UNIVERSITI PUTRA MALAYSIA

EFFECTS OF MYCORRHIZAL INOCULATION ON GROWTH OF ACACIA SPP. PLANTED ON BEACH RIDGES INTERSPERSED WITH SWALES (BRIS) SOILS IN SETIU, TERENGGANU, MALAYSIA

PATAHAYAH MANSOR

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By

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

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

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Problematic soils such as Beach Ridges Interspersed Swales (BRIS) can be rehabilitated through planting of fast-growing and non site-demanding tree species. BRIS is an excessively drained soil, dominated by sand and has higher surface soil temperature, thus only selected species with the ability to tolerate harsh conditions can survive planting with minimal tending input on this site. Acacia species is one the best candidates for planting in such soil conditions and environments. It has the capability to fix the atmospheric nitrogen through root nodules and its roots can also form association with both ectomycorrhiza (ECM) and endomycorrhiza (AM).

A 2.0-ha planting trial of *Acacia* spp. consisting of *Acacia mangium, A. auriculiformis* and the hybrid of both species, was established on Jambu series soil in Setiu, Terengganu, Malaysia. The aims of this trial were to determine the most suitable species of Acacia and the best mycorrhizal treatment for planting on BRIS soils. The trial consisted of four treatments i.e., T1-arbuscular mycorrhiza (AM)

inoculum application, T2-ectomycorrhizal inoculum (ECM) application, T3-AM + ECM application and T4-uninoculated control. All treatments were replicated four times. Survival rate and total height of the plants were monitored at three monthly intervals for the first year and at six-monthly interval thereafter up to 48 months. During the final measurement at 48 months, 48 plants, which represented 4 plants for each treatment, were destructively harvested for determination of biomass accumulation and nutrient uptake. Soil and root samples from each plot were also sampled for mycorrhizal assessment.

At one year after planting, the relative growth rate of *A. mangium* was significantly ($p<0.05$) higher compared to the other two species. *A. mangium* showed best performance when arbuscular mycorrhiza was applied to, either in single or combination with ectomycorrhiza. However, growth of *A. auriculiformis* and *Acacia* hybrid were improved with the application of ectomycorrhiza. After 48 months out-planted, the *Acacia* hybrid showed the significantly ($p<0.05$) highest mean height followed by *A. auriculiformis* and *A. mangium*. The average mean height for the *Acacia* hybrid, *A. auriculiformis* and *A. mangium* were 711 cm, 453 cm and 390 cm respectively.

Based on the chemical analysis of the foliage, the level of macronutrient concentrations were almost equal for all treatments except for N. Higher N concentration was observed in *A. mangium* of all treatments. This could be the influence from nitrogen fixing ability, which we expect to differ for each species.

Root of inoculated AM showed the persistence of AM fungi in the plant roots and occurrence of AM fungal spores in the rhizosphere. The AM colonization found to be highest on *A. mangium* root and the spores were most abundance in the *A. mangium* rhizosphere, which ranged from 18 to 50 spores per 100g soil. However, no ECM presence was detected on roots of all treatments.

The mean total biomass was highest in *Acacia* hybrid, but comparable for *A. mangium* and *A. auriculiformis.* Total biomass for *Acacia* hybrid, *A. mangium* and *A. auriculiformis* were ranged from 23.65 kg to 31.21 kg, 11.76 kg to 15.79 kg and 8.69 kg to 16.21 kg, respectively. The biomass distribution in the plant parts for all species found to concentrated most in the stem, followed by the root, branches and the least in the leaves. The stem biomasses of all species ranged from 38.3 to 49.6 %.

Nutrient uptake was calculated based from the biomass accumulation. The nutrient uptake for all elements (N, P, K, Ca and Mg) was highest in *Acacia* hybrid and the dual mycorrhizal (ECM and AM) application found to significantly ($p<0.05$) enhanced the uptake of N, P and K in this species.

