
UNIVERSITI PUTRA MALAYSIA

# GROWTH AND PHYSIOLOGICAL RESPONSES OF AZADIRACHTA EXCELSA (JACK) JACOBS TO FERTILIZER AND MYCORRHIZAL APPLICATIONS

ONG KIAN HUAT



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By

ONG KIAN HUAT

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*This work is dedicated to*

*All the persons in a way or another*
*showed me the fun of ..*
education

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## GLOSSARY

| | |
|---|---|
| FAO | United Nations Food and Agriculture Organization |
| MAI | Mean annual increment |
| dbh | Diameter breast height |
| NADPH | Nicotinamide adenine dinucleotide phosphate dehydrogenase |
| ATP | Adenosine triphosphate |
| ADP | Adenosine diphosphate |
| DNA | Deoxyribonucleic acid |
| RNA | Ribonucleic acid |

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**Chairman: Associate Professor Kamis Awang, Ph.D.**

**Faculty : Forestry**

*Azadirachta excelsa* (Jack) Jacobs is a fast growing multi-purpose tree species and is one of the species that is being promoted for planting in Malaysia. However, the silvicultural requirements of the species have not been well defined. The objective of this study was to evaluate the effects of fertilizers, mycorrhizal inoculation and mixed planting with *Acacia mangium* Willd seedlings on the growth and physiological changes of *A. excelsa* seedlings on Rengam series soil.

The study consisted of two components. The pot trial examined the physiological changes and growth performance of *A. excelsa* seedlings in response to various fertilizer and mycorrhizal treatments using soil collected from the field. The field trial examined the seedling performance under field conditions when applied with fertilizer and mycorrhizal treatments, as well as mixed planted with *A. mangium*.

Results from the four month pot trial showed that fertilized seedlings grew better than the control plants. Among the fertilizer treatments, Best-Tab slow release fertilizer (20-10-5 NPK with expanded minor and secondary element in 21 g tablet) promoted the best growth with maximum photosynthesis, followed by 40 g of NPK fertilizer (15-15-15

fertilizer (15-15-15 NPK) and finally 20 g of NPK fertilizer (15-15-15 NPK). In contrast, mycorrhizal application failed to promote seedling growth in a similar way. Similarly, combination of treatments failed to improve seedling growth as compared to either slow release fertilizer or NPK fertilizer alone.

The higher the application of fertilizer, the higher the concentration of nutrient accumulated in the plant. This was demonstrated by the application of 40 g of NPK fertilizer. However, the nutrient accumulation failed to increase the photosynthetic rate of the seedlings. Nutrient analysis revealed that magnesium was an important element in promoting a higher rate of photosynthesis. Seedlings with a lower rate of growth were found to record a higher plant starch content. Application of fertilizer was found to reduce root infection by arbuscular mycorrhizal fungi.

The results from the field study were similar to those of the pot trial. Best Tab slow release fertilizer was still the best in terms of promoting the growth of *A. excelsa* seedlings. Mycorrhizal treated seedlings without any fertilizer showed growth depression while mix planting did not show any positive effect. The rates of photosynthesis recorded in the field were comparable to earlier published works on fast-growing species in Malaysia.

In conclusion, growth of *A. excelsa* seedlings was found to be affected by mycorrhiza and fertilizer. The implications of these factors on the establishment of *A. excelsa* plantation are discussed.

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**PERTUMBUHAN DAN TINDAK BALAS FISIOLOGI *AZADIRACHTA EXCELSA* (JACK) JACOBS KEPADA RAWATAN BAJA DAN MIKORIZA**

Oleh

**ONG KIAN HUAT**

**Mac 1998**

**Pengerusi:** **Profesor Madya Kamis Awang, Ph.D.**

**Faculti :** **Perhutanan**

*Azadirachta excelsa* (Jack) Jacobs merupakan satu spesies yang berbagai guna serta mempunyai kadar pertumbuhan yang cepat dan merupakan salah satu spesies yang digalakkan untuk ditanam di Malaysia. Tetapi, keperluan silvikultur spesies ini belum diketahui sepenuhnya. Tujuan penyelidikan ini adalah untuk menilai kesan baja, mikoriza dan penanaman secara campuran dengan anak pokok *Acacia mangium* Willd ke atas pertumbuhan dan tindak balas fisiologi anak pokok *A. excelsa* dengan menggunakan tanah jenis Rengam.

