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ECOLOGY AND TAXONOMY OF MANGIFERA SPECIES (ANACARDIACEAE) IN THE 50-HA PLOT OF PASOH FOREST RESERVE, PENINSULAR MALAYSIA

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By

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LIST OF ABBREVIATIONS

ABG	Above Ground Biomass
BA	Basal Area
BCI	Barro Colorado Island
cpDNA	Chloroplast DNA
CTAB	Cetyl Trimethyl Ammonium Bromide
DBH	Diameter at Breast Height
DNA	Deoxyribonucleic acid
EDTA	Ethylene Diamine Tetraacetic Acid
FAA	Formalin Glacial Acetic Acid
FDP	Forest Dynamics Plot
FRIM	Forest Research Institute of Malaysia
Ha	Hectare
IBP	International Biological Programme
ITS	Internal Transcribed Spacer
MAB	Man and Biosphere
NSF	National Science Foundation
PCR	Polymerase Chain Reaction
PFR	Pasoh Forest Reserve
RNA	Ribonucleic acid
STRI	Smithsonian Tropical Research Institute
UM	University Malaya
UNESCO	United Nations Educational, Scientific and Cultural Organization

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science

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By

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December 1999

Chairman: **Associate Professor Faridah Hanum Ibrahim, Ph.D.**

Faculty: **Forestry**

The study was conducted at the 50-ha plot of Pasoh Forest Reserve, Negeri Sembilan, Peninsular Malaysia to assess the ecological distribution of *Mangifera* and to solve some taxonomic problems on doubtful species by clearly circumscribing the limits among taxa by using morphological, anatomical and DNA sequences evidences.

Thirteen *Mangifera* taxa were recorded to a total population of 1,202 stems. *Mangifera quadrifida* is the most abundant with 275 stems, followed by *M. foetida* with 208 stems. The least is *M. swintonioides* with only two trees, both more than 10 cm dbh. *Mangifera quadrifida* var. *longipetiolata* has 16 trees all less than 10 cm dbh. The common mango, *M. indica* has only 80 stems. *Mangifera griffithii* has the most number of trees with dbh exceeding 10 cm, thereby giving the highest estimates in terms of basal area (0.045 m^2ha^{-1}), volume (0.63 m^3ha^{-1}), and above ground biomass (0.51 tha^{-1}). A total of 163 dead trees were recorded since the initial survey in 1985. High mortality (85%) was found to be trees of less than 10 cm dbh. Mortality of seedlings was primarily caused

by burrowing and nest building by wild pigs, while death of big trees was caused by termite attack. Taxonomic review of the genus was carried out exploiting morphological and anatomical characters. However, due to unavailability of reproductive characters throughout the entire course of the study, investigation was carried out making use of vegetative characters alone. Given all the morphological and anatomical evidences, the genus can be divided into two subgenera viz. *Limus* and *Mangifera*. This subdivision is further supported by examining the molecular phylogeny of 13 *Mangifera* taxa using nucleotide sequences of the intergenic spacer region between *trn*L-*trn*F of the chloroplast DNA. In the phylogenetic study, two major clades were formed from the monophyletic tree. It is noted that *M. subsessilifolia*, a *species incertae* was in a clade with *M. lagenifera* and *M. superba* of the subgenus *Limus*. The second clade on the other hand was composed of species belonging to the subgenus *Mangifera* except for *M. foetida*, which was classified under subgenus *Limus*. However, *M. macrocarpa* of subgenus *Limus* formed a singleton as did *M. gracilipes* of subgenus *Mangifera*. The divergence of the genus *Mangifera* is apparent from the heterogeneous feature of the subgenera. Further analysis of other molecular markers from different genes or genomes and consideration of other species of wild mangoes are necessary to infer a stronger phylogenetic analysis of this taxon.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
Sebgai memenuhi keperluan untuk ijazah Master Sains

EKOLOGI DAN TAKSONOMI SPESIES *MANGIFERA* (ANACARDIACEAE) DALAM KAWASAN PLOT 50-HEKTAR DI HUTAN SIMPAN PASOH, SEMENANJUNG MALAYSIA

