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AGE-RELATED CHANGES IN Shorea dasyphylla FOXW. GROWTH AND PHYSIOLOGY

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AGE-RELATED CHANGES IN *Shorea dasyphylla* FOXW. GROWTH AND PHYSIOLOGY

By

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November 2021

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Shorea dasyphylla Foxw. is an important indigenous timber species in Malaysian forestry. In recent years, initiation of restoration programmes using indigenous tree species such as *S. dasyphylla* is due to continued demand of tropical timbers, especially dipterocarps. However information regarding age-related change in tree growth and physiology is scarce. This study was specifically conducted to assess the growth performance of *Shorea dasyphylla* trees at different stand ages through its physiological and morphological measurements. The study plots were located at the Universiti Putra Malaysia–Mitsubishi Forest Restoration project area of Universiti Putra Malaysia Bintulu, Sarawak Campus. Plots of 300 m^2 were selected, representing stands of different ages namely 1- (P1), 9- (P9), 14- (P14), and 20- (P20) years old. Four *S. dasyphylla* trees or seedlings were selected from in each plot for the study. Tree morphology measurements were assessed every six months for a period of 18 months. On the other hand, the morphology and physiology properties of the leaves as well as the soil properties were also determined. Both total height and diameter breast height growth showed a sigmoid trend as the tree aged. P9 recorded the slowest total height increment pace than the other three stands. P1 focused on both shoot apical meristem growth, especially in the third measurement interval, whereas P20 focused primarily on radial growth. In the third measurement interval of the study (after one year), a significant height increase in P1 was seen, which was most likely due to the well-established root systems that let these seedlings absorb more soil moisture and nutrients. Apart from that, the leaf area, width, length, thickness and chlorophyll content showed significant increment as the tree aged. P1 stand was also observed to have narrow, short and thin leaves compared to both canopy layers of the older stands (P14 and P20). The transpiration rate in P1 leaf was the highest, which then linearly declined over time. No significant difference was observed for leaf stomatal density in all stand age. The photosynthetic rate and stomatal conductance increased gradually until they reached their peak ages (12 to 18 years and 14 years respectively) and the decline continuously over time with a clear polynomial trend. There was no significant relationship identified between leaf N concentration and stand age. P9 recorded the lowest leaf N while the highest was recorded by P14. A constant decrease in P content was found in the leaf over time with polynomial trend. The leaf K, Mg and Ca content shared a similar trend where the value decreased until a certain age 14 years (K), 9 years (Mg) and 9 years (Ca) respectively before they started to increase afterward. Soil available P and exchangeable Mg showed reduction in values with increasing stand age as these nutrients were greatly consumed for tree growth. The value of soil exchangeable K declined until year 10 before it started to increase with a polynomial association. The soil exchangeable Ca increased exponentially with time and significantly higher value was recorded by the oldest stand. The overall results suggested that age does influence the growth, and leaf morphological and physiological development of *S. dasyphylla*.

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

PERUBAHAN PERKAITAN UMUR DALAM PERTUMBUHAN DAN FISIOLOGI *Shorea dasyphylla* Foxw.

Oleh

IRA CARLBRENIE SIMOL

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Shorea dasyphylla Foxw. adalah spesies kayu asli yang penting dalam perhutanan Malaysia. Di dalam beberapa tahun kebelakangan ini, program pemulihan menggunakan spesies pokok tempatan seperti *S. dasyphylla* dimulakan disebabkan oleh permintaan kayu tropika yang berterusan, terutamanya dipterocarp. Walaubagaimanapun maklumat mengenai perubahan berkaitan umur dalam pertumbuhan dan fisiologi pokok adalah terhad. Kajian ini dilakukan secara khusus untuk menilai prestasi pertumbuhan pokok *Shorea dasyphylla* pada dirian usia yang berlainan melalui pengukuran fisiologi dan morfologi. Petak kajian terletak di dalam kawasan projek Hutan Permuliharaan Universiti Putra Malaysia–Mitsubishi, Universiti Putra Malaysia Kampus Bintulu Sarawak. Petak kajian seluas 300 m^2 telah dipilih, yang mewakili kumpulan umur yang berbeza iaitu anak pokok yang berumur 1 (P1), 9 (P9), 14 (P14) dan 20 (P20) tahun. Empat pokok *S. dasyphylla* telah dipilih sebagai pokok kajian dari setiap petak. Pengukuran morfologi pokok dinilai setiap enam bulan untuk jangka masa 18 bulan. Morfologi dan fisiologi daun serta sifat tanah juga ditentukan. Pertumbuhan ketinggian total dan DBH menunjukkan tren sigmoid selari dengan umur pokok. P9 merekodkan peningkatan ketinggian keseluruhan yang paling lambat berbanding pokok-pokok kumpulan umur yang lain. Dalam kajian semasa, P1 *S. dasyphylla* memfokuskan pada pertumbuhan meristem apikal, terutama pada separuh ketiga pengukuran, sedangkan P20 memberi tumpuan terutamanya pada pertumbuhan radial. Pada separuh ketiga kajian (setelah satu tahun), peningkatan ketinggian P1 yang ketara dilihat, yang kemungkinan besar disebabkan oleh sistem akar yang telah mantap di mana dapat membantu anak pokok lebih banyak kelembapan dan nutrien. Selain itu, luas daun, lebar, panjang, ketebalan dan kandungan klorofil menunjukkan kenaikan yang ketara seiring dengan penuaan pokok. Dirian pokok P1 juga didapati mempunyai daun yang tirus, pendek dan nipis jika dibandingkan dengan daun-daun dari pokok yang lebih tua (P14 dan P20). Kadar transpirasi pada daun P1 adalah tertinggi dan kemudian menurun secara linear mengikut masa. Tidak ada perbezaan yang bererti untuk ketumpatan stomatal daun pada semua usia pokok. Kadar fotosintesis dan konduktans stomata meningkat secara beransur-ansur sehingga mencapai usia puncaknya (masing-masing 12 hingga 18 tahun dan 14 tahun) dan selepas ini mencatat penurunan dengan menunjukkan pola polinomial

