In: J. D. Hooker *Flora of British India* 2: 506.

Emig, W. and J.W. Kadereit. 1993. The comparative biology of the closely related *Senecio nebrodensis* and *S. viscosum,* a narrow endemic and a widespread ruderal. *Nord. J. Bot.* 13: 369-375.

Engler, A. 1882. *Versuch einer Entwicklungsgeschichte der Pflanzenwelt.* Leipzig.

Engler, A. 1888. Guttiferae. In: *Flora Brasiliensis* 12(1): 382-486.

Engler, A.G.H. and K. Prantl. (1887-1915). *Die Naturlichen Pflanzenfamilien.* Vols 1-23. 2nd edn.W.Engelmann, Leipzig.

Erdtman, G. 1952. *Pollen morphology and Taxonomy. Angiosperm.* Stockholm.

Favarger, C. and J. Contandriopoulos. 1961. Essai sur Endemisme. *Bul. Soc. Bot. Suisse* 71: 384–408.

Frost, F.H. 1930. Specialization in secondary xylem of dicotyledons: II. The evolution of end of the vessel segment. *Bot. Gaz.* 90: 198-212.

Frost, F.H. 1931. Specialization in secondary xylem of dicotyledons: III. Specialization of the lateral wall of the vessel segment *Bot. Gaz.* 91: 88-96.

Fyson, P.F. 1932. *Flora of South Indian Hill Stations.* Vols. 1&2. Today & Tomorrow printers & Publication. New Delhi.

Gadek, P.A., E.S. Fernando, C.J. Quinn, S.B. Hoot, T. Terrazas, M.C. Sheahan and M.W. Chase. 1996. Sapindales: molecular delimitation and infraordinal groups. *Amer. J. Bot.* 83: 802-811.

Gadgil, M. and V.D. Vartak. 1974. The sacred groves of Western Ghats in India. *Eco. Bot.* 30: 152-160.

Gamble, J.S. 1918. Notes on the Flora of Madras. *Kew Bull.* 1918: 222-228.

Gamble, J.S. 1925. Decades Kewenses: Plantarum Novarum in Herbario Horti Regii Conservatorum. *Kew Bull.* 1925: 329-333.

Gamble, J.S. and C.C. Fischer. 1915–1935. *Flora of the Presidency ofMadras.* London.

Garcia da Orta 1565. *Coloquios dos simples e drogas he cousas medicinais da India.* Lisbon.

Gaston, K.J. 2000. Global patterns in biodiversity. *Nature* 405: 220-227.

Geh, S.Y., and E.H. Keng. 1974. Morphological studies on some inland Rhizophoraceae. *Gard. Bull. Sing.* 27: 183-220.

Gentry, A.H. 1986. Endemism in tropical versus temperate plant communities. In: M. Soule, (ed.). Conservation Biology: *The science of scarcity and diversity.* Sinauer Assoc. Sunderland, Mass.

Givnish, T. 1979. On the adaptive significance of leaf form. In: O. Solbrig, S. Jain, G. B. Johnson and P.H. Raven (eds.) *Topics in Plant population Biology.* Columbia University Press. New York. pp. 375-407.

Good,R. 1964. *The Geography of flowering plants.* Longmans Green & Col. Ltd., London.

Gopalan, R. and A.N. Henry. 2000. *Endemic plants of India: CAMP for the strict endemics of Agasthiyamalai hills, SW Ghats.* Bishen Singh Mahendra Pal Singh. Dehradun.

Graham, J. 1839. *A Catalogue of the plants growing in Bombay and its vicinity.* Bombay.

Hajra, P.K., B.D. Sharma, M. Sanjappa and A.R.K. Sastry. 1996. *Flora India. Introductory volume.* BSI.

Ham, R.W.J.M. van der. 1990. Nephelieae pollen (Sapindaceae): form, function, and evolution. *Leiden Bot. Series* 13: 1-255.

Heel, W.A. Van. 1966. Morphology of the androecium in malvales. *Blumea* 177-394.

Henry, A.N., K. Vivekananthan and N.C. Nair. 1978 (1979). Rare and threatened flowering plants of south India. *J. Bombay Nat. Hist. Soc.* 75: 684-697.

Henry, A.N., M. Chandrabose, M.S. Swaminathan and N.C. Nair. 1984. Agastyamalai and its environs: A potential area for a Biosphere Reserve. *J. Bombay Nat. Hist. Soc.* 81: 282-290.

Hickey, L.F. 1973. Classification of the architecture of dicotyledonous leaves. *Amer. J. Bot.* 60: 17-33.

Hickey, L.J. and J.A. Wolfe. 1975. The bases of angiosperm phylogeny: vegetative morphology. *Ann. Missouri Bot. Gard.* 62: 538-589.

