PROVENANCE PERFORMANCE OF Macaranga tanarius (L.) Mull. Arg. IN PENINSULAR MALAYSIA

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PROVENANCE PERFORMANCE OF *Macaranga tanarius* (L.) Mull. Arg. IN PENINSULAR MALAYSIA

By

ROSDI BIN KOTER

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

April 2019

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DEDICATION

To our Prophet Muhammad who encourages us to learn and educate.

To the beloved late father and mother, Koter Bin Haji Karim and Fatimah Binti Abdullah, their prayers have been a great role to my success today.

To my brothers and sisters, love them heartily.

To my kind and beloved wife, Patahayah Mansor who always supports me as always.

To my children, Hafidz, Haziq, Hakeem, Haris and Nureen Asiah who are bright my eyes as sunlight.

Also, to all my friends and anyone who supports me even if with a word.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

PROVENANCE PERFORMANCE OF *Macaranga tanarius* (L.) Mull. Arg. IN PENINSULAR MALAYSIA

By

ROSDI BIN KOTER

April 2019

Chairman : Associate Professor Mohd Zaki Hamzah, PhD
Faculty : Forestry

Recognizing the importance of growth and yield studies of plantation-grown pioneer fast-growing species for future forest management decisions, coupled with a general need of knowledge on the growth and potential yield of the species planted under plantation condition. *Macaranga tanarius* is considered among the *Macaranga* species that can be an excellent alternative source due to the availability and high yield of seeds throughout the year. This study is expected to provide some necessary information needed to verify *M. tanarius* as a potential species for forest plantation. The data generated on growth and potential of the species can be used in planning for the establishment and management of *M. tanarius* plantation in the future.

This species was found to have a broad distribution, living in groups, producing male and female flowers on separate trees, and flowering throughout the year. *M. tanarius* was found mass flowering twice a year. In the wild, the seeds took two months to germinate. *M. tanarius* seeds were obtained from four provenances in Peninsular Malaysia, namely Northern, Southern, Eastern, and Central provenances for the collection of wildings as a source of planting material used in the experimental plots. For quality and germination ability in the laboratory, the seeds were obtained from six female trees in Kepong, Selangor. *M. tanarius* seeds were found to be able to germinate better upon soaking in water at room temperature rather than in hot water with a germination rate of 68% and 0%, respectively. The seeds started to germinate after two weeks and lasted for another two weeks. Three plant growth regulators (PGR), namely GA_3, BAP and kinetin at three concentrations

were also applied to the seeds as a pretreatment to test germination. The application of GA_3 at 10 mgl^{-1} only managed to result in 40% germination.

The seedlings from the four provenances were then raised in the nursery for 16 months. Total biomass was calculated from each plant part namely, roots, stems, branches and leaves. The proportion of biomass calculated was stem > roots > leaves > branches. Both fresh and dry-biomass showed significant differences ($p<0.05$) between provenances in all parts. The Northern provenance showed the highest mean dry-biomass value, followed by the Eastern, Southern, and Central.

For provenance trial, wildings from each provenance were collected and planted at four established plantation plots in SPF Jeli (Eastern region), SPF Mata Ayer (Northern region), SPF Selandar (Southern region), and Field 52 Bukit Hari, FRIM HQ (Central region). The trial was laid out in a randomized complete block design with three replications, and 16 or 25 seedlings per replicate depending on the size of plantable areas. Growth performance of *M. tanarius* was evaluated based on height, root collar diameter, and survival rate. Assessments were made for 18 months at 3-month intervals. Overall, all provenances showed the highest total height in SPF Jeli > SPF Selandar > Field 52 > SPF Mata Ayer. The Central provenance showed the highest total height over other provenances. Root collar diameter and survival rate for most provenances ahow a similar trend for Jeli and Selandar. All provenances were well adapted and performed well in their growth, and significantly differerent between genotype and the environment. Variation, however, exists in height, root collar diameter, survival, and biomass. Based on the results of this study, *M. tanarius* is a promising pioneer species for forest plantation, but further study needs to be carried out, including exploring genetic make-up of the various provenances.

