GROWTH AND PHYSIOLOGICAL CHARACTERISTICS OF ACACIA SPECIES IN A PROGENY TRIAL

ABDUL LATIB SENIN

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GROWTH AND PHYSIOLOGICAL CHARACTERISTICS OF *ACACIA* SPECIES IN A PROGENY TRIAL

By

ABDUL LATIB SENIN

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

July 2016

DEDICATION

This thesis is dedicated to,

My wife, Rohana Abdul Rahman and my children, for her unconditional support, love, patience, and give me the courage to persevere in pursuing this learning.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Master of Science

GROWTH AND PHYSIOLOGICAL CHARACTERISTICS OF *ACACIA* SPECIES IN A PROGENY TRIAL

By

ABDUL LATIB B. SENIN

July 2016

Chairman: Assoc. Professor Hazandy Abd. Hamid, PhD
Faculty: Institute of Tropical Forestry and Forest Product

Acacia has introduced in Malaysia since 1932, as a shade tree, soil erosion control and widely planted in the tropics area. *Acacia* has introduced as a plantation species since 1978, with a focused on lumber production in the short term rotation. The objective of this study was to increase the knowledge about the best of *Acacia* from four species in term of the regions, provenances, progeny, and physiological characteristics. A field trial was established at Kampung Aur Gading, Kuala Lipis, Pahang, by using a completely randomized block design (RCBD) with four replications from 16 provenances comprising 410 families originated from PNG and QLD region. In this study, significant differences at $p< 0.05$ were observed between regions, provenances, and species for height, diameter at breast height, and survival. Among the four species, *A. mangium* found to be the most outstanding with its potential provenance from Bensbach WP (PNG) and SW of Boset WP (PNG). Meanwhile, *A. aulacocarpa* was better in the stem form, i.e., the second ranking behind *A. mangium*, but uppermost in class two. In another study of *A. aulacocarpa* from four provenances and twenty progenies, significant difference at $p<0.05$ for height, dbh and stem form. Arufi East Morehead WP and West Morehead provenances from PNG has better performance in terms of height, dbh, and survival compared with QLD. The best progenies in terms of height and survival rate were from progeny AR 000011 and BVG 00861 while the progeny BVG 00859 was the best in terms of Dbh. However, progeny GB 100 is the poorest. The gas exchange attributes of *A. aulacocarpa* species confirmed that the effect of different season influenced on the tree growth. The leaf area ratio and crown width also examined and the measurements were performed in dry and wet seasons. The results indicated that all gas exchange parameters exhibited higher rates in PNG provenances compared to QLD provenances, where W. Morehead outperformed the others. The progeny (BVG 00861) had the best overall physiological characteristics while the progeny (BVG 00860) had the best outcomes in the dry season while the progeny BVG 00859 performed best in the wet season. These findings clearly indicated that the differences in genotype, regions, provenances, and progeny contribute to different growth. The season changes, environmental conditions, and geographical location were also influenced the internal physiological characteristics of trees and these factors play a significant part in the growth of a tree.

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

PERTUMBUHAN DAN CIRI-CIRI FISIOLOGI KE ATAS SPESIS *ACACIA* DALAM PERBICARAAN KETURUNAN

Oleh

ABDUL LATIB B. SENIN

Julai 2016

Pengerusi: Professor Madya Hazandy Abd. Hamid, PhD
Fakulti : **Institut Perhutanan Tropika dan Pengeluaran Hutan**