Holderegger, R. 1996. Reproduction of the rare monocarpic species *Saxifraga mutata* L. *Bot. J. Linn. Soc.* 122: 301-313.

Hooker, J.D. and T. Thomson. 1855, *Flora Indica.* London.

Hooker, J. D. 1872- 1897. *Flora of British India.* Vols. 1-7. London.

Hooker, J.D. 1907. Sketch of the Flora of British India. *Imperial Gazetteer of India* (3) 1, (4): 157-212.

Hutchinson, J. 1967. *The genera of flowering plants (Angiospermae)* Vol.2. Oxford: Clarendon Press.

Hutchinson, J. 1969. *Evolution and phylogeny of flowering plants. Dicotyledons, facts and theory.* Academic Press. London.

Hutchinson, J. 1969. Tribalism in the family Euphorbiaceae. *Amer. J. Bot.* 56: 738-758.

Ingle, H.D. and H.E. Dadswell. 1953. The anatomy of timber of the south west Pacific area. III. Myrtaceae. *Austral. J. Bot.* 1: 353-401.

IAWA Committee on Nomenclature. 1964. *Multilingual glossary of terms used in wood anatomy.* Zurich.

IUCN 1994. *IUCN Red List Categories.* Gland, Switzerland: IUCN

Jain, S.K. and A.R.K. Sastry. 1980. *Threatened plants of India- A state-of-the-art report.* BSI.

Johansen, D.A. 1940. *Plant Microtechnique.* 1st edn. McGrew Hill. New York.

Johnson, L.A.S. and B.G. Briggs. 1984. Myrtales and Myrtaceae- A phylogenetic analysis. *Ann. Missouri Bot. Gar.* 71: 700-756.

Joshi, V.C. 2000. *Taxonomic and Phytogeographical investigations on endemic plants of Western Ghats with special reference to Goa.* Ph.D. thesis submitted to Goa University.

Judd, W.S. and S.R. Manchester. 1997. Circumscription of Malvaceae (Malvales) as determined by a preliminary cladistic analysis of morphological, anatomical, palynological and chemical character. *Brittonia* 49: 384-405.

Judd, W.S., R.W. Sanders and M.J. Donoghue. 1994. Angiosperm family pairs: preliminary phylogenetic analyses. *Harvard Papers in Botany* 5: 1-51.

Juncosa, A.M., and P.B. Tomlinson. 1988. Systematic comparison and some biological characteristics of Rhizophoraceae and Anisophylleacee. *Ann. Missouri Bot. Gard.* 75: 1410-1424.

Kadambi, K. 1938. Observations on the growth of *Poeciloneuron indicum. Ind. For.* 64: 212-223.

Kadambi, K. 1942. The evergreen ghat rain forests of the Thunga and Bhadra river source II. *Ind. For.* 68: 305-312.

Kapil, R.P. and K.S. Dhaliwal. 1969. Biology of *Xylocopa* species. II. Field activities, flight range and trials on transportation of nests. *J. Research* (Punjab Agricultural University,Ludhiana) 6: 262-271.

Keating, R.C., and V. Randrianasolo. 1988. The contribution of leaf architecture and wood anatomy to classification of the Rhizophoraceae and Anisophylleaceae. *Ann. Missouri Bot. Gard.* 75: 1343-1368.

Keshav Murthy, K.R., and S.N. Yoganarasimhan. 1990. *Flora of Coorg District, Karnataka, India.* Vismsat Publishers, Bangalore.

Klaassen, R.K.W.M. 1999. *Wood anatomy of the Sapindaceae.* IAWA suppl. 2. 1-214.

Kribs, D.A. 1935. Salient lines of structural specialization in the wood rays of Dicotyledons. *Bot. Gaz.* 96: 547-557.

Kribs, D.A. 1937. Salient lines of structural specialization in the wood parenchyma of Dicotyledons. *Bull. Torrey Bot. Cl.* 64: 177-186.

Kruckeberg, A. R. and D. Rabinowitz. 1985. Biological aspect of endemism in higher plants. *Ann. Rev. Ecol. Syst.* 16: 447- 79.

Kukachka, B.F. and L.W. Rees. 1944. Systematic anatomy of the woods of the Tiliacee. *Univ. of Minnesota Ag. Exp. Sta. Techn. Bull.* 158: 1-70.

Lawrence, G.H.M. 1951. *Taxonomy of vascular plants.* New York.

Leenhouts, P.W. 1971. A revision of *Dimocarpus* (Sapindaceae). *Blumea* 18: 429-430.

Leenhouts, P.W. 1978. Systematic notes on the Sapindaceae-Nephelieae. *Blumea* 24: 395-403.

Levin, G.A. 1986. Systematic foliar morphology of Phyllanthoideae (Euphorbiaceae). I. Conspectus. *Ann. Missouri Bot. Gard.* 73: 29-85.