In conclusion, based on the study, *Acacia* hybrid showed the best growth performance followed by *A. mangium* and *A. auriculiformis* when planted on BRIS soil. Different *Acacia* species however, showed different response towards different mycorrhizal inoculum. *A. mangium* performed best when applied with arbuscular mycorrhizal inoculum while application of ectomycorrhizal inoculum and combination of ectomycorrhiza and arbuscular mycorrhizas to *A. auriculiformis* and *Acacia* hybrid would improve their growth in BRIS soil. Therefore, the application mycorrhizas in plantation of forest tree species especially in the problematic and degraded soil are recommended. However, further study should be conducted to select the best mycorrhizal strain to be used and compatible with the tree host.

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

KESAN INOKULASI MIKORIZA KE ATAS PERTUMBUHAN *ACACIA* SPP. YANG DITANAM DI ATAS TANAH BRIS (BEACH RIDGES INTERSPERSED WITH SWALES) DI SETIU, TERENGGANU, MALAYSIA

Oleh

PATAHAYAH MANSOR

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Tanah bermasalah seperti tanah BRIS (Beach Ridges Interspersed with Swales) boleh dipulihkan melalui penanaman spesis pokok cepat tumbuh dan menuntut tapak yang baik untuk pertumbuhan. BRIS adalah tanah yang berlebihan disalirkan, didominasi oleh pasir dan mempunyai permukaan suhu tanah tinggi, sekaligus hanya spesis tertentu sahaja yang sesuai ditanam yang mana mampu bertoleransi dengan keadaan persekitaran yang melampau dan input penjagaan yang minima. Spesis dari kumpulan Akasia merupakan calon terbaik untuk ditanam di tanah dan persekitaran seperti ini. Ia mempunyai keupayaan untuk menetapkan nitrogen dari atmosfera melalui nodul akar dan akarnya juga boleh membentuk persatuan dengan kedua-dua jenis ekto- (ECM) dan endomikoriza (VAM).

Satu percubaan seluas 2.0 hektar penanaman *Acacia* spp. yang terdiri daripada *Acacia mangium, A. auriculiformis* dan hibrid antara kedua-dua spesis tersebut (*Acacia* hybrid), telah ditubuhkan pada tanah siri Jambu di Setiu, Terengganu.

Tujuan percubaan ini adalah untuk menentukan spesis Akasia yang paling sesuai untuk ditanam dan rawatan mikoriza yang terbaik untuk penanaman di tanah BRIS. Percubaan ini melibatkan empat rawatan mikoriza iaitu, T1-aplikasi mikoriza arbuskular (VAM) sahaja, T2- aplikasi ektomikoriza (ECM) sahaja, T3-aplikasi kombinasi VAM + ECM dan T4-kawalan (tanpa inoulasi). Semua rawatan diulang sebanyak empat kali. Kadar kemandirian dan pertumbuhan seperti tinggi dan diameter dipantau pada setiap 3 bulan untuk tahun pertama dan pada selang enam bulan selepas itu hinggalah ke 48 bulan. Semasa pengukuran akhir pada umur 48 bulan, sebanyak 48 pokok, yang mana mewakili 4 pokok dari setiap rawatan, telah ditebang untuk penentuan biojisim dan penyerapan nutrien. Tanah dan akar dari setiap plot juga disampel untuk penilaian mikoriza.

Satu tahun selepas di tanam, *A. mangium* menunjukkan kadar pertumbuhan relatif yang lebih tinggi dan bererti ($p<0.05$) berbanding *A. auriculiformis* dan *Acacia* hybrid. *A .mangium* menunjukkan prestasi yang terbaik apabila mikoriza arbuskular (VAM) telah digunakan., samada secara tunggal atau kombinasi dengan ektomikoriza. Walaubagaimanapun, *A. auriculiformis* dan *Acacia* hybrid telah menunjukkan peningkatan pertumbuhan dengan adanya aplikasi ektomikoriza (ECM). Selepas 48 bulan, *Acacia* hybrid telah menunjukkan purata ketinggian yang bererti ($p<0.05$), diikuti *A. auriculiformis* dan *A. mangium*. Purata ketinggian bagi *Acacia* hybrid, *A. auriculiformis* dan *A. mangium* ialah 711cm, 453cm dan 390cm masing-masing.

