



UNIVERSITI PUTRA MALAYSIA

***INFLUENCE OF AGE ON GROWTH VARIABLES OF
Dryobalanops beccarii DYER IN A REHABILITATED FOREST***

EMILLA YASTARI BINTI LAPOK

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By

EMILLA YASTARI BINTI LAPOK

**Thesis Submitted to the School of Graduate Studies, Universiti Putra
Malaysia, in Fulfilment of the Requirements for the Degree of
Master of Science**

December 2016

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

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Chairman : Ong Kian Huat, PhD
Faculty : Agricultural and Food Sciences (Bintulu)

Dryobalanops beccarii is one of the vulnerable indigenous tree species in Malaysia. In order to conserve and protect this species, growth response over their lifespan needed to be studied. However information on *D. beccarii* growth rate at different age is limited. Hence, the ontogenetic development study of *D. beccarii* was conducted in Universiti Putra Malaysia (UPM) – Mitsubishi Forest Restoration area at UPM Bintulu Sarawak Campus. The aims of the study were to observe the growth performance of *D. beccarii* and to understand the changes in physiological and morphological of leaves as well as its stem with different tree ontogenetic development stages. Stands of 1, 9, 14 and 20 year-old were selected for this study as where at least 4 stems of *D. beccarii* could be found in each of the stand. The size of the established stand was 30 x 10 m. The parameters observed were tree morphology, leaves morphology and physiology, and selected soil properties. The tree morphology study involved heights (total and merchantable), stem diameter, canopy size (depth and diameter), and Leaf Area Index (LAI) of *D. beccarii*. Total height growth rate increased rapidly during the early stages and decreased in 20-year-old stand due to competition for light and space from the surrounding trees. The change in total height was accompanied by rapid merchantable height growth rate and apparent bulking up in stem diameter in 9-year-old stand. Upon reaching certain height, the young tree focused on the stem growth in order to support the massive tree height. The high tree density in 14-year-old stand contributed to high LAI value. The expansion of canopy size was rapid in 20-year-old stand in order to fill the empty gaps between trees. The tree height increased sigmoidally with time as the growth was rapid from year 1 to year 9 and slowing down after reaching 14-year-old. Meanwhile, stem diameter, canopy size, and LAI still showed continuous growth up to 20 years. The leaf area, width, length, thickness, and stomata

density were determined in the leaf morphology study. The leaf morphology was significantly correlated with the tree morphology parameters, except for leaf width and canopy diameter. Compared to other leaf morphology parameters, the leaf width and stomata density was found to decline significantly ($P<0.05$) during yearly assessment in each stand age due to the response to the drought season. The 20-year-old stand recorded highest leaf area, thickness, width, and length. Due to leaf adaptation to overlapping canopy layer, the leaf size was larger in mature tree than juvenile tree. The photosynthetic rate, transpiration rate, stomatal conductance, and chlorophyll content were included in the leaf physiology study. Similarity was found between the photosynthetic rates, transpiration rate, and stomatal conductance. These parameters rate was low in the freshly emerged saplings, increased rapidly until *D. beccarii* age between 9-14 years, and decreased upon reaching the mature phase. The young tree is not efficient in physiological process as the mature tree that already went through series of environment adaptation in many years. The chlorophyll content decreased as the leaf nitrogen (N) decreased. The chlorophyll content recorded positive correlation ($P<0.05$) with the tree morphology parameters, except canopy size. The rate of photosynthesis, transpiration rate, and stomatal conductance increased from 1-year-old and began to decreased once reached age of 14, while chlorophyll content continuously decrease from 1-year-old to 20-year-old. The leaf N, phosphorus (P), potassium (K), magnesium (Mg), and calcium (Ca) were included in the leaf nutrient analysis. The leaf N was decline significantly ($P<0.05$) in 1-year-old stand while leaf Ca was increase significantly ($P<0.05$) in the 20 years old stand during the yearly assessment. Only leaf P showed significant correlation ($P<0.01$) with LAI. The leaf N, P, and Mg were decreased with stand age, while leaf K and Ca presented the opposite trend. The soil total N, available P, exchangeable K, Mg, and Ca as well as pH, moisture and bulk density were analyzed in the soil property studies. No obvious changes in soil pH, moisture, bulk density and exchangeable Mg between stands. Significant reduction ($P<0.05$) in soil total N, available P and exchangeable K were observed in the older stands. The soil total N was negatively correlated with the tree morphology while soil available P and exchangeable Ca recorded the opposite result. The soil total N, available P, and exchangeable K were reduced as these nutrients were greatly consumed for the tree growth compared to exchangeable Mg and Ca. The current study indicated that forest rehabilitation using *D. beccarii* as one of the tree species can restore a good forest within 20 years.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