Lucas, G. and H. Synge. 1978. *The IUCN Red Data Book.* Morges, Switzerland.

Mabberley, D.J. 1997. *The plant-book.* Cambridge University Press, Cambridge, U.K.

Maguire, B. 1972. Bonnetiaceae. In The Botany of the Guayana Highland- Part IX. *Mem. New York Bot. Gard.* 23: 131-165.

Manilal, K.S. 1988. *Flora of silent valley: Tropical rain forests of India.* Calicut.

Marco, H.F. 1935. Systematic anatomy of the woods of the Rhizophoraceae. *Trop. Woods.* 44: 1-20.

Mc Neely, J.A., Miller, K.R. Reid, W.V. Mittermeir, R. A and T. B. Werner. 1990. *Conserving the World's Biological Diversity.* IUCN, Gland, Switzerland.

Meher-Homji, V.M. 1981. A new classification of the phytogeographic zones of India. *Indian J. Bot.* 7(2): 224-233.

Meher-Homji, V.M. 1991. Phytoclimates of peninsular India. *J. Env. Bio.* 179-190.

Metcalfe, C.R. and R. Chalk. 1950. *Anatomy of the dicotyledons.* vols. 1 & 2. Clarendon Press. Oxford.

Mittermeier, R. A. 1988. Primate diversity and tropical forest: Case studies for Brazil and Madagascar and the importance of the megadiversity countries In: Wilson, E. O. and Peter, F. M. (eds), *Biodiversity.* National Academic press, Washington, D. C. p 145- 154.

Mittermeier, R.A. and Werner, T.B. 1990. Wealth of plants and animals unites megadiversity countries. *Tropicus* 4(1): 1, 4- 5.

Mohanan, N., G. Rajkumar and T. Shaju. 1997. Floristic diversity of Agasthyamalai, Western Ghas. In: *Proceedings of the ninth Kerala science congree.* pp. 444-448.

Momose, K. , T. Yumoto, T. Nagamitsu, M. Kato, H. Nagamasu, S. Sakai, R.D. Harrison, T. Itioka, A.A. Hamid and T. Inoue. 1998. Pollination biology in a lowland Dipterocarp forest in Sarawak, Malaysia. I. Characteristics of the plant-pollinator community in a lowland Dipterocarp forest. *Amer. J. Bot.* 85(10): 1477-1501.

Muller, J. and P.W. Leenhouts. 1976. A general survey of pollen types in Sapindaceae in relation to taxonomy. *Linn. Soc. Symp. Series* 1(I.K. Ferguson and J. Muller. eds.): 407-445.

Murthy, G.V.S. 1992. Palynological notes on the genus *Blepharistemma* Wall. ex Benth. (Rhizophoraceae). *J. Palynology.* 28: 75-77.

Mussel, H. 1952. Flora. *Jena* 139: 333-393.

Myers, N. 1988. Threatned biotas: "hotspots" in tropical forests. *Environmentalist* 8(3): 1-20.

Myers, N. 1990. The biodiversity challenges: expanded hot-spots analysis. *Environmentalist* 10: 243–256.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca and J. Kent. 2000. Biodiversity hotspots for conservation priorities. *Nature* 403: 853-858.

Nair, N.C. and C.N. Mohanan. 1981. On the rediscovery of four threatened species from the sacred groves of Kerala. *J. Econ. Tax. Bot.* 2: 233-235.

Nair, N.C. and P. Daniel, 1986. The floristic diversity of the Western Ghats and its conservation: a review. *Proc. Indian Acad. Sci (Anim./Plant Sci.) Suppl.* 127-163.

Nair, P.K.K. 1960. A modification in the method of pollen preparation. *J. Sci. Industr. Res.* 19C91): 26-27.

Nayar, M.P. 1980. Endemism and patterns of distribution of endemic genera (Angiosperms) in India. *J. Econ. Tax. Bot.* 1: 99–110.

Nayar, M. P. 1996. *Hot Spots of endemic plants of India, Nepal and Bhutan.* TBGRI, Thiruvananthapuram.

Nayar, M. P. and A. R. K. Sastry. (eds.) 1987. *Red data Book of Indian plants.* Vol.1. BSI.

Nayar, M. P. and A. R. K. Sastry. (eds.) 1988. *Red data Book of Indian plants.* Vol.2. BSI.

Nayar, M. P. and A. R. K. Sastry. (eds.) 1990. *Red data Book of Indian plants.* Vol.3. BSI.

Nayar, M.P and M. Ahmed. 1984. Phytogeographical significance of endemic genera (Angiosperms) in Peninsular India and Sri Lanka. *Bull. Bot. Surv. India* 26(1-2): 66–70.

