UNIVERSITI PUTRA MALAYSIA

RADIATION INTERCEPTION BY LOWLAND TROPICAL FOREST AND PRODUCTIVITY OF ITS THREE TREE SPECIES

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By

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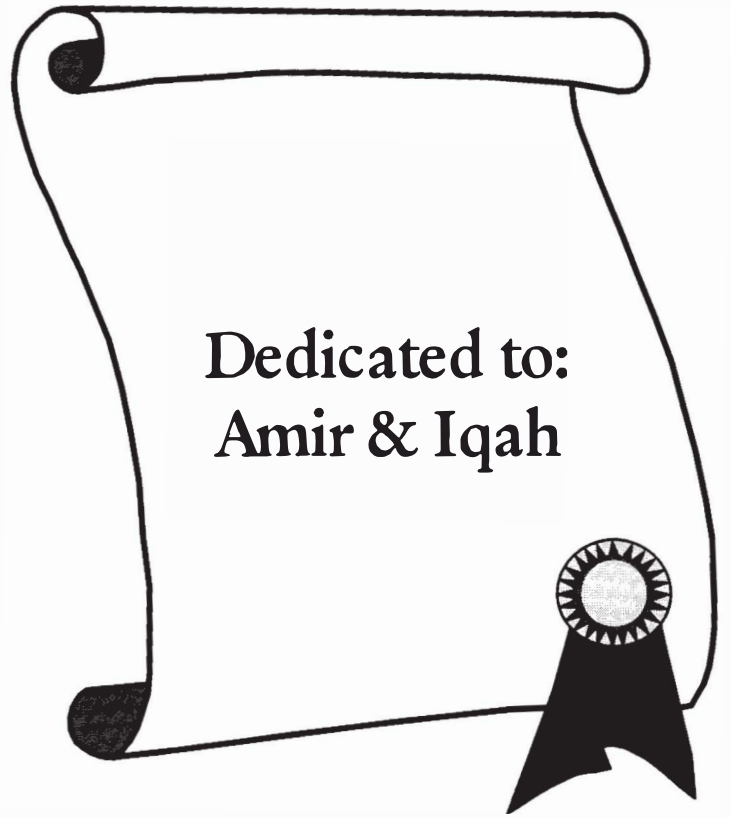
Dedicated to:
Amir & Iqah

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In the name of Allah, Most Gracious, Most Merciful

This is sheer Grace and Blessing of Allah that I am able to present a research manuscript on His creation. This is a humble attempt to describe His creation.

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LIST OF ABBREVIATIONS

Symbol		Unit
A_L	Leaf area	(cm^2)
Ci	CO_2 concentration in the leaf intercellular spaces	(mol mol^{-1})
d	Day length or photoperiod	(hour)
D_L	Longitudinal diameter of leaf	(cm)
D_W	Width diameter of leaf	(cm)
E	Energy	(Joule mol^{-1})
f	Flow of air	(mol s^{-1})
gs	Stomatal conductance to CO_2	(mol m^{-2} s^{-1})
h	Planck's constant	(6.6×10^{-34} J.s)
I	Light radiation	(µmol m^{-2} s^{-1})
I_{comp}	Light radiation at photosynthetic compensation point	(µmol m^{-2} s^{-1})
I_{max}	Maximum light radiation	(µmol m^{-2}-s^{-1})
I_l	Mean light flux density falling on leaves	(µmol m^{-2} s^{-1})
I_o	Light radiation at top of the canopy	(µmol m^{-2} s^{-1})
I_p	Mean light flux density on the plane	(µmol m^{-2} s^{-1})
k	Extinction coefficient	
LAI	Leaf Area Index	(cm^2 cm^{-2})
P	Photosynthesis	(µmol m^{-2} s^{-1})
PAR	Photosynthetic Active Radiation	(W m^{-2})
Pg	Gross photosynthesis	(µmol m^{-2} s^{-1})
P_m	The asymtote value of P at saturating irradiance	(µmol m^{-2} s^{-1})
PFD	Photon Flux Density	(µmol m^{-2} s^{-1})
R	Respiration	
RI	Relative irradiance	(W m^{-2})
RGR	Relative Growth Rate	(kg day^{-1})
s	Leaf area inside the assimilation chamber	(cm^2)
T	Temperature	(°C)

t	time	(hour)
v	Frequency of light	
V	Velocity of light	(m s^{-1})
W_{LA}	Dry weight of leaf	(g. dry wt.)
μ	micron	
λ	Light wavelength	
Φ	Total radiation emitted per unit area per unit time	
ε	Constant	
σ	Stefan Boltzman constant	($5.7x10^{-8}Wm^{-2}K^{-4}$)
π	Phi	
ΔCO_2	Differences in CO_2 concentration	(mol mol^{-1})
α	Photosynthetic efficiency	(mol mol^{-1})
θ	Rate of the curvature line	

Abstract of thesis submitted to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Doctor of Philosophy.

