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GENETIC VARIATION OF GROWTH AND SELECTED WOOD PROPERTIES OF FOUR-YEAR OLD ACACIA AURICULIFORMIS PROVENANCES AT SERDANG, MALAYSIA

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By

MOHD NOOR MAHAT

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LIST OF ABREVIATIONS

ACIAR	-	Australian Centre for International Agriculture Research
ANOVA	-	Analysis of Variance
ASEAN	-	Association of Southeast Asia Nations
ATSC	-	Australian Tree Seed Centre
DBH	-	Diameter at Breast Height
F/FRED		Fuelwood / Forest Research and Development Project
FRIM	-	Forest Research Institute Malaysia
GLM	-	General Linear Model
NT	-	Northern Territory
PNG	-	Papua New Guinea
PROC	-	Procedure
QLD	-	Queensland
SAS	-	Statistical Analysis System
UPM	-	Universiti Putra Malaysia

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

GENETIC VARIATION OF GROWTH AND SELECTED WOOD PROPERTIES OF FOUR YEARS OLD *ACACIA AURICULIFORMIS* PROVENANCES AT SERDANG SELANGOR

By

MOHD NOOR MAHAT

April 1999

Chairperson: Associate Professor Nor Aini Ab Shukor. Ph.D.

Faculty: Forestry

A trial at Universiti Putra Malaysia (UPM) Serdang, Malaysia consisting of twenty eight provenances of *Acacia auriculiformis* A. Cunn. ex. Benth was assessed at four years for total height, diameter at breast height, specific gravity and fibre length. Of these provenances, 7 were from Queensland (QLD), 15 from the Northern Territory (NT) and 6 from Papua New Guinea (PNG). The provenances and geographic regions differed significantly at $p < 0.05$ in their growth performance. Generally the Queensland provenances recorded the best growth in both height and diameter followed by the Northern Territorry and Papua New Guinea Provenances. The mean total heights for provenances from Queensland, Northern Territory and Papua New Guinea were 13.38 m, 12.37 m and 11.89 m respectively. The mean diameters at breast height for provenances from Queensland, Northern

Territory and Papua New Guinea were 12.67 cm, 11.04 cm and 10.69 cm respectively.

A similar pattern of variation was found in the wood properties except for wood specific gravity where there was no significant difference encountered between the three geographic regions. However, there were significant variation between provenances on both wood properties studied. The mean specific gravity ranged from 0.53 for the provenance from Balamuk on Bensbach (PNG) to 0.61 for the provenance from South Balamuk (PNG). The mean fibre length ranged from 0.865 mm for the provenance from Balamuk on Bensbach (PNG) to 0.993 mm for the provenance from Coen River (QLD).

Generally, the percentages of variance components due to between and within provenances for both growth and wood properties were high. Most of the genetic variation was contributed by the variation of the traits between individuals within provenances. This was shown in the residual variance components of all traits that ranged from 31.82 to 71.08%. Based on the basic information obtained on the genetic variation of this species, the alternative selection strategy recommended for the species is via selecting more individuals within provenance levels from all geographic regions.

Most of the correlations between traits were low except for the phenotypic ($r = 0.75$) and genetic ($r_G = 0.88$) correlations between total height and diameter at breast height. The results showed that there was no genetic correlation ($R_G = 0$) between the growth traits and wood propeties. Thus, there would be little scope of using growth traits for selecting wood properties. The broad-sense heritabilities of the traits were generally high. The heritabilities of the growth traits were, however, higher ($H^2 = 0.85$ - total height; $H^2 = 0.82$ - diameter at breast height) than those of the wood properties ($H^2 = 0.37$ - specific gravity; $H^2 = 0.22$ - fibre length). Predicted gains on the provenance selection were generally favourable except for the fibre length which was slightly low. The predicted gains for total height, diameter at breast height, specific gravity and fibre length were 13.3, 20.7, 2.6 and 1.9% respectively.

The finding showed that both intra and inter provenances as well as geographic region variations are important in the initial selection in the breeding programmes of this species. It is recommended that selection involving a large number of individuals within provenances could ensure the capturing of maximum genetic variation for the purpose of germplasm collection in a breeding population.