Akasia telah diperkenalkan di Malaysia sejak tahun 1932, sebagai pokok naungan, kawalan hakisan tanah dan ditanam secara meluas di kawasan tropika. *Akasia* telah diperkenalkan sebagai spesis ladang sejak tahun 1978, dengan memberi tumpuan kepada pengeluaran kayu dalam putaran jangka pendek. Objektif kajian ini adalah untuk meningkatkan pengetahuan mengenai *Akasia* yang terbaik daripada empat spesis dari segi rantau, asal-usul, keturunan, dan ciri-ciri fisiologi. Kajian lapangan dilakukan di Kampung Aur Gading, Kuala Lipis, Pahang, dengan menggunakan reka bentuk blok rawak penuh (RCBD) dengan empat ulangan daripada 16 asal-usul yang terdiri daripada 410 keluarga yang berasal dari wilayah PNG dan QLD. Dalam kajian ini, perbezaan yang signifikan pada $p<0.05$ diperhatikan di antara rantau, asal-usul, dan spesis untuk ketinggian, diameter paras dada, dan kelangsungan hidup. Antara empat spesis, *A. mangium* didapati paling cemerlang potensinya dengan asal-usul dari Bensbach WP (PNG) dan SW Boset WP (PNG). Sementara itu, *A. aulacocarpa* baik dalam bentuk batang, iaitu, kedudukan kedua di belakang *A. mangium*, tetapi tinggi dalam kelas dua. Dalam kajian yang lain, *A. aulacocarpa* daripada empat asal-usul dan dua puluh progeni, terdapat perbezaan yang signifikan pada $p<0.05$ untuk ketinggian, perempang dan bentuk batang. Asal-usul dari Arufi East Morehead WP dan West Morehead dari PNG mempunyai prestasi yang lebih baik dari segi ketinggian, perempang, dan kelangsungan hidup berbanding dengan QLD. Progeni terbaik dari segi kadar ketinggian dan kelangsungan hidup adalah dari keturunan AR 000011 dan BVG 00861 dan keturunan BVG 00859 pula terbaik dari segi perempang. Manakala keturunan GB 100 adalah yang paling miskin. Sifat-sifat pertukaran gas spesis *A. aulacocarpa* mengesahkan bahawa kesan musim yang berbeza mempengaruhi pertumbuhan pokok. Nisbah luas daun dan lebar mahkota juga dikaji dan pengambilan data telah dijalankan pada musim kering dan basah. Keputusan menunjukkan bahawa pertukaran gas dipamerkan tinggi dari asal-usul PNG berbanding asal-usul QLD, di mana W. Morehead mengatasi yang lain. Keturunan (BVG 00861) terbaik keseluruhan manakala keturunan (BVG 00860) terbaik pada musim kemarau, dan keturunan BVG 00859) terbaik di musim hujan. Hasil kajian ini jelas menunjukkan bahawa perbezaan dalam genotip, rantau, asal-usul, dan keturunan menyumbang kepada pertumbuhan yang berbeza. Perubahan musim, keadaan persekitaran, dan lokasi geografi juga mempengaruhi ciri-ciri fisiologi dalaman pokok dan faktor-faktor ini memainkan peranan penting dalam pertumbuhan pokok.

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I certify that a Thesis Examination Committee has met on 20 July 2016 to conduct the final examination of Abdul Latib Senin on his thesis entitled "Growth and Physiological characteristics of *Acacia* species in a Progeny Trial" 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.

Members of the Thesis Examination Committee were as follows:

Azmy bin Mohamed, PhD
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

Mohamad Azani bin Alias, PhD
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Internal Examiner)

Siti Rubiah Zainudin, PhD
Associate Professor
Universiti Malaysia Sarawak
Malaysia
(External Examiner)

_____
ZULKARNAIN ZAINAL, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 23 August 2016

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Hazandy Abd. Hamid, PhD
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

Ong Kian Huat, PhD
Senior Lecturer
Faculty of Agriculture and Food Sciences
Universiti Putra Malaysia (Bintulu Campus)
(Member)

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School of Graduate Studies
Universiti Putra Malaysia

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LIST OF ABBREVIATIONS AND SYMBOLS

ACAIR	Australian Centre for International Agriculture Resources
A_{net}	Net photosynthetic rate
ANOVA	Analysis of Variance
CFPP	Compensatory Forestry Plantation Project
^oC	Degree centigrade
cm^2	Centimetre square
CR	Composite Ranking
CSIRO	Commonwealth Scientific and Industrial Research Organization
D	Leaf vapour pressure
Dbh	Diameter at Breast Height (1.3 m from the ground)
Df	Degree of freedom
DMRT	Duncan's Multiple Range Test
E	East
E	Transpiration
FAO	Food and Agriculture Organization
G	Gram
g_s	Stomata conductance
µg/ml	Microgram per millilitre
g/L	Gram per litre
ha	Hectares
IUFRO	International Union of Forestry Research Organizations
Kg	Kilogram
kg/m^3	Kilogram per metre cubic
kcal kg^{-1}	Kilocalorie per kilogram
kPa	Kilopascal (unit of pressure)
L	Litre
Ψ_L	Leaf water potential
Ψ_{Rw}	Root water potential
LAR	Leaf Area Ratio
LSD	Least Significant Different
m	Meter
MA1	Mean Annual Increment
Mg	Milligram