yang jelas. Tidak terdapat hubungan yang signifikan antara kepekatan daun N dan usia dirian. P9 mencatatkan jumlah N daun yang paling rendah manakala P14 mencatatkan jumlah N daun yang tertinggi. Jumlah kandungan K, Mg dan Ca pada daun menunjukkan corak yang sama di mana kandungan menurun sehingga umurnya 14 tahun, 9 tahun (K) dan 9 tahun (Mg dan Ca) sebelum mereka mulai meningkat kembali mengikut masa. Kandungan tanah P tersedia dan Mg tukarganti menunjukkan pengurangan dengan peningkatan usia pokok, kerana nutrien ini banyak diserap bagi menampung pertumbuhan pokok. Jumlah kandungan tanah K tukar ganti juga merosot sehingga tahun ke 10 sebelum nilainya meningkat dengan tren polinomial. Jumlah kandungan tanah Ca tukrganti meningkat secara eksponen dengan masa dan dirian yang tua merekodkan nilai yang tinggi serta bererti. Berdasarkan hasil kajian ini, usia pokok dikatakan mempengaruhi pertumbuhan, dan morfologi dan fisiologi daun *S. dasyphylla*.

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I certify that a Thesis Examination Committee has met on 26 November 2021 to conduct the final examination of Ira Carlbrenie Simol on her thesis entitled "Age-Related Changes in *Shorea dasyphylla* Foxw. Growth and Physiology" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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Declaration by graduate student

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LIST OF ABBREVIATIONS

%	Percentage
μmol	Micromole
^0C	Temperature (degree Celsius)
A/Q	Photosynthetic light response curves
A_{1500}	Light saturated net photosynthesis
A_{max}	Maximum photosynthetic rate
APAR	Absorbed photosynthetically active radiation
ATP	Adenosine triphosphate
C	Carbon
CO_2	Carbon dioxide
Ca	Calcium
CAI	Current annual increment
CIFOR	Center for International Forestry Research
cm	Centimetre
cm^2	Square centimeter
cm^3	Cubic centimeter
cmol	Centimole
CR	Critically Endangered
DBH	Diameter at breast height
DD	Data Deficient
EN	Endangered
IUCN	International Union for Conservation of Nature
ITTO	International Tropical Timber Organisation

NT	Near Threatened
PAI	Periodic annual increment
PPFD	Photosynthetic photon flux density
RAPA	Regional Office for Asia and Pacific (FAO)
VU	Vulnerable
WWF	World Wildlife Fund

CHAPTER 1

INTRODUCTION

1.1 General Background

Tropical rainforests has one of the most diverse plant communities, with several mono-dominant tree species reported to be endemic in specific regions (Makana *et al.*, 2004). Over the past few decades, tropical rainforests have been intensively degraded into several patches of forest across Southeast Asia (Okuda *et al.*, 2013). Forest degradation activities have greatly affected the dipterocarp forests (Corlett, 2014), owing to the fact that the tree species are ecologically dominant and economically significant. In 2020, tropical timber production accounted for 16.8% of total global production (ITTO, 2021). In Malaysia, dipterocarp is a source of hardwood for wooden furniture, plywood, and sawn timber accounted for almost 72% in the total export value of timber in 2020 (MTC, 2021).

In order to return the degraded forest to a stable and productive condition dominated by trees, forest rehabilitation has been introduced. The fast-growing indigenous tree species, in particular dipterocarp, have now been planted to continuously rehabilitate the forest to a high state of biodiversity (Kobayashi *et al.*, 2001; McNamara *et al.*, 2006; Kenzo *et al.*, 2007).

Shorea dasyphylla Foxw. or locally known as *Meranti batu* is one of the dipterocarp species used in the rehabilitation effort owning to availability of seeds supply in Sarawak. *Shorea dasyphylla* produces light red *Meranti* timber and belong to the medium hardwood. This species possesses reddish sapwood and reddish-brown heartwood (Schulte and Schone, 1996). *Shorea dasyphylla* is widely distributed and can be found in mixed dipterocarp forests of Peninsular Malaysia, Sumatra and Borneo (Chua *et al.*, 2010; Yong *et al.*, 2011). Naturally, this species is an emergent tree, and can grow up to 45 m tall with diameter up to 110 cm with stout buttresses (Soepadmo *et al.*, 2004). Globally *S. dasyphylla* is labelled as an endangered species (IUCN, 2021), however, regionally this species is categorized as vulnerable in Peninsular Malaysia (Chua *et al.*, 2010) and least concern in Sarawak respectively (Julai *et al.*, 2014).