Berdasarkan analisis kimia daun, tahap kepekatan makronutrien hampir sama rata untuk semua rawatan kecuali N. Kepekatan N yang tinggi dapat diperhatikan dalam

A. mangium pada semua rawatan. Ini mungkin pengaruh daripada kemampuan penetapan nitrogen yang dijangka berbeza untuk setiap spesis.

Akar yang diinokulasi AM menunjukkan kehadiran AM dalam akar pokok dan kewujudan spora AM di tanah persekitaran akar. Kolonisasi AM didapati tertinggi pada akar *A. mangium* dan spora juga paling banyak dalam tanah persekitaran akar *A. mangium* dengan julat 18 hingga 50 spora setiap 100g tanah. Walaubagaimanapun, tiada kehadiran ECM dikesan pada akar bagi semua rawatan.

Purata jumlah biojisim tertinggi didapati pada *Acacia* hybrid, tetapi hampir menyamai bagi *A. mangium* dan *A. auriculiformis.* Purata jumlah biojisism bagi *Acacia* hybrid, *A. mangium* dan *A. auriculiformis* adalah dalam julat 23.65 kg ke 31.21 kg, 11.76 kg ke 15.79 kg dan 8.69 kg ke 16.21 kg, masing-masing. Taburan biojisim bagi setiap pokok untuk semua spesis didapati tertumpu pada bahagian batang, diikuti oleh akar, ranting dan paling sedikit pada daun. Biojisim batang bagi semua spesis adalah dalam julat 38.3 ke 49.6 %.

Penyerapan nutrien dikira berdasarkan pada pengumpulan biojisim. Penyerapan nutrien untuk N, P, K, Ca dan Mg adalah tertinggi dalam *Acacia* hybrid dan kombinasi aplikasi dua mikoriza (ECM dan AM) ditemui dengan bererti ($p<0.05$) meningkatkan penyerapan N, P dan K dalam spesis ini.

Kesimpulannya, berdasarkan kajian ini, *Acacia* hybrid menunjukkan pertumbuhan yang terbaik diikuti oleh *A. mangium* dan *A. auriculiformis* apabila ditanam ditanah BRIS. Walaubagaimanapun, spesis Akasia yang berlainan, menunjukkan tindakbalas yang berbeza terhadap inokulum mikoriza yang berlainan. *A. mangium* menunjukkan pertumbuhan terbaik dengan aplikasi AM manakala aplikasi ECM dan kombinasi AM dan ECM pada *A. auriculiformis* dan *Acacia* hybrid membantu memperbaiki pertumbuhan mereka di tanah BRIS. Oleh itu, aplikasi mikoriza untuk perladangan pokok hutan terutamanya di tanah bermasalah dan terdegradasi adalah disyorkan. Walaubagaimanapun, kajian lanjut perlu dijalankan bagi memilih jenis mikoriza yang terbaik dan sesuai dengan pokok perumah.

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I certify that a Thesis Examination Committee has met on 23rd February 2012 to conduct the final examination of Patahayah Mansor in her thesis entitled "**Effects of Mycorrhizal Inoculation on Growth of *Acacia* spp. Planted on Beach Ridges Interspersed With Swales (BRIS) Soils in Setiu, Terengganu, 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 Master of Science.

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or any other institution.