Mg/L	Milligram per litre
Ml	Millilitre
Mm	Millimetre
MPa	MetrePascal
µM	MicroMolar
$\mu molm^{-2}s^{-1}$	Micromole per metre squares per second
N	Nitrogen
pH	Negative logarithm of the hydrogen concentration
ppm	Part per million
%	Percentage
MOST1	Ministry of Science, Technology and Innovation
Ms	Mean of Square
Mt.	Mountain
N	North
NAS	National Academy of Science
PAR	Photosynthetic Active Radiation
PNG	Papua New Guinea
Ppm	Part per Millions
Q	Photon flux
QLD	Queensland
RCBD	Randomized Complete Block Design
SAFODA	Sabah Forestry and Development Authority
SAS	Statistical Analysis System
syn.	Synonym
UPM	Universiti Putra Malaysia
V	Volumes
v/v	Volume over volume
w/v	Weight over volume
W	West
WP	West Provenance
WUE	Water used efficiency

CHAPTER 1

INTRODUCTION

1.1 General background

In the Asia Pacific region, forest areas covered a little less than a third of the total land area. Based on estimated data from the Food and Agriculture Organization of the United Nations (FAO, 2011), the forest area in Asia was 740 million hectares in 2010, and the Southeast Asian region had 214 million hectares of forest. However, the total forested area in Peninsular Malaysia had decreased to 579,000 hectares (43.9%), and forest plantations were about 200,000 hectares (Department of Forestry, 2012). The forest cover reduction was due to various factors, such as logging operations, population increase, and the transmigration program for expanding agriculture, and this had reduced the forests by converting forested land to other uses. It is clear that in order to overcome this deficit and to provide for the potential increase in wood demand from the downstream processing activities, hence the tree planting is required (Mahmud, 1997).

According to Barnett and Jeronimidis (2003), demand for forest products increased by 1% per year, and this contributed to increasing the growing worldwide demand for high-value products. According to FAO, demand reached 3.9 billion m^3 in 2010, of which half was fuel wood, which was used generally in the developing countries (Asia Timber, 1998). FAO has forecasted a shortage of industrial round wood of about 110 million m^3 by the year 2015, with the consumption attaining 2.28 billion m^3 compared to a yield estimated at 2.17 billion m^3 (Asian Timber, 1998). In the Seventh Malaysia Plan (1996 – 2000), the annual log production was only 28.3 million m^3, which are 7.4, 5.4 and 15.5 million m^3 respectively from Peninsular Malaysia, Sabah, and Sarawak. This represents a decrease of 17% compared to the average of 34 million m^3 per year under the Sixth Malaysia Plan (Thai, 1995). The local supply of logs up to the year 2010 has been projected about 13.7 million m^3 (Abdul Razak, 1997). Based on this projection, it is obvious that in order to overcome the deficit and to provide for the potential increase in demand for the downstream processing of the industry, hence, extensive tree planting is needed (Mahmud 1997).

In Malaysia, with the increasing domestic demand for wood and timber products due to population increase, there is an urgent need to develop and expand the forest resources in the country. One of the adopted strategies is to implement fast-growing tree species that can increase the supply for the wood industry. Both the public and private sectors are encouraged to be seriously involved in tree planting with short rotation cycles for higher economic returns from investments in forest plantations. In addition, forest plantations can provide a significant yield of uniform quality wood in a short period and reduces the strain on the remaining natural forest resources (Brown et al., 1997; Turnbull et al., 1998a). Moreover, large-scale development of industrial forest plantations with fast growing tree species, especially on degraded lands, anticipated to be essential in tropical forestry in the 21st century (Sayer et al., 1997). In spite of the growing plantation activities, the growing demand for industrial wood, the mostly wood pulp will continue to degrade the natural forest without a substantial increase in the plantation industry (Sunderlin, 1999). The insistence of this problem faced by the

Forestry Department, which has put extra effort in establishing trials of various tree species to identify the potential species for large-scale forest plantation establishment in a broad range of habitats.

In Malaysia, the fast growing species initially introduced were the *Acacia* species in 1932. As an exotic species, *Acacia* planted in over 70 countries and covered approximately 2 million hectares (Maslin and McDonald, 1996; Turnbull et al., 1998a). Thus, the tropical *Acacia* species, which grow rapidly in a short rotation period, was opted as the species for the plantation program. Accordingly, in 1982, the government implemented the Malaysian Forestry Sector Master Plan. This program proposed to add the additional timber supply to overcome the shortage of wood supply from the natural forests. In Peninsular Malaysia, for instance, nearly 55,000 ha were set-up by the Forest Department in 1983 compared to the 188,000 ha targeted by 1995 (Thai and Bongkik, 1996). Among the exotic species, *A. mangium* was the most common and extensively planted species. However, the forest plantation sector witnessed serious competition from the agricultural plantation sector, especially from the oil palm and rubber industry, which often favoured by owners of private plantations.