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

KEUPAYAAN PROVENAN *Macaranga tanarius* (L.) Mull. Arg. DI SEMENANJUNG MALAYSIA

Oleh

ROSDI KOTER

April 2019

Pengerusi : Profesor Madya Mohd Zaki Hamzah, PhD
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Mengiktiraf kepentingan kajian pertumbuhan dan hasil spesies perintis yang ditanam untuk keputusan pengurusan hutan yang akan datang, ditambah dengan keperluan pengetahuan umum mengenai pertumbuhan dan potensi hasil spesies yang ditanam secara perladangan. *Macaranga tanarius* dianggap di kalangan spesies *Macaranga* yang boleh menjadi sumber alternatif yang sangat baik kerana ketersediaan dan berbuah sepanjang tahun. Kajian ini diharapkan dapat memberikan beberapa maklumat yang diperlukan untuk mengesahkan *M. tanarius* sebagai spesies berpotensi untuk perladangan hutan. Data yang dihasilkan pada pertumbuhan dan potensi spesies boleh digunakan dalam perancangan untuk penubuhan dan pengurusan ladang *M. tanarius* di masa depan.

Spesies ini didapati mempunyai taburan yang luas, hidup dalam kluster, menghasilkan bunga jantan dan betina pada pokok-pokok yang berasingan, dan berbunga sepanjang tahun. *M. tanarius* didapati berbunga dua kali setahun. Di dalam hutan, anak benih mengambil masa dua bulan untuk bercambah. Biji *M. tanarius* diperolehi dari empat wilayah di Semenanjung Malaysia, iaitu Utara, Selatan, Timur dan Tengah manakala sumber anak liar sebagai digunakan sebagai sumber bahan tanaman dalam petak percubaan. Bagi kajian ujian percambahan dan kualiti biji benih di makmal, biji benih diperoleh dari enam pokok betina di sekitar Kepong, Selangor. Biji benih *M. tanarius* didapati mampu bercambah dengan baik apabila direndam ke dalam air pada suhu bilik dan bukannya dalam air panas dengan kadar percambahan sebanyak 68% dan 0%. Biji benih mula bercambah selepas dua minggu dan bertahan selama dua minggu selepas itu. Tiga hormon penggalak tumbuhan

(PGR), iaitu GA_3, BAP dan kinetin dengan tiga kepekatan diberikan kepada biji benih sebagai pre-rawatan bagi kajian percambahan. Penerapan GA_3 pada 10 mgl^{-1} hanya berjaya menghasilkan percambahan 40%.

Anak benih dari keempat-empat wilayah ini kemudiannya dibesarkan di tapak semaian selama 16 bulan. Jumlah biomass dikira dari setiap bahagian iaitu akar, batang, dahan dan daun. Keputusan berat pembahagian biomass mengikut bahagian tertinggi ke rendah ialah batang> akar> daun > dahan manakala keputusan statistik biomass basah dan kering menunjukkan perbezaan bererti yang ketara ($p<0.05$) dalam semua bahagian. Wilayah Utara menunjukkan nilai biomas kering tertinggi, diikuti oleh Timur, Selatan dan Tengah.

Untuk percubaan provenan, anak liar dari setiap provenan dikumpulkan dan ditanam di empat petak percubaan iaitu di SPF Jeli (wilayah Timur), SPF Mata Ayer (wilayah utara), SPF Selandar (wilayah selatan), dan Field 52 Bukit Hari, FRIM HQ (Tengah). Rekabentuk kajian ialah menggunakan reka bentuk blok rawak lengkap dengan tiga replikat, 16 atau 25 anak benih ditanam di petak percubaan bergantung kepada saiz kawasan kajian. Prestasi pertumbuhan *M. tanarius* dinilai berdasarkan ketinggian, diameter kolar akar dan peratus kehidupan. Penilaian dibuat selama 18 bulan pada selang masa 3 bulan pengutipan data. Secara keseluruhan, peratusan bagi ketinggian menunjukkan ranking SPF Jeli> SPF Selandar> Field 52 > SPF Mata Ayer. Provenan Tengah menunjukkan ketinggian tertinggi berbanding provenan lain. Diameter kolar akar dan peratus kehidupan menunjukkan trend yang sama di Jeli dan Selandar. Kesemua provenan memberikan pertumbuhan yang baik dan ianya menunjukkan perbezaan bererti antara genotip dan persekitaran. Walaubagaimanapun wujud variasi kesemua paramater yang diuji. Berdasarkan hasil kajian ini, *M. tanarius* adalah spesies perintis yang berpotensi untuk dijadikan sumber baru perladangan tetapi kajian lebih lanjut perlu dijalankan seperti kajian genetik dari pelbagai provenan yang dipilih.