Nicolson, D.H. C.R. Suresh and K.S. Manilal 1988. *An Interpretation of Rheede's Hortus Malabaricus*. Koeltz, Germanay. pp.214.

Pandurangan, A.G., V.S. Ramachandran and N.C. Nair. 1984. A note on new distribution and undescribed fruits of the rare plant *Meteoromyrtus wynadensis* (Bedd.) Gamble (Myrtaceae) - Kerala, India. *J. Econ. Tax. Bot.* 5(5): 1185-1188.

Parkin, J. 1914. The evolution of inflorescence. *J. Linn. Soc. Bot.* 42: 511-563.

Pascal, J.P. 1988. *Wet Evergreen Forests of the Western Ghats of India.* Institut Francais de Pondicherry.

Payne, W.W. 1969. A quick method for clearing leaves. *Ward's Bull.* 8(61): 4-5.

Perring, F.H. and L. Farewell. 1977. *British Red Data Book. I. Vascular Plants.* Society for the Promotion of Nature Conservation, London.

Pilger, R.K.F. 1922. Uber verzweigung und Blutenstandsbildung bei den Holzgewachsen. *Bibl. Bot.* 23: 1-38.

Pimm, S. L. and P. H. Raven 2000. Extinction by numbers. *Nature* 403: 843-845.

Pleasants, J.M., and J.F. Wendel. 1989. Genetic diversity in aclonal narrow endemic *Erythornium propullans,* and in its widespread progenitor, *Erythronium albidum. Amer. J. Bot.* 76(8): 1136-1151.

Prain, D. 1903. *Bengal plants.* 2 vols. Calcutta.

Prance, G.T., J. H. Beent, J. Dransfield and R. Johns. 2000. T*he Tropical Flora Remains Undercollected.* Missouri Bot. Gard. Scientificc Publications, St. Louis, Missouri.

Rabinowitz, D., S. Cairns and T. Dillon. 1986. Seven forms of rarity and their frequency in the Flora of the British Isles. In: M. Soule (ed.) *Conservation Biology: The Science of scarcity and diversity.* Sinauer Assoc. Sunderland, Mass.

Radlkofer, L. 1933. Sapindaceae. In: A. Engler (ed.), *Das Pflanzenreich,* Heft 98. Lepzig.

Raghavan, R.S. and N.P. Singh. 1984. An inventory of endemic and vulnerable species of Western India deserving conservation. *J. Econ. Tax. Bot.* 5(1): 153-164.

Ramachandran, V.S., N.C. Nair and V.J. Nair. 1983. Rediscovery of *Meteoromyrtus wynaadensis* (Bedd.) Gamble (Myrtaceae) more than a century after its earlier collection. *J. Bombay Nat. Hist. Soc.* 79: 461-462.

Ramesh, B.R. and J.P. Pacal. 1991. Distribution of endemic arborescent evergreen species in the Western Ghats. In: *The proceedings of the symposium on rare, endangered and endemic plants of the Western Ghats.* Kerala Forest Department. Trivandrum. pp. 20-29.

Ramesh, B.R. and J.P. Pascal. 1997. *Atlas of Endemics of the Western Ghats (India): Distribution of tree species in the evergreen and semi - evergreen forests.* Institut Francais de Pondicherry.

Rao, C.K. 1972. Angiosperm genera endemic to the Indian floristic region and its neighbouring area. *Ind. For.* 98(9): 560-565.

Rao, M.R. 1914. *The flowering plants of Travancore.* Trivandrum.

Rao, M.R. and S.N. Yoganarasimhan. 1986. On the occurrence of *Meteoromyrtus wynadensis* (Bedd.) Gamble. in Karnataka. *Curr. Sci.* 55(4): 188-189.

Ravikumar, K. 1993. *Systematic studies on the Dictotyledonous Plants of Madurai District, Tamil Nadu.* Ph.D. thesis submitted to Bharathiar University, Coimbatore.

Razi, B.A. 1955. Some observations on plants of the south Indian hill tops and their distribution. *Nat. Inst. Sci. India* 21 B. 2: 79-89.

Rheede Van, H.A. 1678-1703. *Hortus Indicus Malabaricus.* Amsterdam. Vols. 1-12.

Richards, P.W. 1952. *The tropical rain forest.* Cambridge University Press. Cambridge.

Richards, P.W. 1996. *The Tropical Rain Forest: An Ecological Study.* 2nd edn. Cambridge University Press. London.

Richardson, I.B.K. 1978. Endemic taxa and taxonomist . In: H. E. Street (Ed.) *Essays in plant Taxonomy.* pp. 245-262. London.

Richter, T.S., P.S. Soltis and D.E. Soltis. 1994. Genetic variation within and among populations of the narrow endemic, *Delphinium viridescens* (Ranunculaceae). *Amer. J. Bot.* 81(8): 1070-1076.