Oleh

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Disember 1999

Pengerusi: **Profesor Madya Faridah Hanum Ibrahim, Ph.D.**

Fakulti: **Perhutanan**

Kajian ini telah dijalankan di plot 50-ha dalam Hutan Simpan Pasoh, Negeri Sembilan, Semenanjung Malaysia bagi mendapatkan taburan ekologi spesies *Mangifera* dan menyelesaikan beberapa masaalah taksonomi ke atas spesies yang masih kabur dengan menentukan had antara takson dengan menggunakan bukti-bukti morfologi, anatomi dan jujukan DNA.

Tiga belas takson *Mangifera* telah dicatatkan dalam kawasan seluas 50 hektar di Hutan Simpan Pasoh yang merangkumi populasi berjumlah 1,202 dirian. *Mangifera quadrifida* paling banyak didapati dengan 275 dirian diikuti oleh *M. foetida* dengan 208 dirian. *M. swintonioides* paling kurang didapati dengan hanya dua pokok dan kedua-duanya berdiameter paras dada lebih daripada 10 cm. *M. quadrifida* var. *longipetiolata* pula terdiri daripada 16 pokok dan kesemuanya berdiameter paras dada kurang daripada 10 cm. Tumbuhan mangga yang biasa ditemui, *M. indica* diwakili oleh 80 dirian. *M. griffithii*, mempunyai paling banyak bilangan pokok yang berdiameter melebihi 10 cm

serta memberikan nilai luas pangkal sebesar 0.045 m^2ha^{-1}, isipadu tertinggi sebanyak 0.63 m^3ha^{-1} dan biojismim atas tanah yang tertinggi dengan berat 0.51 tha^{-1}. Sejumlah 163 pokok didapati mati semenjak tinjauan awal pada tahun 1985. Kebanyakan pokok yang mati (85%) terdiri daripada pokok yang berdiameter paras dada kurang daripada 10 cm. Sebab utama kematian anak-anak pokok ini adalah kerana kegiatan penyondolan dan pembuatan sarang oleh babi hutan manakala pokok-pokok yang besar pula mati akibat diserang anai-anai. Perlakuan taksonomi ke atas genus ini dilakukan berdasarkan ciri-ciri morfologi dan anatomi. Sungguhpun begitu, akibat ketiadaan ciri-ciri pembiakan sepanjang kajian dijalankan, penyelidikan hanya dibuat berpandukan ciri-ciri vegetatif. Berdasarkan cirri-ciri morfologi dan anatomi, genus ini boleh dibahagikan kepada dua subgenus iaitu *Limus* dan *Mangifera*. Pembahagaian ini disokong dengan mengkaji filogeni molekul 13 takson *Mangifera* menggunakan jujukan nukleotida dari penjarak *trn*L-*trn*F DNA kloroplas. Dalam kajian filogenetik, dua klad utama dibentuk daripada pokok monofiletik. Adalah didapati *M. subsessilifolia*, suatu spesies yang sukar ditentukan, telah membentuk satu klad bersama *M. lagenifera* dan *M. superba* daripada subgenus *Limus*. Klad yang kedua pula terdiri daripada spesies dalam subgenus *Mangifera* kecuali *M. foetida* yang dikelaskan dalam subgenus *Limus*. *M. macrocarpa* daripada subgenus *Limus* dan *M. gracilipes* daripada subgenus *Mangifera* tidak bergabung dengan mana-mana klad tetapi membentuk cabang yang tersendiri. Perbezaan nyata dalam genus *Mangifera* adalah sidebabkan oleh keadaan heterogen dalam subgenus tersebut. Analisis selanjutnya menggunakan penanda molekul daripada gen atau genom yang lain serta mengambilkira spesies mangga liar yang lain adalah perlu untuk mendapatkan analisis filogenetik yang lebih baik untuk takson ini.