**PENGARUH UMUR KE ATAS PERMBOLEHUBAH
PERTUMBUHAN *Dryobalanops beccarii* DYER DI SEBUAH HUTAN
PEMULIHAN**

Oleh

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Dryobalanops beccarii adalah salah satu spesies pokok asli yang terdedah di Malaysia. Untuk memulihara dan melindungi spesies ini, tindak balas pertumbuhan sepanjang hayat species ini perlu dikaji. Walau bagaimanapun, maklumat mengenai kadar pertumbuhan *D. beccarii* pada usia yang berlainan adalah terhad. Oleh itu, kajian perkembangan ontogenetik *D. beccarii* telah dilakukan di kawasan Hutan Pemulihan Universiti Putra Malaysia (UPM)-Mitsubishi di UPM Kampus Bintulu Sarawak. Tujuan kajian ini adalah untuk memerhati perkembangan pertumbuhan *D. beccarii* dan memahami perubahan fisiologi dan morfologi daun serta batang pokok pada setiap perkembangan ontogenetik yang berbeza. Dirian pokok yang berusia 1, 9, 14 dan 20 tahun telah dipilih untuk kajian ini di mana sekurang-kurangnya 4 batang *D. beccarii* dapat dijumpai di setiap dirian umur. Saiz dirian pokok yang diwujudkan adalah berukuran 30 × 10 m. Parameter yang dikaji adalah morfologi pokok, morfologi dan fisiologi daun, dan sifat-sifat tanah yang terpilih. Kajian morfologi *D. beccarii* melibatkan ketinggian pokok (ketinggian keseluruhan dan batang pokok boleh niaga), diameter batang pokok, saiz kanopi (kedalaman dan diameter), dan Indeks Luas Daun (ILD). Kadar pertumbuhan ketinggian keseluruhan telah meningkat dengan cepat pada tahap awal dan menurun ketika dirian pokok berusia 20 tahun disebabkan persaingan untuk mendapatkan cahaya dan ruang daripada pokok persekitaran. Perubahan dalam ketinggian keseluruhan kemudiannya diiringi dengan kadar pertumbuhan yang cepat dan jelas oleh ketinggian batang pokok boleh niaga dan diameter batang dalam dirian pokok yang berusia 9 tahun. Apabila mencapai ketinggian yang tertentu, pokok muda mula memberi tumpuan terhadap pertumbuhan batang untuk menyokong ketinggian pokok. Kepadatan pokok yang tinggi dalam dirian pokok yang berusia 14 tahun menyumbang kepada nilai ILD yang tinggi. Pengembangan saiz kanopi adalah cepat dalam dirian pokok yang