Once established on site, trees are subjected to countless environmental conditions as they survive and grow across different ontogenetic stages. As they aged, trees experienced complex changes in morphology and biology that developed into versatile structures (Coste *et al.*, 2009). Plasticity of leaves morphology and physiology characteristics is momentously affected by development of tree structure. Leaves are a crucial organ of a tree. They have an ability to produce food and act as the sensor to detect changes for a tree. Their adaptability in various environmental conditions is remarkable. Shape of leaves, their sizes and permanency may vary significantly as tree age (Kertiens, 1996b).

Leaf gas exchange performance is greatly influenced by changes in its traits (Kertiens, 1996a). Leaf upper surface effectively gathers energy from sunlight while the underside exchanges CO_2 and O_2. To facilitate the gas diffusion process, leaf thickness is optimally minimized. Exteriorly, epidermal cell layers that stash waxy and impermeable cuticles to protect the leaf from dehydration. Interiorly, the number of stomata and chlorophyll content directly influence gas exchange properties. Lawson and Blatt (2014) suggested that the abundant number of stomata may directly affect the rate of photosynthesis, stomatal conductance, and transpiration rate. However these leaf gas exchange characteristics may differ as the tree age due to ever changing environmental conditions in rainforest and dynamic tree structures (Day *et al*., 2001; Hubbard *et al*., 2001).

Tree species vary sustainably in acquiring resources (C, nutrient, and water), investing them into different tissue parts, and losing them through turnover although most of these species have similar basic physiological roles. Cornewell *et al*. (2014) reported that up to 10% of the world's plant species noticeable traits such as leaf, wood, or seed are now made available. As more data accumulated, more predictions on plant growth, lifespan, and performance patterns were conducted (Van Kleunen *et al*., 2010; Wright *et al*., 2010; Adler *et al*., 2014). Recently Visser *et al*. (2016) and Gibert *et al*. (2016) have established that plant growth can be altered by plant size. Woody plants growth rates when expressed as height, or diameter incline to display hump-shaped relationships with size (Hérault *et al*., 2011; King, 2011).

There is still a lack of available information on the growth performance of different age as well as relationship responses between the tree characteristics and physiological changes over time. This study was carried out to observe the growth performance of *S. dasyphylla* during the different stages of tree development. Measurement conducted also help to understand the physiological and morphological changes of the leaves.

1.2 Problem Statement

The problem to be addressed by this study is the lack of information on age-related changes in growth and leaf traits (form and physiology) over the long life spans of tropical wood species.

As a tree grows and ages, changes in terms of morphology and biology become more complex, while various environment conditions across ontogenetic phases, changes its growth, size and structure (Coste *et al*., 2009). Large amount of research findings were reported on age and size-related changes as summarized by Hincklet *et al*. (2011). They also identified research gaps needed to improve the understanding of changes in structure and function changes that happen over the lifespan of a tree. Differences in pattern needed to be clarified among taxonomic groups (angiosperms and gymnosperms) and different stages of growth. Angiosperms and gymnosperms usually followed different developmental and physiological directions. Reported research is currently concentrated more on gymnosperms. In recent years, tree species in angiosperms are getting more attention. Although tropical rainforests accounted for a significant portion of global primary production (Kumagai *et al*., 2004), information on age- or size-related changes in growth and leaf traits is much lacking (see Literature Review). Therefore, there is a need for a detailed understanding of the changes in growth and leaf characteristics over their lifetime.

Most trees planted or grown naturally in multi-cohort stands will experience diverse environmental conditions over their life cycle. They are subjected to different light regimes, wind intensities, water stress, temperature variation and space competition (Sanches *et al*., 2010). In an unpredictable environment, trees will change their growth traits in order to continue to survive by maximizing their fitness (Bazzaz, 1991). Over a lifetime, seedling stage is one of the most selective for tropical tree species as they usually experienced higher mortality rate due to availability of limited supply of resources due to their underdeveloped and shallow root systems and their low photosynthetic capacity (Ishida *et al*., 2005). Many found that under similar light conditions, fully expended leaves differ in leaf traits among different stages of ontogenetic development, however the reasons for these differences still remain unclear (Ishida *et al*., 2005). Therefore, to understand the establishment and growth processes of trees, concurrent measurement during different phases of ontogenetic development are critical. Available information will provide additional details to develop CO_2 fixation models for tropical rainforests (Kenzo *et al*., 2006).

1.3 Study Objectives

This study was conducted specifically to:

i. assess growth performance of *S. dasyphylla* trees at different age;

ii. determine physiological and morphological of *S. dasyphylla* leaves at the different stages of tree development; and

iii. establish the relationship between growth performance, leaf physiological and morphological, and soil characteristic properties.

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