CHAPTER I

INTRODUCTION

The tropical rainforest is the world's richest terrestrial ecosystem, yet it is still poorly understood. Nowadays, several strategies are prevalent not only to conserve the biodiversity of tropical forests but also to answer questions that were impossible to address just few years ago. Scientific collaborators around the world are undertaking long-term studies of tropical forest diversity and change in Asia, Africa and Latin America to achieve greater understanding of this important ecosystem. They are discovering basic biological principles that explain tropical dynamics, while at the same time generating data that resolves critical forest management and conservation concerns. The establishment of dynamics plots in Panama, Malaysia, India, and recently in Sri Lanka, Singapore, Thailand and the Philippines by the Smithsonian Tropical Research Institute (STRI) aimed to establish a rigorous global and regional site and species-specific rules concerning the functioning of the biodiverse tropical forest.

Substantial to the management and conservation of biodiversity is an in-depth understanding of every integral element of the ecosystem. Malaysia, being one of the 12 megadiversity countries, is appropriate to lead research in this imaginative concept as it has a prodigious diversity of plant and animal life, vast areas of permanent forest estates and commitment in its forest management and services.

Hence, two forest dynamics plots were established in Pasoh Forest Reserve, Negeri Sembilan and in Lambir Hills National Park, Sarawak.

Statement of the Problem

In 1985, the STRI and the National Science Foundation (NSF) of Harvard University in collaboration with the Forest Research Institute of Malaysia (FRIM) initiated the establishment of a 50-ha permanent plot in Pasoh Forest Reserve (PFR). All trees with a diameter of 1 cm and above were tagged, mapped and monitored. A total of 335,240 trees, belonging to 78 families, 290 genera and 814 species were recorded (Kochummen, 1997). Aside from the initial census, periodic recensus are carried out to yield long-term information on species growth, mortality, regeneration, distribution and productivity in relation to topography, hydrology, soils, climate and other biotic factors.

Due to the relatively large size of the plot and considering the high diversity of lowland tropical forests, misidentification of some species is a common mistake to which the genus *Mangifera* is not an exception. Discrepancies on stem counts between Kochummen *et al.* (1990) and Appanah and Weinland (1993) is evident and needed to be resolved. From the initial 1985 census, a total of 1,365 trees under 13 taxa of the genus *Mangifera* was recorded (Table 1). A subsequent survey in 1990 obtained a record of 1,273 stems, showing a significant decrease in the total population after 5 years. The decrease in number is attributed to mortality caused by biotic and abiotic factors, and exclusion of individuals that were formerly identified

to be *Mangifera*. Moreover, in the Tree Flora of Pasoh Forest (Kochummen, 1997), it is interesting to note that a new species *M. subsessilifolia* was added to the original enumeration.

Table 1: Total Population per Species in Three Periodic Surveys

Species	Periodic Surveys		
	1985	1990	1995
M. foetida	240	233	218
M. gracilipes	135	133	122
M. griffithii	147	144	137
M. indica	92	82	88
M. lagenifera	32	33	30
M. macrocarpa	53	50	51
M. magnifica	133	130	128
M. quadrifida var. *longipetiolata*	17	12	16
M. quadrifida var. *quadrifida*	328	321	303
M. rufocostata	11	11	11
M. sp.1	91	87	90
M. superba	84	82	77
M. swintonioides	2	3	2
	1365	1321	1273

The Stand Table and Distribution of Species (Manokaran *et al.*, 1992), on the other hand, has an unidentified *Mangifera* sp. 1. There is a chance that *M. subsessilifolia* could possibly be the unidentified taxon mentioned in the previous enumeration. A thorough investigation on *Mangifera* sp. 1 however, showed that two more species were found under this taxon namely, *M. superba* and *M. lagenifera*. Both were listed in the first two enumerations. Hence, a complete taxonomic investigation is indeed relevant to solve taxonomic problems of the genus,

which will then be of primary importance in the analysis of ecological aspects such as species distribution, growth, mortality and spatial distribution in relation to soil and topography in the entire 50-ha plot.