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

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Anon	Anonymous
ANOVA	Analysis of Variance
a.s.l	Above Sea Level
BAP	6-Benzylaminopurine, benzyl adenine
cm	Centimeter
DBH	Diameter at Breast Height
DF	Degree of freedom
DMRT	Duncan's Multiple Range Test
FDPM	Forestry Department Peninsular Malaysia
FRIM	Forest Research Institute Malaysia
g	Gram
GA_3	Gibberellic acid
GLM	Generalized Linear Model
Ha	Hectare
KEP	Kepong Herbarium
m	meter
mm	Millimeter
^{O}C	Degree Celcius
PLUS	Projek Lebuhraya Utara Selatan
PROC	Procedure
RCD	Root Collar Diameter
SAS	Statistical Analysis System
UPM	Universiti Putra Malaysia

CHAPTER 1

INTRODUCTION

1.1 General background

Forest plantation is one of the options to replace wood supply from the natural forests. By establishing forest plantation, the natural forest can be conserved from further exploitation and degradation, and restored to serve for other intangible and environmental benefits.

Forest plantation development is considered as a strategic vehicle in supplementing sustainable timber supply for the wood-based industries in Malaysia. Indeed, the National Timber Industry Policy 2009-2020 (NATIP) clearly indicates that forest plantation sector to yield 16.7 million cubic meters of logs per year from 2016 to 2020. Natural forests are expected to produce only 14 million cubic meters of logs annually during the same period. One of the main obstacles in the establishment of large scale forest plantation in Malaysia is the availability of suitable land. In general, forest plantations in Malaysia are established on low-quality soils compared to soils used for agriculture. The reason is mainly due to the fact that most of the fertile lands in Malaysia were allocated to commercial tree crops and food crops, while the poorer soils are reserved for forest trees.

Fortunately, Malaysia has vast stretches of idle and degraded lands which can be recovered for plantation forestry purpose. There are about 200,000 ha of BRIS soils in the east coast of Peninsular Malaysia and Sabah, and more than 100,000 ha of ex-mining land mainly in the states of Johor, Perak and Selangor (Ang, 2002; Zakaria & Ang, 1992; Yap & Chan, 1990). These areas can be restored and converted into forest plantations, using appropriate site amelioration approaches. In Sabah and Sarawak, large areas of abandoned shifting cultivation areas remain unproductive. In Sarawak, an estimated 3 million ha of land was affected by shifting cultivation (Lee, 2004). Reforestation of these degraded areas is needed to restore forest productivity. These types of lands are less suitable for agricultural purposes due to high input requirements. Plantation forestry, owing to its flexibility and restorative in nature is considered as a more appropriate land use system. Thus, new strategic approach has to be devised for forest plantation development to transform the barren and low productivity lands into sustainable forest plantations, geared for timber and non-timber production, given future demand and end uses. Issues of monoculture (Liu *et. al.*, 2018; Brockerhoff *et. al.*, 2017) , use of exotic species and 'fast-wood' (Nair, 2001), in the

plantation forestry need to be seriously thought, in the light of current and future socio-economic needs, environmental awareness, sustainable supply of wood and non-wood products, and international trade mechanisms.