Abstrak tesis ini di kemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk mendapatkan Ijazah Master Sains

VARIASI GENETIK DI DALAM PERTUMBUHAN DAN SIFAT-SIFAT KAYU TERPILIH BAGI PROVENANS *ACACIA AURICULIFORMIS* BERUMUR EMPAT TAHUN DI SERDANG, MALAYSIA

Oleh

MOHD NOOR MAHAT

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Kajian terhadap 28 provenans *Acacia auriculiformis* berumur 4 tahun ke atas ketinggian, diameter paras dada, ketumpatan bandingan dan kepanjangan gentian sel dijalankan di Universiti Putra Malaysia. Dari kesemua provenans ini, 7 daripadanya adalah dari rantau Queensland (QLD), 15 dari Northern Territory (NT) dan 6 dari Papua New Guinea (PNG). Terdapat perbezaan pertumbuhan yang bererti pada $p < 0.05$ di antara provenans dan di antara rantau geografi. Secara amnya provenans dari Queensland menunjukkan prestasi pertumbuhan yang terbaik diikuti oleh provenans dari Northern Territory dan seterusnya oleh provenans dari Papua New Guinea. Purata ketinggian bagi provenans-provenans dari Queensland, Northern Territory dan Papua New Guinea masing –masing ialah 13.38 m, 12.37 m dan 11.89 m. Manakala purata diameter paras dada bagi provenans-provenans dari Queensland, Northern Territory dan Papua New Guinea pula, masing-masing ialah 12.67 cm, 11.04 cm dan 10.59 cm.

Corak variasi yang hampir serupa juga diperolehi bagi sifat-sifat kayu kecuali pada ketumpatan bandingan di mana tiada perbezaan yang bererti di antara rantau geografi ditemui. Walaubagaimanapun terdapat perbezaan yang bererti di peringkat provenans yang dikaji bagi kedua-dua sifat kayu tersebut di mana nilai purata bagi ketumpatan bandingan adalah berjulat daripada 0.53 (Balamuk on Bensbach dari PNG) hingga 0.61 (South Balamuk dari PNG) dan kepanjangan gentian sel dari julat 0.865 mm (Balamuk on Bensbach dari PNG) ke 0.993 mm (Coen River dari QLD).

Secara amnya peratusan komponen varian di antara dan dalam provenans bagi ciri-ciri pertumbuhan dan sifat-sifat kayu adalah tinggi. Kajian juga menunjukkan bahawa sebahagian besar daripada variasi genetik yang wujud adalah di antara individu di dalam provenans. Ini dapat dilihat dari komponen varian residu bagi kesemua ciri di mana ianya berada dalam julat 31.82 hingga 71.08%. Berdasarkan kepada maklumat asas variasi genetik bagi spesies yang dikaji, kaedah aternatif yang dicadangkan bagi membaikbiak spesies ini adalah melalui pemilihan yang melibatkan lebih banyak individu di dalam provenans dari ketiga-tiga rantau geografi tersebut.

Secara keseluruhannya korelasi genetik dan fenotip di antara sifat-sifat yang dikaji adalah rendah kecuali korelasi genetik dan fenotip di antara ketinggian pokok dan diameter paras dada, di mana nilai korelasi fenotip ialah 0.88 dan korelasi genetik ialah 0.75. Kajian mendapati tiada korelasi genetik diantara ciri-ciri pertumbuhan dan sifat-sifat kayu. Oleh itu kebarangkalian untuk menggunakan ciri-ciri pertumbuhan dalam pemilihan sifat-sifat kayu adalah amat terhad. Walaubagaimanapun, nilai heritabiliti umum bagi kesemua sifat-sifat yang dikaji adalah tinggi. Namun demikian, nilai heritabiliti umum bagi ciri-ciri pertumbuhan (ketinggian - 0.85; diameter - 082) adalah lebih tinggi berbanding dengan heritabiliti sifat-sifat kayu (ketumpatan bandingan - 0.37; kepanjangan serat - 0.22). Justeru itu anggaran perolehan genetik secara amnya adalah tinggi kecuali perolehan genetik bagi kepanjangan serat. Nilai anggaran perolehan genetik bagi ketinggian, diameter, ketumpatan bandingan dan kepanjangan gentian sel ialah 13.3, 20.7, 2.6 dan 1.9%.

Hasil kajian ini menunjukkan variasi di antara dan di dalam provenans serta rantau geografi adalah amat penting dalam proses pemilihan awal program membaik-biak spesies ini. Justeru itu, pemilihan lebih banyak individu di dalam provenans bagi memastikan pengumpulan variasi genetik yang maksima untuk pembentukan suatu gemplasma populasi biak-baka awal adalah dicadangkan.