Significance of the Study

Before any detailed work can commence in an area, especially to one that is known to be faunistically and floristically diverse like the PFR, it is necessary to know the species present, distribution and the relative degree of dominance of each species. Considering hundreds of genera present within the 50-ha plot, this study on the genus *Mangifera* is like a drop of water in the ocean. It does not aim to present the whole picture of the dynamics of a forest ecosystem, but nonetheless, it aims to provide a model on the dynamics of population since the start of the enumeration in 1985. Data from this demographic study on a single genus will provide insights into better understanding of ecological processes and functions of the rainforest. Moreover, these can be useful as baseline information in support of other related studies. Likewise, this study reveals some of the limitations and pressures affecting the behaviour of each species under consideration in which other species/genera can be patterned to, if not contrasted.

Goals and Objectives

Given the above scenario, this study intends to clarify the discrepancy in the previous surveys (the initial census in 1985 and the recensus in 1990) and to solve the taxonomic problem on doubtful species by clearly circumscribing the limits among taxa. It is likewise necessary to determine the ecological distribution of the entire population of *Mangifera* in the 50-ha plot. Hence the objectives of the study can be divided into two aspects, namely ecology and taxonomy:

Ecology

1. To present the spatial distribution of *Mangifera* in the 50-ha plot in relation to topography and soil type;
2. To estimate the mortality and growth in terms of basal area, volume and above ground biomass between 1985 and 1998.

Taxonomy

1. To rectify the record of all *Mangifera* species in the 50-ha plot by conducting a hundred percent inventory of the entire population;
2. To correct taxonomic problems on uncertain/doubtful species by employing different taxonomic tools such as morphology, anatomy and DNA sequencing.

CHAPTER II

LITERATURE REVIEW

Pasoh Forest Reserve

Historical Background

Pasoh Forest Reserve (PFR) received and is continuously receiving exuberant attention from renowned institutions to study not only its floristic composition but understand every component of this complex, uniquely fragile ecosystem. Numerous teams of international scientists from Japan, the United Kingdom and the United States working in close collaboration with local scientists have looked into many aspects of the lowland forest ecology. Some of the research areas covered include productivity studies, floristic surveys, soil and soil nutrients, hydrology, nutrient cycling, faunistic and other related ecological aspects.

As early as 1947, the first two plots were established. Since then, they remained under continuous periodic measurements and are frequently referred to in several rain forest literatures (Ashton, 1971a; 1971b; 1976; 1978; 1989; Leigh, 1978a; 1978b; Leow, 1978; Lim, 1978; Richards, 1978; Bullock, 1978; Kira, 1978; Tho, 1982; Wong, 1983). The information accumulated from these studies has no

doubt contributed tremendously to the current understanding of the tropical rainforest ecosystem.

From 1970 to 1978, Pasoh was the site of intensive research on lowland rain forest ecology and dynamics under a joint research project between the University of Malaya (UM) and the International Biological Programme (IBP), the Man and Biosphere (MAB) and the joint Rainforest Research Project of the University of Malaya (UM) and the University of Aberdeen, United Kingdom (Pong, 1981). With all the comprehensive information that has already been accumulated over the years, PFR is now an extremely important field site for ecological studies on the Tropical Rainforest Ecosystem (TRE). In fact, PFR was then declared an International Biosphere Reserve (IBR) under the MAB Programme sponsored by UNESCO (United Nations Educational, Scientific, and Cultural Organization) (Lee, 1995).

In December 1977, the Forest Research Institute (now FRIM) took over the management of PFR from UM. This was made possible through collaboration with the Negeri Sembilan State Forest Department. Pasoh has since become a field research station of FRIM (Lee, 1995). To date, it has now a substation known as the Pasoh Forest Research Centre (PFRC) equipped with hostel and laboratory facilities, a long history of ecological research and a well-studied tree flora (Manokaran *et al.*, 1990; Kochummen, 1997). In 1985, FRIM in collaboration with the National Science Foundation of Harvard University and the Smithsonian Tropical Research Institute established the 50-ha plot.