Ridley, H.N. 1930. *The dispersal of plants throughout the world.* L. Leeve & Co. London.

Sasidharan, N. and V.V. Sivarajan. 1996. *Flowering plants of Thrissur forest (Western ghats, Kerala, India).* Scientific Publishers, Jodhpur.

Schimper, A.F.W. 1898. Rhizophoraceae. In A. Engler and K. Prantl (eds.). *Die naturlichen Pflanzenfamilien.* 42-56. W. Engelmann, Lepzig, Germany.

Schmid, R. 1972. A resolution of the *Eugenia-Syzygium* controversy (Myrtaceae). *Amer. J. Bot.* 59: 423-436.

Schmid, R. 1980. Comparative anatomy and morphology of *Psiloxylon* and *Heteropyxis* and the subfamilial and tribal classification of Myrtaceae *Taxon* 29: 559-595.

Schofield, E.K. 1968. Petiole anatomy of the Guttiferae and related families. *Mem. New York Bot. Gard.* 18:1-55.

Schumann, K. 1895. Elaeocarpaceae, Tiliaceae, Malvaceae, Bombacaceae, Sterculiaceae. In: A. Engler and K. Prantl (eds.). *Die naturlichen Pflanzenfamilien.* 3(6): 1-99. Leipzig.

Schwarzbach, A.E. and R.E. Ricklefs. 2000. Systematic affinities of Rhizophoraceae and Anisophylleaceae, and intergeneric relationships within Rhizophoraceae, based on chloroplast DNA, nuclear ribosomal DNA, and morphology. *Amer. J. Bot.* 87(4): 547-564.

Seetharam, Y.N. 1985. *Clusiaceae: Palynology and Systematics;* Trav. Sect. Sci. Tech. Inst. Fr. Pondicherry. 21. 1-80.

Seetharam, Y.N. and S.A.J. Pocock. 1978. Taxonomy and pollen morphology of *Poeciloneuron* (Guttiferae). *Bull. Jard. Bot. nat. Belg.* 48: 359-365.

Sharma, B.D. 1969. Pollen morphology of Tiliaceae in relation to plant taxonomy. *J. Palynology* 5: 7-29.

Singh, N.P. 1988. *Florà of Eastern Karnataka.* vol. 1. BSI.

Smith, J.F. and T.V. Pham. 1996. Genetic diversity of the narrow endemic *Allium aaseae* (Alliaceae). *Amer. J. Bot.* 83(6): 717-726.

Stebbins, G.L. and J. Major. 1965. Endemism and speciation in the California flora. *Ecol. Monogr.* 35: 1 - 35.

Stebbins. G. L. 1942. The genetic approach to problems of rare and endemic species. *Madrono* 6: 241-258.

Steyermark, J.A. and R.Liesner. 1983. Revision of the genus *Sterigmapetalum* (Rhizophoraceae). *Ann. Missouri Bot. Gard.* 70: 179-183.

Subramanyam, K. and M.P. Nayar. 1974. Vegetation and phytogeography of the Western Ghats. In: M. S Mani (ed.) *Ecology and Biogeography of India.* pp.178 - 196.

Takhtajan, A. 1980. Outline of the classification of flowering plants (Magnoliophyta). *Bot. Rev.* 46: 225-359.

Takhtajan, A. 1987. *Systema magnoliophytorum.* Editoria nauka, Leingrad (St. Petersburg).

Takhtajan, A. 1997. *Diversity and classification of flowering plants.* Columbia University Press, New York, New York, USA.

Talbot, W.A. 1909. *Forest flora of Bombay Presidency and Sind.* Vols. 1 & 2. Poona.

Thorne, R.F. 1968. Synopsis of a putatively phylogenetic classification of the flowering plants. *Aliso* 6: 57-66.

Thorne, R.F. 1976. A phylogenetic classification of the Angiospermae. In M.K. Hecht, W.C. Steere and B. Wallace (eds.). *Evolutionary Biology* 9: 35-106.

Thorne, R.F. 1992. An updated phylogenetic classification of the flowering plants. *Aliso* 13: 365-389.

Thorne, R.F. 1992. Classification and geography of the flowering plants. *Bot. Review* 58: 225-328.

Tobe, H. and P.H. Raven. 1983. An embryological analysis of Myrtales: its definition and characteristics. *Ann. Missouri Bot. Gard.* 74: 1-26.

Tobe, H. and P.H. Raven. 1988. Seed morphology and anatomy of Rhizophoraceae, inter- and intrafamilial relationships. *Ann. Missouri Bot. Gard.* 75: 1319-1342.

Turrill, W. B. 1964. Plant Taxonomy, Phytogeography and Plant Ecology. In: *Vistas in Botany.* Vol. IV. Pergamon Press, London.