RADIATION INTERCEPTION BY TROPICAL LOWLAND EVERGREEN RAIN FOREST AND PRODUCTIVITY OF ITS THREE TREE SPECIES

By

AHMAD MAKMOM BIN HJ ABDULLAH

JULY 1997

Chairman : Prof. Dr. Muhamad Bin Awang

Faculty : Science and Environmental Studies

The present study was conducted at Pasoh Forest Reserve, located in Negeri Sembilan Malaysia, at about 2°59'N and 102°18'E. The aims of the study were to determine the light environment in the lowland tropical forest and the light interception by the forest canopy and to understand the physiological responses of those selected species to different light in relation to their growth performances. Photon flux densities in different microsites and a clearing within a lowland evergreen tropical forest has been measured and compared between dry and rainy seasons under various of weather conditions. Measurements of PFD were monitored continuously at 5 min intervals over 14-29 day period using quantum sensors under the understorey, small gap, medium gap, big gap and open area. Vertical distribution of PFDs at different height levels of 52 m, 42 m, 33 m, 23 m, 19 m, 14 m, 7 m and on the forest floor were also measured. Daily

average PFD, total daily PFD and average daily frequency distribution were analyzed. Daily total PFD in the open area, big gap, medium gap, small gap and understorey sites during the rainy season of November to January 1992 were 51-55, 17.8, 8.1, 8 and 4.51 %, of the daily total PFD recorded in the clearing, respectively. Daily total PFD in the big gap during the dry season was on the average 2 times lower than during the rainy season. In the clearing, high proportion of 5-min average was greater than 500 μmol m^{-2} s^{-1}, while in the medium, small gaps and understorey, were between 10 and 50 μmol m^{-2} s^{-1}. On diurnal basis, there were high variations in PFD distributions at canopy height of 42 and 52 m during the midday. Mid canopy showed high variations in PFD during the study period. The highest daily total PFD recorded at 52 m was 50 mol m^{-2} and the lowest value was found to be at the forest floor. The canopy of the emergent at 33 m height intercepted more than 50% of PFD.

In situ growth experiments were carried out by establishing uniform sized seedlings of *Shorea leprosula* and *Neobalanocarpus heimii* in each microsite. Diurnal photosynthesis and growth performances were measured accordingly. Open area and big gap sites showed higher growth and photosynthetic rates. Photosynthetic light response curves of *S. leprosula* and *Neobalanocarpus heimii* seedlings grown inside the microsites were established. In addition, *P-I* response curves of *N. heimii* and *Dipterocarpus sublamellatus* canopy leaves were also established. The average photosynthetic light response parameters, α, P_{max}, R and θ which were calculated based on Thornley model. The α, P_{max}, R and θ in canopy leaves of *N. heimii* and *D.*

sublamellatus were 0.070 mol mol^{-1}, 9 µmol m^{-2} s^{-1}, 0.445 µmol m^{-2} s^{-1}, 0.93 and 0.0312 mol mol^{-1}, 8.875 µmol m^{-2} s^{-1}, 0.388 µmol m^{-2} s^{-1}, 0.938, respectively. While *S. leprosula* seedlings were 0.028 mol mol^{-1}, 5.9 µmol m^{-2} s^{-1}, 0.375 µmol m^{-2} s^{-1} and 0.93, respectively. These values were then used in photosynthetic productivity simulation study by exploiting the PFD distribution records. The simulation study estimates the seasonal production of *S. leprosula* at different microsites and annual productivity of canopy leaves. The annual production of canopy leaves was estimated to be in the range of 40 and 44 ton ha yr^{-1}.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Falsafah Kedoktoran.

HADANGAN RADIASI OLEH HUTAN HUJAN TROPIKA MALAR HIJAU TANAH PAMAH DAN PRODUKTIVITI TIGA SPESIS POKOK

Oleh

AHMAD MAKMOM BIN HAJI ABDULLAH

JULY 1997

Pengerusi : Prof. Dr. Muhamad Awang

Fakulti : Sains dan Pengajian Alam Sekitar

Kajian ini telah dijalankan di Hutan Simpanan Pasoh yang terletak di Negeri Sembilan, sekitar 2° 59'U dan 102°18'T. Matlamat kajian ini ialah untuk menentukan persekitaran cahaya di hutan tanah pamah tropika dan hadangan cahaya oleh kanopi hutan dan memehami tidakbalas fisiologi spesis-spesis yang telah terpilih terhadap cahaya yang berbeza-beza dalam hubungan pertumbuhan mereka. Densiti fluk foton di pelbagai tapak mikro dan satu kawasan terdedah di hutan hujan malar hijau tanah pamah tropika telah diukur dan dibandingkan diantara musim kering dan musim hujan di bawah pelbagai keadaan cuaca. Pengukuran DFF telah dijalankan dengan menngunakan pengukur kuantum di bawah lindungan, ruang terbuka kecil, besar dan kawasan terbuka. DFF telah diukur berterusan dengan selang masa 5 min selama tempoh di antara 14 hingga 29 hari bagi setiap lokasi. Taburan menegak DFF juga diukur pada ketinggian-ketinggian; 52 m, 42 m, 33 m, 23 m, 19 m, 14 m, 7 m, dan di lantai hutan. Purata harian DFF, jumlah harian dan taburan frekuensi purata harian telah dianalisis. Jumlah harian