1.2 Significance of the Study

The main problem for establishing forest plantations is to determine the most adaptable species from the selected good genotype. Therefore, the choice of species and the origin are important before setting up the new plantation for growth trial and benefits of the available timber resource, including control of the global environment. At present, there are no proper guidelines for selecting and testing of materials and quality control in *Acacia* plantations in Malaysia. Thus, it is difficult to find uniformity in growing *Acacia* plantations in Malaysia. Moreover, the purpose of the tree improvement program is to combine stem volume growth with stem straightness for desired wood properties. Moreover, so as to produce well-adapted trees capable of supplying high-quality logs for lumber and pulpwood (Doede and Adams, 1998; Zobel and Talbert, 1984).

However, if the species are not choosing carefully and appropriately, the effects of biological disasters can occur, and results in the production of wood resources are low. In this case, the supply of appropriate seed sources should be a priority. Larsen (1954), Callahan (1964) and Lacaze (1978) states, that the successful establishment of plantations and productivity largely determined by the choice of tree species and seed sources from natural stands or seed orchards (Harwood et al., 1991). According to Steenberg (1983), the plantations in the developing countries often fail because of the lack of provenance research and the existing low genetic base has resulted in severe inbreeding depression. Moreover, the genetic gain from growing exotic species determined by the quality of the geographic race or the seed source used (Squillace, 1966). In addition, Eldridge (1978) also emphasized the importance of the correct choice of species and provenances to ensure a large and reliable supply of inexpensive forest products, which indirectly will increase the supply of forest products to magnify the role of exotic tree species. The attributes of commercially successful plantation trees such as rapid growth under plantation conditions, straight stem with limited branching, and appropriate wood quality suitable for a particular end-use. This species should tolerate a variety of soils, site conditions, and resistant to pests and diseases.

To cope with the annual world demand and reduced reliance on wood from natural forests, it is necessary to plant trees under all planting schemes to satisfy the real demand. Coinciding with the reduction in natural forest logging activities in Malaysia, there has been a rapid expansion with the establishment of short rotation medium hardwood plantations as the source of fibre pulp and wood. As tree species vary in numbers, the primary fast-growing multipurpose tree species have the potential to become the tropical tree species of choice. Among the exotic leguminous tree species selected, *A. aulacocarpa*, *A. Auriculiformis*, *A. crassicarpa*, and *A. mangium* are best adapted to humid and sub-humid tropical regions. These species grow rapidly and are suited for wood production (pulp, sawn timber). Due to their established success, a large portion of the present plantation development based on *Acacia* species particularly *A. mangium*. Meanwhile, *A. auriculiformis* and *A. crassicarpa* has successfully grown in a wide range of soil and environmental conditions, and become a popular species for reforestation, particularly in the dry zone where its performance has surpassed native species in terms of adaptability, growth, and survival. Its only disadvantage is the poor form, which precludes its use for quality poles and sawn timber (Nor Aini et al., 1994; Kamis et al., 1995).

Moreover, newcomer such as *A. aulacocarpa* species are now being accepted and will contribute to the number of species in the establishment of forest plantations in the region (National Academy of Science, 1980 (NAS); National Research Council, 1983 (NRC); Turnbull, 1986 and 1991). Although, *A. aulacocarpa* has recognized as one of the suitable species for forest plantation programs, but almost no research, information, and data support the suitability of this species for the establishment of forest plantations. Similarly, the information such as region, provenances, and progeny was not sufficient to fully exploit of this species for planting on a wide scale. Therefore, this study aimed to examine the effectiveness in terms of region, provenances, and progeny as well as the suitability of this species to the Malaysia environment.

In addition, failures in forest plantation programs are usually due to the limited knowledge of properly established techniques and inadequate maintenance of the plantations. This is also clear in many of the government-run plantation projects, which is not optimally operated and do not carry out sufficient research. With this emphasis, it is important that significant research work to be undertaken to ensure its success.

1.3 Research Objective

The general objectives of this study are to define the growth performance of the common *Acacia* species (*A. mangium*, *A. auriculiformis*, and *A. crassicarpa*) found in Malaysia and also newly introduced *A. aulacocarpa*. Further study also carried out to determine the performances of *A. aulacocarpa* with regard to growth and physiological attributes. The specific objectives of this study are:

1) To evaluate the four selected *Acacia* in terms of variations based on its growth characteristics and to further study the best-selected species.

2) To determine the growth performance of *A. aulacocarpa* progeny.

3) To assess the physiological attributes of *A. aulacocarpa* for future tree improvement and breeding program.

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