Vajravelu, E. and P. Daniel. 1983. Enumeration of threatened plants of Peninsular India. In: S.K. Jain and A.R.K. Sastry (eds.) *Materials for a catalogue of threatened plants of India.* 8-43. BSI. Calcutta.

Van Vliet, G.J.C.M. 1976. Wood anatomy of the Rhizophoraceae. *Leiden Bot. Ser.* 3: 20-75.

Van Vliet, G.J.C.M. and P. Baas. 1984. Wood anatomy and classification of the Myrtales. *Ann. Missouri Bot. Gard.* 71: 783-800.

Venkata Rao, C. 1952. Floral anatomy of some Malvales and its bearing on the affinities of families included in the order. *J. Indian Bot. Soc.* 31: 171-203.

Vezey, E.L., V.P. Shah, J.J. Skvarla, and P.H. Raven. 1988. Morphology and phenetics of Rhizophoraceae pollen. *Ann. Missouri Bot. Gard.* 75: 1369-1386.

Warming, E. 1895. *A handbook of systematic botany.* Macmillan, New York.

WCMC (World Conservation Monitoring Centre) 2000. *The World list of Threatned Trees.* Cambridge, UK.

Webster, G.L. 1956. A monographic study of the West Indian species of *Phyllanthus* (Parts 1-3). *J. Arnold. Arbor.* 37: 91-122, 217-268, 340-359.

Webster, G.L. 1967. The genera of Euphorbiaceae in the southeastern United States. *J. Arnold Arbor.* 48: 303-430.

Webster, G.L. 1994. *J. Arn. Arbor.* 81: 45.

Wherry, E. T. 1944. A classification of endemic plants. *Ecology* 25: 247–248.

Wight, R. 1834. *Contributions to the Botany of India.* London.

Wight, R. 1838 - 1853. *Icones plantarum Indiae Orintalis.* (6 vols.) Madras

Wight, R. 1840 - 1850. *Illustrations to Indian Botany.* London.

Willis, J. C. 1922. *Age and Area. A study of geographical distribution and origin of species.* Cambridge University Press.

Appendix i

Character table and data set for the endemic genera Poeciloneuron and Agasthiyamalaia and closely related genera

1. Leaves more than 12 cm in length (1); less than 12 cm in length (0)
2. Leaves oblong (1); leaves variable (0)
3. Leaf apex acuminate (1); bluntly acuminate or obtuse (0)
4. Venation in leaf conspicuous (1); inconspicuous (0)
5. Venation in leaf prominantly reticulate (1); otherwise (0)
6. Flowers in panicle (1); Flowers solitary (0)
7. Sepals in two whorls (1); sepals in single whorl(0)
8. Sepals campanulate (1); twisted (0)
9. Petals 4-6 (1); petals variable (0)
10. Petals twisted (1); imbricate (0)
11. Stamens attached to the disc(1); Stamens free (0)
12. Stamens few (1); numerous (0)
13. Anthers lobulate (1); anthers 2-celled (0)
14. Ovary 2-celled (1); ovary 1-celled(0)
15. Stigma 2 (1); Stigma 1 (0)
16. Stigma peltate (1); stigma indistinct (0)
17. Fruits capsular drupe (1); drupe (0)
18. Fruits single seeded (1); more than one seeded (0)
19. Vessels diameter >100μ (1); <100μ (0)
20. Vessels length >720μ (1); <720μ (0)
21. Perforation plate simple (1); scalariform (0)
22. Vessels to ray pits simple (1); bordered or scalariform (0)
23. Rays uniseriate (1); Rays multiseriate (0)
24. Intercallery cells in the ray cells present (1); absent (0)
25. Wood parenchyma Paratracheal (1); Apotracheal (0)
26. Fibre tracheids present (1); absent (0)
27. Lamina thickness >300μ (1); <300μ (0)
28. Upper epidermal thickness >15μ (1); <15μ (0)
29. Palisade single layered (1); two layered (0)
30. Resin canals present in mesophyll (1); present in mesophyll and epidermis (0)
31. Pollen axis of pollen type =<20μ (1); >20μ (0)
32. Equatorial axis of pollen type <25μ (1); >25μ (0)
33. P/E ration less than or equal to 1 (1); more than 1 (0)
34. Ectoaperature of the pollen <15μ (1); >15μ (0)
35. Endoaperature of the pollen <7μ (1); >7μ (0)