Forestry Department of Peninsular Malaysia (FDPM) has devised few strategies to make up for the impending deficit in timber production. One of the strategies is to set up forest plantation using fast growing quality timber tree species over short-term rotation of about 15 years (FDPM, 2011). To achieve this strategy, eight forest tree species were identified as suitable for the forest plantation programme namely: rubberwood, acacia hybrid, african mahogany, teak, sentang, kelempayan, batai, and binuang. These species were shortlisted based on timber and fiber utilization aspects, i.e., for furniture, general utility, specific uses, and reconstituted wood. To implement this programme, the state governments identified about 2.8 million hectares of land area to become potential forest plantation area including the state lands and degraded soil areas (Malaysia Timber Council, 2004).

Based on the species listed above, it is necessary to consider introducing a new species which are fit for the purpose and likely to survive in degraded soil condition. One of the alternatives is to consider the Malaysian native pioneer species.

Pioneers are generally assumed to require high light conditions to establish successfully. In recent years, much emphasis has been placed on the growth and yield of mixed tropical forest and management activities related to tropical and sub-tropical forests (Rautiainen *et. al.*, 2001; Bona *et. al.*, 2016). However, a full understanding of the growth and yield of plantation-grown pioneer species is still lacking and yet need to be further explored.

1.2 Statement of Problems

Forest plantation in Malaysia has started for more than a century; however, experience in forest plantation development is still at its infancy stage compared to other countries such as Indonesia, China, and India. Hashim *et. al.* (2015) emphasized that there are several problems faced by the plantation forestry in Malaysia, which need to be solved to enable the next phase of forest plantation development for commercialization. One of the problems is the use of exotic species in the plantation programme such as *Acacia mangium, Gmelina arborea, Paraserianthes falcataria, Khaya ivorensis, Tectona grandis, Maesopsis eminii* and *Eucalyptus deglupta*, to name a few.

The extensive use of exotic species has disadvantages from the ecological and biodiversity points of view. These drawbacks include the decrease in plants and animal's diversity, increase susceptibility to disease infection and insect outbreaks, and the potential to become invasive weeds beyond the plantation borders (Liu, 2018; Nair, 2001). Moreover, as most of the forest plantation species are classified as pioneers, they are light-demanding species and generally thrive under a full light condition or in big forest gaps (Hashim, 2003). Furthermore, pioneers are voracious in soil moisture and nutrients uptake, and fix a substantial amount of soil nutrients in their biomass (Wan Rasidah *et. al*., 1998), leaving the site almost exhausted. As most of the tropical soils are deficient in essential soil nutrients, planting of invasive exotic species such as *A. mangium* would deplete the soil fertility.

Moreover, the building up of soil seed bank can arrest the succession process and deprive the recruitment of native trees. Native species is seldom used in reforestation programme due to the lack of information on various silvicultural aspects of the species. To date, only a few native species have been selected for reforestation programmes such as *Aquilaria malaccensis*, *Azadirachta excelsa, Chukrasia tabularis, Ficus* spp., *Neolamarckia cadamba,* and *Octomeles sumatrana*. Other lesser known native species such as *Alstonia scholaris*, *Duabanga* sp., *Dyera costulata, Endospermum diadenum, Hopea odorata, Lagerstroemia* spp., *Pentaspadon motleyi, Podocarpus* spp., *Pouteria* spp., *Pterocymbium tinctorium, Sterculia* spp., and *Toona* spp. are potential species for forest plantation establishment.

Lack of silvicultural knowledge, and insufficient growth and yield data have prevented the use of native species for large scale plantations. Hence, research and development programme should be intensified to determine and document the lacking aspects of silviculture and the growth and yield of selected species. Native pioneer and fast-growing species such as *Alstonia scholaris*, *Arenga pinnata, Duabanga grandiflora, Dyera costulata, Endospermum diadenum, Hopea odorata,* and *Pterocymbium tinctorium* should be trial planted on different soil types and site conditions at various planting distances (spacing) and planting densities in order determine their growth and yield under different silvicultural regimes and site conditions. Propagation of planting materials through rooted stem cuttings and micropropagation (e.g., tissue culture) should be initiated to increase the availability of planting materials. Nutrient requirement of the native species needs to be determined to enhance the growth and yield under plantation conditions. Growth model for a particular native species should be developed based on sample plot data and used as a management tool to predict future growth and yield.

