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

ROSDI BIN KOTER

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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.
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 GA₃, 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 mg l$^{-1}$ 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 show a similar trend for Jeli and Selandar. All provenances were well adapted and performed well in their growth, and significantly different 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
Fakulti : Perhutanan

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.

(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 mg/l hanyanya 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 biomass kering tertinggi, diikuti oleh Timur, Selatan dan Tengah.

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I wish to express my most sincere and deepest thanks to the Chairman of my Supervisory committee, Associate Professor Dr. Mohd Zaki Hamzah for his valuable guidance, advice, encouragement, constructive criticisms and suggestions throughout the study. I also wish to express my sincere thanks to the other committee members, Professor Dr. Nor Aini Abdul Shukor, Professor Dr. Hazandy Abdul Hamid and Dr. Wan Rasidah Abdul Kadir for their guidance rendered.

Grateful acknowledgement is due to the Director General of Forest Research Institute Malaysia (FRIM) Dato’ Dr. Abd Latif Mohmod for his permission and encouragement to undertake this programme. I also acknowledge the permission granted by SPF Mata Ayer, Perlis; Selandar, Melaka and Jeli, Kelantan for allowing me to use the study site. Sincere thanks are due to the staff of the Biotechnology Division, FRIM especially to Dr. Mohd Lokmal Ngah for his valuable statistical guidance and also the staff of the Agroforestry Unit Samsul Bahrin Abdullah, Ruszaida Yahya, Mr. Adenan Idris, Mr. Afizi Osman and Rodziah Hashim for assistance in data collection and analysis. Not to forget my colleagues Zaki, Rosli, Farid, Rizal, Fauzi, Parid, Din B, Aza and Fakhri.

Finally, I would like to dedicate this work to my late parents, my wife Fatah and my children Hafidz, Haziq, Hakeem, Haris and Nureen, who without their love and devotion, this study would not have completed. I love you all!
I certify that a Thesis Examination Committee has met on 30 April 2019 to conduct the final examination of Rosdi bin Koter on his thesis entitled "Provenance Performance of *Macaranga tanarius* (L.) Mull. Arg. in Peninsular Malaysia" 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 Doctor of Philosophy.

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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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Signature: __________________________________________
Name of Member of Supervisory Committee: Professor Dr. Hazandy Abdul Hamid

Signature: __________________________________________
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<tr>
<td>Anon</td>
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<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
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<tr>
<td>a.s.l</td>
<td>Above Sea Level</td>
</tr>
<tr>
<td>BAP</td>
<td>6-Benzylaminopurine, benzyl adenine</td>
</tr>
<tr>
<td>cm</td>
<td>Centimeter</td>
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<td>DBH</td>
<td>Diameter at Breast Height</td>
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<td>DF</td>
<td>Degree of freedom</td>
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<td>DMRT</td>
<td>Duncan’s Multiple Range Test</td>
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<td>FDPM</td>
<td>Forestry Department Peninsular Malaysia</td>
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<td>FRIM</td>
<td>Forest Research Institute Malaysia</td>
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<tr>
<td>g</td>
<td>Gram</td>
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<tr>
<td>GA₃</td>
<td>Gibberellic acid</td>
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<tr>
<td>GLM</td>
<td>Generalized Linear Model</td>
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<tr>
<td>Ha</td>
<td>Hectare</td>
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<td>KEP</td>
<td>Kepong Herbarium</td>
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<tr>
<td>m</td>
<td>meter</td>
</tr>
<tr>
<td>mm</td>
<td>Millimeter</td>
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<td>ºC</td>
<td>Degree Celcius</td>
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<td>PLUS</td>
<td>Projek Lebuhraya Utara Selatan</td>
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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, kelemayan, 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 falcatoria, 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 hypothesized 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.
REFERENCES


Basri, M.H.A. 2014. Effects of organic and inorganic fertilizer on BRIs fertility and growth performances of selected kenaf (Hibiscus cannabinus L.) varieties (Master dissertation, University Putra Malaysia)


Hill, DS 2008. Pest of Crop in Warmer Climates and Their Control. Springer-United Kingdom


Poorter, L. 2007. Are species adapted to their regeneration niche, adult niche, or both? The American Naturalist, 169, 433–42.


Soedjito, H. 1987. Nutrient dynamics following shifting cultivation in Long Sungai Barang, East Kalimantan Indonesia. Regional Workshop on Impact of Man’s Activities on Tropical Upland Forest Ecosystems, Serdang, Selangor (Malaysia), 3-6 Feb 1986. Faculty of Forestry, UPM