Penyelidikan ini mengandungi dua komponen. Kajian pasu dilakukan untuk melihat perubahan fisiologi dan pertumbuhan anak pokok *A. excelsa* apabila dirawat dengan beberapa jenis baja dan mikoriza dengan menggunakan tanah yang diambil dari lapangan. Kajian lapangan pula dibuat untuk melihat pertumbuhan anak pokok di lapangan apabila dirawat dengan baja dan mikoriza serta ditanam secara berselang dengan *A. mangium*.

Keputusan kajian pasu menunjukkan bahawa anak pokok yang dirawat dengan baja mempunyai pertumbuhan yang lebih baik berbanding kawalan. Di antara rawatan

baja, anak pokok yang dirawat dengan baja lepas perlahan Best-Tab (20-10-5 NPK dengan elemen tambahan dalam bentuk ketul 21 g) menunjukkan pertumbuhan yang paling baik serta mencatatkan kadar fotosintesis yang maksima, diikuti dengan 40 g baja NPK (15-15-15 NPK) dan akhir sekali 20 g baja NPK (15-15-15 NPK). Sebaliknya, mikoriza tanpa rawatan baja gagal meningkatkan pertumbuhan anak pokok seperti mana baja. Berbanding dengan rawatan baja lepas perlahan atau baja NPK, kombinasi rawatan gagal meningkatkan pertumbuhan anak pokok.

Semakin banyak baja yang diberi, semakin tinggi kandungan nutrien di dalam pokok. Ini dibuktikan dengan rawatan 40 g baja NPK. Akan tetapi, ia gagal meningkatkan kadar fotosintesis anak pokok yang terlibat. Analisis nutrien menunjukkan bahawa magnesium merupakan satu elemen yang penting dalam meningkatkan kadar fotosintesis. Anak pokok yang mempunyai kadar pertumbuhan yang rendah merekodkan kandungan kanji yang tinggi. Baja yang diberikan didapati mengurangkan jangkitan arbuskula mikoriza pada akar.

Keputusan kajian lapangan adalah menyerupai dengan apa yang diperolehi dalam kajian pasu. Baja lepas perlahan merupakan rawatan terbaik. Mikoriza gagal meningkatkan pertumbuhan anak pokok begitu juga dangan tanaman campuran. Kadar fotosintesis yang dicatat di lapangan adalah dalam julat yang telah direkodkan oleh spesies cepat tumbuh yang lain di Malaysia.

Kesimpulannya, pertumbuhan anak pokok *A. excelsa* dipengaruhi oleh mikoriza dan baja. Kesan faktor-faktor ini ke atas pertubuhan ladang *A. excelsa* dibincangkan.

# CHAPTER I

# INTRODUCTION

## General Background

The timber industry is a very significant contributor to the Malaysian economy. In 1994, the industry accounted for 15.4% of the total export, making it the largest foreign exchange earner among Malaysia's commodities (Ismail, 1996) However, projections made on forest production including rubberwood and forest plantation, indicate that log supply in Malaysia is still expected to be gradually reduced over the coming decade. In 1997, Malaysia was projected to face 3.06 x $10^6$ $m^3$ log deficit (Ismail, 1996).

To overcome this situation, the Malaysian government has been promoting forest plantation using fast growing species. Approximately 500,000 ha of forest plantations will be established in Malaysia by the year 2000 (Ministry of Primary Industries Malaysia, 1989). However, the majority of the sites for forest plantation establishment in the country consist of marginal land. It is estimated that a total of 1.47 x $10^6$ ha of forest land is degraded The effects of devastation of natural forest on soil fertility have been long recognized. The soil fertility problem is further aggravated by high rainfall. The heavy rainfall has resulted in increased soil erosion and nutrient leaching This leads to a very serious reduction in soil fertility and increased sedimentation in the streams

Establishment of fast-growing plantation will place a high demand on soil nutrients, especially at the initial stage of establishment These are situations where management of mycorrhizal systems are likely to be of great benefit, which are always over-looked, for the main mode of mycorrhizal stimulus of plant growth is via increased nutrient uptake