berusia 20 tahun untuk mengisi ruang kosong di antara pokok. Ketinggian pokok meningkat secara *sigmoid* mengikut masa kerana pertumbuhan adalah cepat pada usia 1 hingga 9 tahun dan berkurangan apabila mencapai umur 14 tahun. Sementara itu, diameter batang, saiz kanopi, dan ILD menunjukkan pertumbuhan berterusan sehingga mencapai umur 20 tahun. Keluasan, lebar, panjang, tebal daun, dan ketumpatan stomata telah ditentukan dalam kajian morfologi daun. Morfologi daun berkorelasi secara signifikan dengan parameter morfologi pokok, kecuali lebar daun dan diameter kanopi. Berbanding dengan parameter morfologi daun yang lain, lebar daun dan ketumpatan stomata didapati telah menurun dengan ketara ($P < 0.05$) semasa penilaian tahunan di dalam setiap dirian pokok yang berbeza usia disebabkan tindakbalas menghadapi musim kemarau. Dirian pokok yang berusia 20 tahun mencatat keluasan, ketebalan, lebar, dan panjang daun tertinggi. Disebabkan penyesuaian daun kepada pertindihan lapisan silara pokok, saiz daun adalah lebih besar di pokok matang daripada pokok juvana. Kadar fotosintesis, transpirasi, kealiran stomata, dan kandungan klorofil telah dimasukkan dalam kajian fisiologi daun. Persamaan di antara kadar fotosintesis, kadar transpirasi, dan kealiran stomata dijumpai. Kadar parameter ini adalah rendah pada anak pokok *D. beccarii* yang baharu ditanam, meningkat dengan pesat di antara usia 9-14 tahun, dan menurun apabila mencapai fasa matang. Pokok muda tidak cekap dalam proses fisiologi berbanding dengan pokok matang yang sudah melalui siri adaptasi persekitaran selama beberapa tahun. Kandungan klorofil menurun apabila jumlah nitrogen (N) daun menurun. Kandungan klorofil mencatatkan hubungan yang positif ($P < 0.05$) dengan parameter morfologi pokok, kecuali saiz kanopi. Kadar fotosintesis, transpirasi, dan kealiran stomata telah meningkat pada dirian pokok yang berusia 1 tahun dan mula menurun apabila dirian pokok mencapai umur 14 tahun, manakala kandungan klorofil terus berkurangan dari dirian pokok yang berusia 1 hingga 20 tahun. Jumlah N, fosforus (P), kalium (K), magnesium (Mg), dan kalsium (Ca) telah dimasukkan dalam analisis daun nutrien. Daun N mencatat penurunan ketara ($P < 0.05$) dalam dirian pokok yang berusia 1 tahun manakala daun Ca mencatat peningkatan ketara ($P < 0.05$) di dalam dirian pokok yang berusia 20 tahun semasa penilaian tahunan. Hanya daun P menunjukkan hubungan kolerasi yang signifikan ($P < 0.01$) dengan LAI. Daun N, P, dan Mg telah menurun dengan usia dirian pokok, manakala daun K dan Ca menunjukkan tren yang sebaliknya. Untuk analisis tanah, jumlah tanah N, P tersedia, K, Mg, dan Ca tukarganti, pH tanah, kelembapan tanah, dan ketumpatan pukal telah dianalisis. Tiada perubahan yang ketara direkodkan untuk pH tanah, kelembapan tanah, ketumpatan pukal, dan Mg tukarganti di antara dirian pokok. Penurunan yang ketara ($P < 0.05$) dalam jumlah tanah N, P tersedia, dan K tukarganti telah diperhatikan di dalam dirian yang matang. Jumlah N telah berkolerasi secara negatif dengan morfologi pokok manakala P tersedia dan Ca tukarganti mencatat keputusan yang bertentangan. Jumlah N, P tersedia, dan K tukarganti berkurangan kerana nutrien tersebut banyak digunakan untuk pertumbuhan pokok berbanding Mg dan Ca tukarganti. Kajian ini menunjukkan pemulihan hutan menggunakan *D. beccarii* sebagai salah satu species pokok boleh memulihkan dirian hutan yang baik dalam masa 20 tahun.