CHAPTER I

INTRODUCTION

Forest plantation has become an important issue in the forestry sector especially in the ASEAN countries. As the harvest of natural forest declines, there is a need to supplement the industrial wood supply with wood from plantations. The fast growing species have been given greater attention in the forest plantation programmes. Among the fast growing species that have been chosen for the reforestation activities are the *Acacia* species. *Acacia auriculiformis* A. Cunn. ex Benth is one of the potential candidate species for this purpose.

Acacia auriculiformis is one of the most widely planted tropical acacias in Asia and to lesser extent, in Africa and South America (Kamis and Venkateswarlu, 1994). The species occurs naturally in Australia, Papua New Guinea and Irian Jaya, Indonesia. However, it is better known outside its natural range of distribution as a fast growing species and one of the most adaptable species for planting activities in tropical humid and subhumid low land regions. It is found to grow better under environmental conditions which are quite different from those in its natural range of occurrences (Pinyopusarerk, 1990). The species is primarily planted for the production of fuelwood, pulp and paper, rehabilitating degraded lands and as ornamentals (Kamis and Venkateswarlu, 1994).

The important attributes of this species are rapid early growth, good wood quality and tolerance to a wide range of environmental conditions. According to Mitchell (1963), it has been recommended as a potential reforestation species because it possesses favourable traits such as fast growth, low site selectivity and high resistance against disease and insect attack. It can be used to rehabilitate and revegetate problematic or difficult sites such as tin tailing areas (Mitchell, 1957), *Imperata cylindrica* grassland (Voogd, 1948), eroded land (Ali, 1986), wasteland (Jha, 1987) and mining areas (Prasad and Chadhar, 1987). Apparently its abilities to fix atmospheric nitrogen and grow on very poor soils are important attributes for its success in the rehabilitation programmes in the tropics. This species produces a strong rooting system with sturdy stem which requires little attention once planted (Ratnasabapathy, 1974).

***Acacia auriculiformis* in Malaysia**

Acacia spp. are exotic to Malaysia. Among the species that have been introduced include *A. mangium, A. auriculiformis*, *A. richii, A. gray, A. confusa*, *A. cincinata*, *A. holosericea*, *A. aulacocarpa*, *A. farnesiana* and *A. podalyriifolia* (Barnard and Beverage, 1957; Mitchell, 1964; Tham, 1979; Selvaraj and Mohammad, 1985). Among these species, *A. auriculiformis* and *A. mangium* are the most common and extensively planted. The adaptability of *A. auriculiformis* to Malaysian conditions has been noted since its first introduction to Peninsular Malaysia in 1931 (Barnard and Beverage, 1957). Since then it has been commonly planted as an ornamental or shade tree in parks, gardens or along roadsides (Nor Aini *et al*., 1994).

Despite the mentioned impressive advantages and excellent early growth performance, this species was not chosen for the Compensatory Forest Plantation Programme initiated in 1982 by the Department of Forestry in Peninsular Malaysia (Thang and Zulkefly, 1992). The heavy branching and crooked form which are commonly exhibited by this species are its major drawbacks. These characteristics could be genetically controlled, perhaps perpetuated from a narrow genetic base from its earlier introductions (Nor Aini *et al*., 1994). This phenomenon persists because little work associated with this characteristics has been emphasized in the tree improvement programmes and mixed seed sources have been used in planting in the past (Zakaria, 1991; Sim, 1992).

Background of the Study

Considerable attention has been given to evaluate the performance of various provenances of this species when a provenance trial was established in 1989 at the Universiti Putra Malaysia (UPM). The research was part of a collaborative effort between the Fuelwood / Forest Research and Development Project (F/FRED) and the Australian Centre for International Agriculture Research (ACIAR) to evaluate the performances of these provenances by establishing multilocational trials in 1989 (Kamis *et al*., 1994). The early growth performance at thirty-six months of these provenances at Serdang UPM, showed that there were significant differences among the provenances. Significant differences were also found between the provenance regions as well as among the provenances within the region (Nor Aini *et al*., 1994). These early assessments, however, indicated a low genetic variability observed in the growth parameters such as height, diameter at breast and basal diameter (Venkateswarlu *et al*., 1994). The low genotypic variation found in this species suggested that the environmental influences had more impact on those characters than its genetic constituents. Indeed, similar provenances have been reported by Luangviriyasaeng *et al*. (1991) to exhibit a strong genotype x environment interaction effect. They indicated that environment factors also played an important role in determining the growth performance of the provenances.