Character No.	Poeciloneuron	Agasthiyamalaia	Mammea	Mesua	Calophyllum
1	1	0	1	1	1
2	0	1	0	0	0
3	1	0	0	1	0
4	1	0	1	0	1
5	1	0	1	0	0
6	1	0	1	0	1
7	0	1	1	1	1
8	1	0	0	0	0
9	1	1	0	0	0
10	1	0	0	0	0
11	1	1	0	1	0
12	1	1	0	0	0
13	1	1	0	0	0
14	1	1	1	1	0
15	1	1	0	0	0
16	0	0	1	1	1
17	1	1	0	0	0
18	1	1	0	0	1
19	1	0	0	0	0
20	1	0	0	1	0
21	1	1	0	1	1
22	1	0	0	0	0
23	1	1	0	1	1
24	0	0	1	0	0
25	1	0	0	0	0
26	1	1	0	0	0
27	1	0	1	0	0
28	0	0	1	0	1
29	1	1	0	1	1
30	1	0	1	1	1
31	1	1	0	0	0
32	1	1	0	0	0
33	1	1	0	0	0
34	1	1	0	0	0
35	1	1	0	0	0

Appendix ii.

Characters and data set used in numerical analysis of Erinocarpus and closely related genera.

1. Plants suffrutescent to herbaceous (1); plants trees or shrubs (0).
2. Leaves not lobed (1); lobed (0).
3. Leaf venation palmate (1); venation pinnate (0)
4. Leaves palmately compound (1); leaves simple (0)
5. Leaves shape ovate-orbicular (1); orbicular (0)
6. Margins of lamina serrate (1); margin of lamina entire(0)
7. Leaf length >10 cm (1); <10 cm (0)
8. Glands at leaf base present (1); absent (0)
9. Lenth of the petiole >20cm (1); <15 cm (0)
10. Tile-cells present in xylem rays(1); absent (0).
11. Vessels only grouped (1); vessels grouped as well as solitary (0).
12. Vessels abundance $>50/mm^2$ (1); $<50/mm^2$ (0).
13. Vessel diameter more than 100μ (1); less than 100μ (0).
14. Xylem parenchyma storied(1); unstoried(0)
15. Axile parenchyma aliform, confluent, or in bands (1); axial parenchyma reticulate or sparse but not aliform, confluent or in bands(0)
16. Axial parenchyma forming ground tissue of xylem with smaller amount of fibres and thus wood very low density (1); axial parenchya not forming ground tissue of xylem and thus wood heavier (0)
17. Mucilage cavities or canals present (1); mucilage cavities or canals lacking(0)
18. Resin canals present (1); such canals lacking (0).
19. Unusual pith like wood parenchyma present (1); absent (0).
20. Position of the infloresecense is terminal (1); axillary (0)
21. Inflorescense panicles (1); variable (0).
22. Leaf thickness >20μ (1); <20μ (0).
23. Leaf epidermal thickness < 15μ (1); >20μ (0).
24. Palisade layers three (1); four (0).
25. Palisade thickness < 100μ (1); > 100μ (0).
26. Spongy parenchyma present (1); absent (0).
27. Flowering bud constricted in the middle (1); subglobose (0)
28. Staminate flowers produced (1); all flowers perfect (0).
29. Sepal longer than petal(1); equal to petal (0);
30. Floral nectaries composed of densely packed, multicellular, glandular hairs on calyx, corolla or androgynophore (1); nectaries lacking or not as above (0)
31. Androecium developed exclusively from antipetalous whorl (1); androecium developed from two whorls (0)
32. Stamens few (1); stamens numerous (0).
33. Stamens connate into a distinct tube (1); stamens free or only slightly fascicled (0).
34. Anther locule septate (1); non septate (0).
35. Anthers lacking conspicuous connective appendage (1); anther with conspicuous sterile appendage (0).
36. Flowers with elongate androgynophore (1); androgynophore inconspicuous or lacking (0).
37. Pollen spiny (1); non spiny (0)
38. Pollen globose (1); Pollen oblate or prolate (0).
39. Pollen 3-5 aperturate (1); polyaperturate (0).
40. Pollen exine reticulate (1); retipilariate (0).
41. Carpels more than 5 (1); carpels 5 or fewer (0).
42. Stigma indistinct (1); stigma distinct (0)
43. Fruits indehiscent (1); dehiscent (0).
44. Fruits with projections (1); without projections (0).

Character No.	Erinocarpus	Triumfetta	Heliocarpus	Grewia	Character No	Erinocarpus	Triumfetta	Heliocarpus	Grewia
1	0	1	0	0	23	1	0	1	1
2	1	1	1	0	24	1	0	1	0
3	1	1	1	1	25	1	1	1	0
4	0	0	0	0	26	1	1	1	0
5	0	1	0	1	27	1	1	1	0
6	1	1	1	1	28	0	0	1	0
7	0	1	1	0	29	1	1	1	1
8	1	0	1	0	30	1	1	0	1
9	1	0	0	0	31	1	1	1	0
10	0	0	0	1	32	0	1	0	0
11	1	0	0	0	33	0	0	0	0
12	1	0	0	0	34	0	0	0	0
13	0	0	1	0	35	1	1	1	1
14	1	1	1	1	36	0	0	0	0
15	0	0	0	0	37	0	0	0	0
16	1	0	0	1	38	0	0	0	0
17	1	1	1	1	39	1	1	1	1
18	0	0	0	0	40	1	1	1	0
19	0	1	0	0	41	0	0	0	0
20	1	0	1	0	42	1	1	1	0
21	1	0	1	0	43	1	1	1	1
22	0	1	0	1	44	1	1	1	0

Appendix iii.