Optimization of yield per unit land area is the main objective of forest plantation and other forms of intensive forest management (Fisher and Mexal, 1984) Fertilization is an efficient silvicultural means which helps tree establishment and growth (Gupta, 1991) thereby contributing to increase productivity of the tree plantation (Ericsson *et al*, 1992) Thus, there is a need to focus on the fertilizer requirement of various timber species planted for further species selection

Theoretically, slow release fertilizers have several advantages over compound fertilizers (1) better utilization by the crop due to more constant rate of release (Raigon *et al*, 1996), (2) less chance of causing mortality due to their low silt index (Raigon *et al*, 1996), and (3) reducing losses from leaching (Ballard, 1979), volatilization (Prasad, 1976) and immobilization (Salonius and Mahendrappa, 1979) Despite the theoretical advantages, especially in the tropics, the use of slow release fertilizers is still unpopular Most forest managers prefer to use compound fertilizers

Ecological theory suggests that there is a potential productivity benefits to be gained in forest plantations which consist of more than one tree species The basic

advantage of mixed plantation is that two or more species may use resources differently if they are to coexist on a site (Vandermeer, 1989). There is a long history of mixed-species silviculture in Europe, but unfortunately, little work has been done elsewhere (Assmann, 1970; Kerr *et al.*, 1992).

Currently, a limited number of fast-growing species are being promoted as forest plantation species. *Azadirachta excelsa* (Jack) Jacobs, an indigenous multi-purpose species, is one of the tree species promoted. *A. excelsa* has (vesicular)-arbuscular mycorrhiza (AM) associations (Junaini, 1996) which may be necessary for normal tree growth (Habte *et al.*, 1993). Thus, detailed information on the influence of environmental conditions on the growth is required. However, little work has been carried out on the responses of *A. excelsa* to nutrition. An early study by Ong (1995) found that *A. excelsa* seedlings performed poorly under nutrient stress.

## Objectives and Scope of Study

The general objective of the studies was to determine the growth response and physiological changes of *A. excelsa* seedlings grown on Rengam series soil to multiple treatments of (1) slow release fertilizer, (2) NPK fertilizer, (3) arbuscular mycorrhiza, and (4) interplanting with *Acacia mangium* Willd seedlings.

The study which was conducted from May 1996 to July 1997 consisted of two trials: a pot trial in the glasshouse at Universiti Putra Malaysia and a field trial at Setul Forest Reserve in Negeri Sembilan, Malaysia. The pot trial which was conducted for four

months, comprised three treatments: granular NPK fertilizer, Best-Tab slow release fertilizer, and mycorrhizal application. The field studies involved interplanting of *A. excelsa* with *A. mangium*, application of granular NPK fertilizer, Best-Tab slow release fertilizer, and mycorrhizal inoculation. The trial was conducted for a period of eight months.

# CHAPTER II

# LITERATURE REVIEW

## Forestry in Malaysia

Malaysia is a country rich in natural resources. Peninsular Malaysia has vast supplies of petroleum, bauxite, copper, iron ore and gold. In addition, timber is abundant both in Peninsular as well as in East Malaysia. Approximately 72% of the land area in Malaysia is covered with trees. This is particularly high when compared to the remainder of Southeast Asia (52.6%), South America (48.6%) and the entire world (27.6%) (Ministry of Primary Industry Malaysia, 1992).

The Malaysian forests have and will continue to provide a renewable source of raw materials, energy and services for the people, contributing to their social and economic well-being, and form a vital component of their environment. Moreover, the survival of the forest is important for the sustainability of other key resources such as water and soil, which are essential for the survival and development of the nation.

The timber industry is a very significant contributor to Malaysia's economy. In 1994, the industry accounted for RM13.5 billion which was 15.4% of the total export,

making it the largest foreign exchange earner among Malaysia's commodities. The timber industry also provides direct employment to about 200,000 people (Ismail, 1996).

## Forest Area in Malaysia

### Natural forest

Forest resources in Peninsular Malaysia have depleted from 60% in 1955 down to 48% in 1990 (Ministry of Primary Industries Malaysia, 1991). Issues on deforestation have been discussed in detail by many researchers (Chong, 1979; Salleh and Ho, 1982; Freezailah, 1984; Thang, 1986). Many complicating factors are involved in the depletion of forest resources. These include agricultural and industrial development, mining, settlement and illegal encroachment. By 1994 the total forested area in Malaysia was $18.88 \times 10^6$ ha (Table 1).