Most of the research on this species, however, focused mainly on the growth performances of the provenances and very limited studies have been conducted on its wood properties since its introduction to Malaysia. Knowledge on genetic variation of wood properties is also important if it is to be used as one of the main species in forest plantation programme in Malaysia. Research should not only focus on the genetic variation of the wood quality of the species as a whole but also more particularly on the amount of variation that exists among and within the provenances. Although the primary emphasis of most tree breeding programmes is to obtain faster growth, better form, better adaptation and pest resistance, improved wood properties should also be stressed from the same programme. Research has shown that most wood qualities as well as tree form and growth characteristics that affect wood are strongly inherited, therefore rapid economic gains can be obtained through genetic manipulation (Zobel and Talbert, 1984).

No matter what specific type of wood is desired in the future, improvement in wood characteristics will be of value in almost every programme. Wood is notably non-homogenous, both within and among trees of a species as well as among species and geographic sources. Genetic manipulation of wood properties in a breeding programme can result in a higher proportion of desired wood with better homogeneity. This is best captured through improvement work. Tree improvement programmes which include wood production as a goal should consider manipulation of its wood qualities. Therefore research on wood properties especially on its genetic variation between and within provenances is necessary before proceeding to the actual improvement programme.

Understanding the genetics of forest tree species is the basis for an appropriate utilisation of forest genetic resources. Knowledge pertaining to genetic variation between and within provenances of a species is important for the selection strategy in a tree improvement programme. The results from this study will provide information on genetic variation of the growth and some wood properties of *A. auriculiformis* provenances that is required in improvement programme of the species. Information on wood properties would possibly serve as a marker for achieving better selection in tree improvement for particular end uses. Therefore this study was undertaken to identify the amount of genetic variation present in the growth characteristics as well as in the selected wood properties of *A. auriculiformis* provenances planted at UPM, Serdang, Malaysia.

The Objectives

The specific objectives are:

1. To determine genetic variation in the growth and selected wood properties of *A. auriculiformis* provenances.

2. To establish any correlation among growth parameters with selected wood properties.

3. To estimate the heritabilities and expected gains through selection of growth traits and wood properties at the provenance level.

CHAPTER II

LITERATURE REVIEW

Acacia auriculiformis as a Plantation Species

Natural Distribution and Ecology

A. auriculiformis A. Cunn. ex Benth., is a leguminous tree of the subfamily Mimosoideae which formerly belongs to the genus, *Racosperma* (Pedley, 1987). However, in this citation the genus *Acacia* will be used as synonymous to *Racosperma*. Generally the species of this genus are pioneer and fast growing which play significant roles in secondary succession through nutrient conservation, replacement and redistribution (Adams and Attiwill, 1984).

A. auriculiformis grows naturally in Australia, Papua New Guinea and Indonesia between latitudes of 5^0 and 17^0S (Turnbull, 1986). It can be found growing at altitudes of up to 400 m above sea level. In Australia, it is found in the north of the Northern Territory (between latitudes 11-140^0S and longitudes

130-135^{0}E) (Pinyopusarerk, 1990). In Papua New Guinea, it occurs mainly in Western Province ranging from 9^{0}S, 141^{0}E to 9^{0}S, 143^{0}E. The occurrence of *A. auriculiformis* in Indonesia is mainly in Irian Jaya and on Kai Islands (Pinyopusarerk, 1990).

Climatically, *A. auriculiformis* occurs in hot humid and sub-humid zones with mean maximum temperature of the warmest month of 32-38^{0}C and mean minimum temperature of the coldest month of 12-20^{0}C. Annual rainfall varies from 760 mm in the Northern Territory, Australia to 2000 mm in Papua New Guinea (Gunn *et al*., 1988) and Indonesia (Pinyopusarerk, 1990). However, the species has been found near Kerema in Papua New Guinea where its annual rainfall can even reach 3000 mm. On the other hand, it has also been reported to survive in areas having a prolonged dry season with annual rainfall as low as 650 mm. At the other extreme, it can also grow satisfactorily in areas receiving an annual rainfall of 6000 mm (Pinyopusarerk, 1990).

A. auriculiformis grows in a wide range of soil and environmental conditions. It is found to thrive well in areas with seasonal water logging (Boland, 1990), pollution of industrial gases (Kong, 1988), acidic soils (Turnbull, 1986), alkaline soils (Basappa, 1983) and saline soils (Midgley *et al*., 1986). In Papua New Guinea it occurs on heavy-clay soils with pH ranging from 4.0 to 6.0. This