Characters and data set used in numerical analysis of Otonephelium and closely related genera.

1. Leaflets less than 5-jugate (1); more than 5-jugate (0)
2. Pseudostipules present (1); absent (0)
3. Leaflets oblong (1); Leaflets variable (0)
4. Glands on nerve axils of leaf present (1); absent (0)
5. Sepals rusty tomentose (1); hairy (0)
6. Petals present (1); absent (0)
7. Stamens less than 6 (1); more than 6 (0)
8. Ovary 2 celled (1); 2-3 celled (0)
9. Stigma sub-sessile (1); stalked (0)
10. Fruits spinescent (1); granular or smooth (0)
11. Seeds half-full arilloid (1); full arilloid (0)
12. Embryo curved and straight (1); straight (0)
13. Leaf thickness more than 180μ (1); less or equi to 180μ (0)
14. Thickness of upper epidermis 12μ (1); more than 12 μ (0)
15. Cuticular projection longer (1); shorter (0)
16. Intercellular spaces in mesophyll larger (1); shorter (0)
17. Polar axis of pollen grain more than 17μ (1); less or equal to 17μ (0)
18. Equatorial axis less than or equal to 20μ (1); more than 20μ(0)
19. P/E ratio nearly one (1); less than one (0)
20. Tectum striate (1); heterogenous (striate, perforate, psilate, finely reticulate) (0)
21. Vessel pit diameter >4μ (1); <4μ (0)
22. Growth ring distinct (1); indistinct or absent (0)
23. Vessel wall thickening present (1); absent (0)
24. Vessesl frequency >20 mm^2 (1); <20 mm^2 (0)
25. Scanty Wood parenchyma present (1); absent (0)
26. Aliform to confluent wood parenchyma present (1); absent (0)
27. Crystals in ray cells present (1); absent (0)
28. Crystals in fibrous elements present (1); absent (0)

Character No.	Otonephelium	Dimocarpus	Litchi
1	1	0	0
2	1	0	0
3	0	1	1
4	1	1	0
5	0	1	0
6	1	0	0
7	1	0	0
8	1	0	0
9	1	0	0
10	1	0	1
11	1	0	0
12	1	0	1
13	1	0	1
14	1	0	0
15	1	0	0
16	1	0	1
17	1	0	0
18	1	0	0
19	1	0	1
20	1	0	0
21	0	1	1
22	1	0	1
23	1	0	0
24	0	1	1
25	1	0	0
26	1	0	0
27	0	1	1

Appendix iv

Character table and data set for the endemic genus Meteoromyrtus and closely related genera

1. Leaves opposite (1); leaves alternate or opposite (0)
2. Flowers solitary (1); Flowers in inflorescense (0)
3. Caly tube short, lobes long (1); Calyx tube long; lobes shorter (0)
4. Staminal disk present (1); absent (0)
5. Pendulous ovule present (1); absent (0)
6. Axile placentation present (1); absent (0)
7. Seeds solitary (1); seeds variable (0)
8. Anthopodia present (1); absent (0)
9. Petals 4-merous (1); 5-merous (0)
10. Carpel isomerous with perianth (1); carpel less than perianth lobes (0)
11. Sunken style base present (1); not sunken (0)
12. Vessels solitary (1); grouped (0)
13. Vessels diameter >100μ (1); <100μ (0)
14. Vessel pit diameter >7μ (1); <7μ (0)
15. Wood rays biseriate (1); variable (0)
16. Vessel-ray pitting simple rounded (1); elongeted scalariform (0)
17. Wood parenchyma apotracheal (1); Paratracheal (0)
18. Conscipicuous bordered pits in fibres present (1); absent (0)
19. Stomata Anomocytic (1); variable (0)

Character No.	Meteoromyrtu	Eugenia	Syzygium
1	1	1	0
2	1	0	0
3	1	0	0
4	1	0	1
5	1	0	0
6	0	1	1
7	1	0	0
8	0	0	1
9	0	1	1
10	1	1	0
11	0	0	1
12	1	1	0
13	0	0	1
14	0	0	1
15	1	0	0
16	1	1	0
17	1	0	1
18	1	1	0
19	1	0	0