In Malaysia, there are several pioneer species from the genus *Trema, Mallotus, Neomalackia, Endospermum,* and *Macaranga* found abundantly growing wild. Of these genera, the genus *Macaranga* seems to be the most abundant in terms of number of species and growth, and least researched; *Macaranga gigantea* and *M. tanarius* being the two top performing species regarding growth and biomass production (Susanto *et. al.*, 2016). The former with slow germination and seasonal flowering, while the latter germinates readily and with frequent flowering (Taylor, 1982).

Based on a pilot study by FRIM, on wood properties and medicinal uses, *Macaranga tanarius* can be considered as a multipurpose tree species. This species has the potential to be exploited and become a future source for the wood industry. Thus, this study was initiated after recognizing the importance of growth and yield studies of plantation-grown pioneer fast-growing species for future forest management decisions, coupled with a general lack of the knowledge on the growth and potential yield of the species planted under plantation condition. *M. tanarius* is regarded as among the most promising *Macaranga* species as the seeds are available throughout the year and germination rate is high compared to other species (Rosdi *et. al.*, 2014). Among four species of Macaranga tested, *M. tanarius* showed the highest percentage of germination (Rosdi *et. al.*, 2013).

The success story of breeding programmes in rubber plantation, oil palm plantation and many agriculture species in Malaysia must be adopted in the forestry sector, especially in relation to research on pioneer species to fulfill the supply needs of raw material. This studies would provide an opportunity to generate baseline information for future planting of *M. tanarius* under plantation conditions. Data on growth and potential yield of the species can be used in the planning for future establishment and management of *M. tanarius* plantation.

Four populations of *M. tanarius* selected for this study were based on administrative regions of the states in the peninsular, i.e., Northern (Perak, Penang Kedah, Perlis), Eastern (Terengganu, Kelantan, Pahang), Central (Selangor, Federal Territory) and Southern (Negeri Sembilan, Malacca, Johor). The seedlings collected from these provenances were raised in a nursery and later planted at four different sites with an appropriate design as provenance trial. This trials would be able to give answers to a few basic questions regarding the next action plan in the breeding programme. This study was expected to answer the following questions:

1. Are there any variations in growth within or between provenances of *M.tanarius*?
   Genetic variation is one of the keys and essential factors underlying the tree breeding programme. Substantial genetic variation within provenances provides excellent opportunity to be exploited in the selection
2. Are there any provenances by sites interaction (different climatic region) in growth and how stable are these provenances across these sites?
   Other than genetic factors, environmental conditions play an important role in growth and wood formation of the trees (Denne & Dodd, 1981; Downes & Drew, 2008). An environment is defined as all natural biotic, climatic and edaphic factors influencing growth or phytochemical contents of the species. Environmental variations reflect the response of the tree towards the combined effect of edaphic and climatic conditions. The environmental factors provide the physical condition for all biological process in the growing trees. There are many environmental factors which could affect the tree growth, the wood structure and leaves active compounds such as soils, climate and the occasional environmental factors like flooding, fire, and wind (Wodzicki, 2001). In additions, provenance trials have shown that climate determines survival and growth when tree populations are planted on a range of field environments (Rehfeldt, 1999 & Rehfeldt *et. al.,* 2002).

It is expected that by the end of the study, the best provenance of *M. tanarius* will be decided and made available, and become a base population for a breeding programme of *M. tanarius*. These outputs are essential to ensure a sustainable supply of elite planting materials, and for *M. tanarius* to become one of the potential short term species, harvestable within five years after planting.

1.3 Research Hypothesis

It is hyphotesized that there will be no significant different in term of growth of the four *M.tanarius* provenances regardless of any environment conditions and genotype.

1.4 Objectives of the study

This study was proposed with the objectives to identify and to gather planting materials from various populations or provenances of *M. tanarius* throughout Malaysia, which will serve as a base breeding population for a breeding programme of *M. tanarius*.

Generally, the primary objectives of the study were:

1. To study the distribution of *M. tanarius* in the natural habitat in Peninsular Malaysia;
2. To determine the phenology characteristics and seed germination of *M. tanarius*; and
3. To assess the variation of growth in selected provenances of *M. tanarius* in the plantation trial.

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