PATAHAYAH MANSOR

Date: 23 February 2012

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LIST OF ABBREVIATIONS

° C	Degree Celsius
asl	Above Sea Level
AM	Arbuscular mycorrhiza
Anon	Anonymous
ANOVA	Analysis of Variance
BRIS	Beach Ridges Interspersed with Swales
C	Carbon
Ca	Calcium
cec	Cation exchange capacity
cm	Centimeter
dbh	Diameter at Breast Height
DMRT	Duncan's Multiple Range Test
ECM	Ectomycorrhiza
FAO	Food Agriculture Organization
FDPM	Forestry Department Peninsular Malaysia
FRIM	Forest Research Institute Malaysia
g	Gram
GLM	Generalized Linear Model
ha	Hectare
K	Kalium/Potassium
kg	Kilogram
KOH	Kalium hydroxide/potassium hydroxide
m^3	Cubic meter

MARDI	Malaysian Agriculture Research and Development Institute
meq	Mili equivalent
mg	Milligram
Mg	Magnesium
MTIB	Malaysian Timber Industry Board
N	Nitrogen
P	Phosphorus
ppm	Part per million
PROC	Procedure
RGR	Relative growth rate
SAS	Statistical Analysis System
SPV	Special Purpose Vehicles
t/ha	Tonne per hectare
UPM	Universiti Putra Malaysia
v/v	Volume per volume

CHAPTER 1

INTRODUCTION

The current major issue in Malaysian forestry is the environmental issue. An adverse effect of massive forested land conversion to agriculture, together with up stream logging, constitutes one of the two challenges. Depletion of wood resources represents the second major issue in Malaysian forestry. Various industry analyst and researchers have forecast that in the post-2000 period Malaysia will suffer a deficit in log supply, compared to the demand for logs from timber processing industries (FAO, 1997). It is expected that there will be a likely average shortfall of about 3.85 million m^3 per year from 2006 onward (FAO, 2005).

Forestry Department of Peninsular Malaysia (FDPM) has devised few strategies in order to make up for the impending deficit in timber production. They are, first, to carry out silvicultural treatments in logged over areas at a rate consistent with the annual logging rate; second, to treat and regenerate all previously logged areas and third, to set up forest plantations using fast growing quality timber tree species over short-term rotations of about 15 years.

With the timber supply crisis looming ahead, it was felt that Malaysia should concentrate on few selected species in order to ensure the success of its forest plantation programme. Malaysia had identified forest plantation development as a viable and sustainable method to produce high-value commercial timber to supplement the raw material requirement of the wood based processing industry in the country (Annonymous, 2008). Therefore a task force has been initiated by the Ministry of Plantation Industries and Commodities to oversee and streamline the programme. The technical Committee is responsible for providing comprehensive technical advice to the private sector pertaining the species for plantation programme.

There are more than 40 forest trees species have been identified to have potential for forest plantation purposes. Of the total, 14 species have been short-listed for forest plantation project based on timber and fiber utilization aspects, i.e. for furniture, general utility, specific uses and reconstituted wood. Among those 14 species, eight were identified as suitable for the forest plantation programme namely Malaysian Rubberwood (*Hevea brasiliensis*), *Acacia* spp. (*Acacia* hybrid), African Mahogany (*Khaya ivorensis/Khaya senegalensis*), Teak (*Tectona grandis*), Sentang (*Azadirachta excelsa*), Kelempayan (*Neolamarckia cadamba*), Batai (*Paraserianthes falcataria*) and Binuang (*Octomeles sumatrana*) (MTIB, 2010).

The Government through the Malaysian Timber Industry Board (MTIB) has established a Special Purpose Vehicle (SPV) to coordinate a funding scheme which will attract more investors to plant forest trees. A strategic forest plantation programme embarked in 9th Malaysian Development Plan (9MP) eventually allow an annual harvest of at least 25,000 hectares of timber, based on projection of a 15 year rotation, from 2022 onward. This is to ensure the availability of raw materials particularly sawn timber for the benefit of the wood industry. From the 25,000 hectares, it is projected that 5 million cubic meter of wood can be harvested annually. To implement this programme, about 2.8 million hectares of land area in

Malaysia have been identified to become potential forest plantation area. This included the state lands and degraded soils area. Planting trees or rehabilitation of highly degraded forest sites is a part of forestry activities undertaken to fulfill Sustainable Forest Management in Malaysia (Malaysian Timber Council, 2007).