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LIST OF ABBREVIATIONS

CR	Critically Endangered
DD	Data Deficient
DBH	Diameter at Breast Height
EN	Endangered
EX	Extinct
IUCN	International Union for Conservation of Nature
LAI	Leaf Area Index
LC	Least Concern
NT	Near Threatened
RA	Rare
VU	Vulnerable
WWF	World Wildlife Fund



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CHAPTER 1

INTRODUCTION

Tropical rainforest has one of the most diverse plant communities, with several monodominant tree species reported to be endemic in specific regions (Makana *et al.*, 2004). The distribution of tree species varies, based on the type of geography, habitat boundaries, and climate (Bermingham *et al.*, 2005; Lieth and Werger, 2012; Osborne, 2000). Throughout Southeast Asia, tropical rainforest has been degraded intensively into several patches of forests over the past few decades. The conversion and land-use activities created disturbances to the forests. Depending on the severity of disturbances, plant diversity may be scarcer than those of the virgin tropical rainforest (Okuda *et al.*, 2013). As the time elapsed after the disturbances, forest regeneration or succession of secondary forests occurs, filling the empty gaps between the fragmented forests (Kenzo *et al.*, 2007). Koh (2007) reported that the secondary forest constituted 63% of Southeast Asia total forest cover in 2005. However, having similar fate as the virgin tropical rainforest, the secondary forest was also facing the risk of land conversion and intensive logging, due to declining timber stocks and reduction in timber concessions (Dennis *et al.*, 2008; Food and Agriculture Organization, 2007).

Forest rehabilitation was implemented in order to return the degraded forest into stable and productive condition dominated by trees. Forest rehabilitation efforts require inclusive understanding and assessment on the ecosystem and species diversity involved, as each type of degraded forest has to be rehabilitated using different approaches and technologies (Lee and Maheswaran, 2010). One of the rehabilitation methods already being implemented was the planting of fast growing indigenous tree species, especially dipterocarp species, to continuously revert the degraded forest into rich forest biodiversity state (Kenzo *et al.*, 2007; Kobayashi *et al.*, 2001; McNamara *et al.*, 2006). The dipterocarp forest was greatly affected by forest degradation activities (Corlett, 2014), due to the fact that the tree species are ecologically dominant and economically substantial. The dipterocarp from Southeast Asia countries contributes 80% of the world timber exports (ITTO, 2008). In Malaysia, dipterocarp is a hardwood source for plywood and sawn timber, which accounted for 25.1% and 12.4% respectively of the total timber export value in 2010 (Malaysian Timber Council, 2015).

Among the dipterocarp tree species, *Shorea* spp., *Dipterocarpus* spp., and *Dryobalanops* spp., were severely harvested from hill and swamp forest in Sabah and Sarawak (Pakhriazad, 2010). The uncontrollable exploitation activities of the dipterocarp forest leads to decreasing number of tree

species and deteriorates the environment (Julia *et al.*, 2014). Thus, the selection of priority species was performed due to the tremendous variation in growth among the species. Several studies have been conducted in Sarawak to understand the ecological aspects of rehabilitating tropical rainforests. These studies focus on species selection, for replanting in relation to the growth performance, numerous planting methods, and soil properties on areas after establishment of rehabilitation activities (Daisuke *et al.*, 2013; Kenzo *et al.*, 2007; Kobayashi *et al.*, 2001; Yit Leng *et al.*, 2009).

Available information on growth performance of different age stands as well as relationship responses between the tree characteristic and physiological changes over time is still lacking. One of the dipterocarp species selected for the rehabilitation programs is *Dryobalanops beccarii* Dyer. In commercial dipterocarp timber, *D. beccarii* belong to the medium hardwood, which possesses yellowish-brown sapwood color which is sharply defined from the reddish-brown heartwood. The trade name of *D. beccarii* is *Kapur* (Schulte and Schone, 1996). Due to the rarity of *D. beccarii*, the species is classified as endangered under the Global IUCN Red List (Julia *et al.*, 2014).

Hence, this study was carried out in order to observe the growth performance of *D. beccarii* and to understand the changes in physiological and morphological of leaves as well as growth performance during different tree ontogenetic development stages. This study hypothesized that growth performance as well as leaf physiological and morphological changes of *D. beccarii* increase with stand age. The tree morphology measurement was assessed every 6 months in Universiti Putra Malaysia (UPM)-Mitsubishi Forest Restoration area. The morphology and physiology of leaves as well as soil properties were done twice, which was at the beginning and at the end of the study.

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