DFF dikawasan terbuka besar, kecil dan dibawah lindungan ketika musim hujan dari November hingga Januari tahun 1992 adalah masing-masing diantara 51-55, 7-8, 8.1, 8 dan 4.51% berbanding dengan jumlah harian di kawasan terdedah. Jumlah harian DFF di ruang terbuka besar ketika musim kering adalah dua kali lebih rendah jika dibandingkan dengan musim hujan. Di kawsan terdedah sebahagian besar purata 5 min bacaan adalah melebihi 500 μmol m^{-2} s^{-1} di ruang kecil, sederhana dan di bawah lindungan sebahagian besar purata 5 min bacaan adalah di antara 10 hingga 150 μmol m^{-2} s^{-1}. Secara harian, terdapat perbezaan besar di waktu tengahari bagi taburan DFF di ketinggian kanopi 42 m dan 52 m. Pertengahan kanopi menunjukkan perbezaan yang tinggi dalam DFF semasa tempoh kajian. Jumlah harian DFF yang paling tinggi telah dicatitkan pada ketinggian 52 m adalah 50 mol m-2 dan nilai-nilai terendah telah dicatitkan di lantai hutan. Lebih daripada 50% DFF telah dihadang oleh kanopi puncak pada ketinggian 33 m.

Anak-anak pokok *S. leprosula* (Meranti Tembaga) yang bersaiz seragam di pupuk di dalam setiap tapak. Keadaan fotosintesis diurnal dan pertumbuhan telah diukur. Kawasan terbuka dan ruang terbuka besar telah menunjukkan kadar pertumbuhan dan fotosintesis yang tinggi. Garislengkung tindakbalas cahaya dan fotosintesis bagi anak-anak pokok *S. leprosula* dan *N. heimii* yang tumbuh ditapak-tapak kajian telah ditetapkan dan hubungan tindakbalas fotosintesis dan cahaya bagi daun kanopi juga telah ditetapkan. Purata paramter bagi tindakbalas fotosintesis iaitu α, P_{max}, R dan θ yang telah di kira berdasarkan model Thornley bagi anak-anak pokok *S.*

leprosula masing-masing adalah 0.028 mol mol^{-1}, 5.9 µmol m^{-2} s^{-1}, 0.375 µmol m^{-2} s^{-1} dan 0.93. Nilai-nilai α, P_{max}, R dan θ bagi daun kanopi *N. heimii dan D. sublamellatus* adalah masing-masing 0.0702 mol mol^{-1}, 9 µmol m^{-2} s^{-1}, 0.445 µmol m^{-2} s^{-1}, 0.93 dan 0.0312 mol mol^{-1}, 8.88 µmol m^{-2} s^{-1}, 0.388 µmol m^{-2} s^{-1} dan 0.94 juga telah dikira. Nilai-nilai ini telah digunakan dalam simulasi produktiviti fotosintesis menggunakan rekod tahunan DFF. Simulasi telah memberikan hasilan musim bagi *S. leprosula* di pelbagai tapak-tapak kajian dan hasilan tahunan daun kanopi. Hasilan tahunan daun kanopi telah dianggarkan berada dalam julat daripada 40 hingga 44 ton ha^{-1} setahun.

CHAPTER I
INTRODUCTION

General Background

Forests have been regarded as highly valuable resources for a long period of man's history (Gareth, 1979). There were 18.88 million hectares of forest comprising 61.8% of the total land area of Malaysia in 1994 (Ismail, 1996). Out of this, 5.82 million hectares were in Peninsular Malaysia, 4.41 million hectares in Sabah and 8.65 million hectares in Sarawak. In terms of major forest types, 16.57 million hectares were classified as Dipterocarp forest, 1.72 million hectares as freshwater swamp and 0.59 million hectares as mangrove. Dipterocarp forest, which represented 87.8% of the total forested lands, consists of *Anisoptera, Dipterocarpus, Dryobalanops, Hopea, Shorea* and *Parashorea* as dominant species. As of 1994, about 14.29 million hectares of forested land were earmarked as permanent forest estate. A total of 10.9 million hectares of the forest estate has been identified as productive and the remaining 3.39 million hectares as protective and amanate forest.

Earlier in 1993, about 19.1 m.ha (58%) of land area in Malaysia remained under forest cover, 9.0 m.ha (15%) was under other tree crops such as rubber, oil palm, cocoa and coconut plantation and 4.8 m.ha (27%) is other land uses. According to National Forest Policy, 14.01 m.ha or 73% of forested area were