Degraded land areas would be reforested and under-stocked forests would be line planted. A lot of degraded or under-utilized land is found in the country and it was estimated about 2% of Malaysia's land area. A total of 153,900 ha of degraded forest land in the country have been identified for the purpose of forest plantation. This potential land included the marginal soils of ex-tin mining land, shifted cultivation areas and BRIS (Beach Ridges Interspersed with Swales) soils.

It is estimated that about 162,000 ha of Peninsular Malaysia is covered with BRIS soil. This soil has very limited usage for agriculture due to high percentage of sand fractions which exceed 95% and high soil surface temperature, ranging from 40 ^{o}C to 50 ^{o}C (Abdul Wahab, 1984). This soil is inherently poor in nutrients due to the low percentage of clay and organic materials. Very little progress has been made to rehabilitate BRIS soil except for some work by Malaysian Agriculture Research and Development Institution (MARDI) and Forest Research Institute Malaysia (FRIM) lately. It is estimated that only 5-10% of this land area is being utilized, with the majority being left idle. One means to rehabilitate these soils is by planting pioneer, fast growing timber tree species, which can tolerate with the harsh conditions before the introduction of other high value commercial timber species.

As referred to Parrotta *et al*. (1997), the choice of fast growing timber trees should meet certain criteria. The species preferred should have regularly available seeds, rapid growth over a short rotation, can be easily handled in the nursery, low maintenance cost, and high tolerance to poor soil and relatively free from pest and disease (Appanah and Weinland, 1993). Among those tree species, tree from the Leguminosae family was chosen. This is because species of this family group, beside their economic potential, they are obviously has potential for rapid biomass production and useful for the reclamation of degraded land.

The ability of the leguminous species to grow in such harsh soils, where nutrients, particularly nitrogen and phosphorus are deficient may be attributed to their dual symbiosis with the nitrogen fixing bacteria (rhizobia) and mycorrhizal fungi (De La Cruz and Yantasath, 1993). Rhizobia are soil micro-organisms found in root nodules of leguminous trees and plants that can fix atmospheric nitrogen, while mycorrhizas benefits trees by enhancing absorption of nutrients from soils, reducing the effects of stress related to drought and transpiration. Many nitrogen fixing tree species depend on mycorrhizas for absorbing nutrients required for plant growth and efficient nitrogen fixation.

Acacias, a group of Leguminous, are known to form both vesicular-arbuscular mycorrhizas (AM) as well as ectomycorrhizas. This tree-mycorrhizal association has been successfully used in rehabilitating degraded sites, such as *Imperata* grassland in the Philippine (De la Cruz and Garcia, 1992), arid zones in India (Mukerji and Dixon, 1992), ex-nickel mine sites in Indonesia (Setiadi, 1996) and sandy tin tailings in Malaysia (Nik Muhamad and Azizah, 1994; Patahayah *et al.*, 2011). The Forest

Research Institute Malaysia (FRIM) currently has also set up a study to rehabilitate ex-tin mining land using ectomychorrizas with Acacia and Dipterocarp species (Patahayah *et al.*, 2011) but no such study has been carried out on BRIS soil.

The establishment of fast growing timber species requires high availability of soil nutrient, especially at the initial stage of growth. This condition opens avenue for the application of mycorrhizal fungi to promote plant growth and survival. Thus, the presence of mycorrhizal fungi as biofertiliser is highly recommended.

Therefore, mycorrhizas can play an important role in the establishment of forest plantations on degraded sites such as BRIS soils. However in most cases, successful application of mycorrhizal fungi still require a better understanding of the mechanisms regulating the interactions between the host plants and fungi *in situ*. In view of the importance of tree planting on BRIS soil and the benefits of mycorrhizas on plant growth, the following studies were conducted;

1. To determine the best Acacia species (*A. mangium, A. auriculiformis* and *Acacia* hybrid (*A. mangium* x *A. auriculiformis*) to be planted on BRIS soils
2. To determine the effects of mycorrhizal application on growth and nutrient uptake of Acacia species.

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