**Table 1:** Distribution and Extent of Natural Forests by Major Forest Types in Malaysia, 1994 ($\times 10^6$ ha)

| Region | Land area | Dipterocarp forest | Swamp forest | Mangrove forest | Total forested land | Percentage total of forested land |
|---|---|---|---|---|---|---|
| Peninsular Malaysia | 13.16 | 5.41 | 0.30 | 0.11 | 5.82 | 44.2 |
| Sabah | 7.37 | 3.90 | 0.19 | 0.32 | 4.41 | 59.8 |
| Sarawak | 12.33 | 7.26 | 1.23 | 0.16 | 8.65 | 70.2 |
| Malaysia | 32.86 | 16.57 | 1.72 | 0.59 | 18.88 | 57.5 |

Source: Ismail (1996)

### Plantation forest

As a result of the timber boom in 1970's, the fear for timber shortage became apparent. To avoid the possibility of a shortage of timber and timber products in Peninsular Malaysia by mid 1990's, the Forestry Department of Peninsular Malaysia

launched the Compensatory Forest Plantation Project in 1982. This project aimed to grow and supply general utility timber for the domestic market. Plantation establishment is being looked upon to supplement the declining log supply from the natural forest. This plantation was to cover 188,200 ha by the year 1995 with 15 year rotation. Subsequently, fast-growing tropical hardwoods such as *A. mangium*, *Gmelina arborea* Roxb., *Paraserianthes falcataria* Becker and *Eucalyptus camaldulensis* Dehnh. were chosen for the project.

However, majority of the plantings to date have been with *A. mangium*. About 54,189 ha of this forest plantation have been established (Forest Department Peninsular Malaysia, 1995). In Sarawak some 6,613 ha of forest plantation have been established (Sandum and Wong, 1992) while in Sabah commercial forest plantation totaled at least 74,799 ha, much of which was planted with *A. mangium* (Udarbe, 1994). In addition there are 2,020 ha of teak plantations and 5,682 ha of *Pinus caribaea* Mor. plantations (Forest Department Peninsular Malaysia, 1995).

**Importance of Establishing Forest Plantation**

The interest in developing plantations and tree-planting in the tropics has increased rapidly. In fact, between 1965 and 1990, areas covered by plantations increased by six times (Evans, 1982). Establishment of new plantations in the tropical countries proceeded at the rate of about $1.1 \times 10^6$ ha yearly (FAO, 1993). By 1989, a total of $10 \times 10^6$ ha of forest plantations had been established in the tropics.

One good example is the forest plantation establishment in Malaysia. The followings are four reasons favouring plantation establishment in this country.

a. Projections made on forest production, where by log supply in Malaysia is expected to be reduced gradually over the coming decade. For the period of the Seventh Malaysia Plan (RM7), the total log supply for Malaysia, including rubberwood log and forest plantation wood is projected to reduce from 36.14 x $10^6$ $m^3$ in 1996 to 31.68 x $10^6$ $m^3$ in 2000. The demand for logs, on the contrary, is expected to increase marginally from 38.54 x $10^6$ $m^3$ to 39.14 x $10^6$ $m^3$ over the same period, giving rise to a log deficit ranging from 2.40 x $10^6$ $m^3$ to 7.46 x $10^6$ $m^3$ (Ismail, 1996). The details of log supply and demand for Malaysia for the period 1996 to 2000 are shown in Table 2.

**Table 2:** Summary of Projections of the Supply and Demand of Logs in Malaysia (x $10^6$ $m^3$)

| Year | Log supply | Log demand | Deficit |
|---|---|---|---|
| 1996 | 36.14 | 38.54 | -2.40 |
| 1997 | 36.08 | 39.14 | -3.06 |
| 1998 | 34.60 | 39.14 | -4.54 |
| 1999 | 34.49 | 39.14 | -4.65 |
| 2000 | 31.68 | 39.14 | -7.46 |
| Total | 172.99 | 195.10 | -22.11 |

**Source**: Ismail (1996)

This acute shortage in log supply to meet the demand of local consumption is further aggravated by the nominal quantum of log imports. For example, between 1990 to 1994, the total amount of log imported by Malaysia was only 662,850 $m^3$ or approximately 132,570 $m^3$ annually. This is however still grossly insufficient to meet the increasing demand of the wood industry sector.