Forest Type and Structure

The world's tropical rainforests occur in three main blocks. Tropical America is the largest and has about half the total, with potential cover of roughly 4 million km^2, mostly in the Amazon and Orinoco basins. Southeast Asia comes second, with approximately 2.5 million km^2, in the Malay Archipelago, extending into continental Southeast Asia as far as Sri Lanka and India, and into Queensland (10,000 km^2), Melanesia and Polynesia. The heartland of the region is known to botanist as Malesia. It extends from the Kra Ishtmus, the narrow part of the Malay Peninsula through the archipelago to the Torres Strait (between Australia and New Guinea) and the Bismarck Archipelago (east of New Guinea). The third and smallest rainforest is that of Africa, approximately 1.8 million km^2, mainly the Zaire basin of central Africa but extending westward along the shores of Guinea (Whitmore, 1995).

The dipterocarp forest is the principal Indo-Malayan tropical rainforest formation (de Guzman, 1986). Pasoh Forest Reserve is a lowland dipterocarp forest located at 2°59' N latitude, 102°18' E longitude in Negeri Sembilan, Peninsular Malaysia. It is 37 kilometers northwest of Kuala Pilah and 140 kilometers southeast of Kuala Lumpur (Pong, 1981; Manokaran *et al.*, 1990, 1992). Several layers of vegetation and multiplicity of tree species characterise this rainforest. It is not a pure stand of tree species belonging to the family Dipterocarpaceae but rather a mix forest consisting of species of various families with the dipterocarps as dominant components. Hence, on account of the dominance of the species *Dipterocarpus* (Keruing) and *Shorea* (Red Meranti group), Wyatt-Smith (1961, 1987) described the

forest as "Red Meranti-Keruing" of the central and southern type. It consists of a core area of 650 ha of primary lowland mixed dipterocarp forest surrounded by another 650 ha of buffer zone of partly regenerated and partly virgin forest. A further 150 - 1,000 ha of primary hill dipterocarp forest rises to about 600 meters above sea level (Manokaran *et al.*, 1990).

The Genus *Mangifera* L.

Mango (*M. indica* and its cultivars) is popularly known worldwide and is one of the best-loved fruits of the South Asian tropics (Saw, 1987; Kochummen, 1989; Saw *et al.*, 1991; Sharma, 1993). The ripe fruit is yellow, kidney-shaped one seeded drupe eaten fresh and commonly used to prepare jam, jellies and preserves. The unripe fruit is green usually brought over in pickles, chutneys and vinegar. However, there are many varieties differing chiefly in figure, size, colour and taste. Young leaves of some species are also used as vegetables.

In addition to the highly valued fruits produced by several species (Burkill, 1935; Allen, 1967; Whitmore, 1972; Anderson, 1980) the timber of some *Mangifera* is acclaimed for its high quality and beauty characterized by wide black streaks interspersed with light brown narrow lines (Lee, 1987). This unique feature makes them extremely attractive furniture. The streaky corewood favours the demand for high-class cabinet works, interior furnishing, panelling and partitioning. However, the timber is not durable and hence suitable only for light construction, planking,

flooring and plywood manufacture, to name a few The standard timber trade name is known as 'machang'

Mango leaves and flowers play significant roles in Hindu religious ceremonies (Kostermans and Bompard, 1993) Mango represents the fable transformation of Peajapat, the God of Creation The pancha-pallava or the bunch of five sprigs from the mango tree is used by Hindus in various ceremonies Mango flowers on the other hand are used for the worship of Sasawati, Goddess of Wisdom and Arts, and also for Shiva

Medicinal uses of some species have also been reported (Ridley, 1922) The mango is apt to throw out troublesome boils (Loudon *et al.*, 1973). Moreover, the fruit is known to be eaten by gentlemen on hot months in the absence of wine (Kostermans and Bompard, 1993)

Medicinal uses

The bark is astringent, anthelmintic and useful in haemoptysis, haemorrhage, nasal catarrh, diarrhoea, ulcers and diphtheria It accelerates the rate of wound healing, stops dysentry and corrects blood borne disorders It is also known to heal menorrhagia, bleeding piles and gonorrhoea (Burkill, 1935)

When the mango fruit is detached from its stem, a thin fluid is produced known as 'chep', popularly regarded as a cure for scabies and other cutaneous