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

PATAHAYAH MANSOR

FH 2012 28
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By

PATAHAYAH MANSOR

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

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PATAHAYAH MANSOR

February 2012

Chairman: Associate Professor Mohamad Azani Alias, PhD

Faculty: Forestry

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

Februari 2012

Pengerusi : Profesor Madya Mohamad Azani Alias, PhD

Fakulti : Perhutanan

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 hingga 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. Walau bagaimanapun, 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 sekitaran akar. Kolonisasi AM didapati tertinggi pada akar A. mangium dan spora juga paling banyak dalam tanah sekitaran 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.

Members of the Examination Committee were as follows:

Ahmad Ainuddin b. Nuruddin, PhD
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
(Chairman)

Azmy b. Mohamed, PhD
Associate Professor
Faculty of Forestry
Universiti Putra Malaysia
/Internal Examiner

Mohd Nazre Saleh @ Japri, PhD
Faculty of Forestry
Universiti Putra Malaysia
/Internal Examiner

Aminuddin Mohamad, PhD
Professor
International School of Forestry
Universiti Malaysia Sabah
Malaysia
/External Examiner

________________________________
SEOW HENG FONG, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 28th June 2012
This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

**Mohamad Azani Alias, PhD**  
Associate Professor  
Faculty of Forestry  
Universiti Putra Malaysia  
(Chairman)

**Mohd Zaki Hamzah, PhD**  
Associate Professor  
Faculty of Forestry  
Universiti Putra Malaysia  
(Member)

**BUJANG BIN KIM HUAT, PhD**  
Professor and Dean  
School of Graduate Studies  
Universiti Putra Malaysia

Date:
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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<td>°C</td>
<td>Degree Celsius</td>
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<tr>
<td>asl</td>
<td>Above Sea Level</td>
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<tr>
<td>AM</td>
<td>Arbuscular mycorrhiza</td>
</tr>
<tr>
<td>Anon</td>
<td>Anonymous</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>BRIS</td>
<td>Beach Ridges Interspersed with Swales</td>
</tr>
<tr>
<td>C</td>
<td>Carbon</td>
</tr>
<tr>
<td>Ca</td>
<td>Calcium</td>
</tr>
<tr>
<td>cec</td>
<td>Cation exchange capacity</td>
</tr>
<tr>
<td>cm</td>
<td>Centimeter</td>
</tr>
<tr>
<td>dbh</td>
<td>Diameter at Breast Height</td>
</tr>
<tr>
<td>DMRT</td>
<td>Duncan’s Multiple Range Test</td>
</tr>
<tr>
<td>ECM</td>
<td>Ectomycorrhiza</td>
</tr>
<tr>
<td>FAO</td>
<td>Food Agriculture Organization</td>
</tr>
<tr>
<td>FDPM</td>
<td>Forestry Department Peninsular Malaysia</td>
</tr>
<tr>
<td>FRIM</td>
<td>Forest Research Institute Malaysia</td>
</tr>
<tr>
<td>g</td>
<td>Gram</td>
</tr>
<tr>
<td>GLM</td>
<td>Generalized Linear Model</td>
</tr>
<tr>
<td>ha</td>
<td>Hectare</td>
</tr>
<tr>
<td>K</td>
<td>Kalium/Potassium</td>
</tr>
<tr>
<td>kg</td>
<td>Kilogram</td>
</tr>
<tr>
<td>KOH</td>
<td>Kalium hydroxide/potassium hydroxide</td>
</tr>
<tr>
<td>m³</td>
<td>Cubic meter</td>
</tr>
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</table>
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 m³ 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 (Anonymous, 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 °C to 50 °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.
REFERENCES


Estaun, M.V. 1991. Effects of NaC1 and Mannitol on the germination of two isolates of the vesicular arbuscular Mycorrhizal fungus *Glomus mossae*, Abstract In *European Symposium on Mycorrhizas*, University of Sheffield, U.K


**Tropical Rainforest Ecosystems: Research and Development Priorities. 66-82. Kuching, Sarawak.**


PROSEA. 1995. *Plant Resources of South-East Asia 5 (2).* Timber Trees: Minor Commercial Timbers. 655 pp


Setiadi, Y. 1996. The practical application of arbuscular mycorrhizal fungi for enhancing tree establishment in degraded nickel mine sites at PT INCO, Soroako. Paper presented on IUFRO international Symposium on Accelerating Natural succession of Degraded Tropical Lands. 11-13 June. Washington DC.


