UNIVERSITI PUTRA MALAYSIA

RADIAL VARIATION OF WOOD AXIAL ELEMENTS IN YOUNG ACACIA MANGIUM WILLD. AND SERIAL CROSS SECTIONING OF SHOREA LEPROSULA MIQ.

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BY

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

February 2002

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

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February 2002

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Wood quality, namely wood structure, physical and mechanical properties, and other qualities of woodworking, are greatly influenced by the proportion, type, morphology, arrangement, distribution, and specific gravity of xylem constituent cells. The present study was conducted to determine the radial variation pattern of wood axial elements in *Acacia mangium* Willd. In addition, the suitability of serial cross sectioning technique for wood fibre length determination in *Shorea leprosula* Miq. was also investigated.

In the first part of the study, the radial variation pattern in the length of wood fibre and vessel element in *Acacia mangium* was investigated to reveal the difference in the pattern between dominant and suppressed

trees. The correlation between the radial variation of wood fibre length and monthly climatic factors (average temperature and precipitation) in the early stage of tree growth was established.

Wood fibre length gradually increased from the pith to the bark and leveled off at a distance of 3 to 4 cm from the pith in dominant trees, but increased throughout the stem in suppressed trees of about 4 cm diameter. Vessel element length remained at approximately 0.2 mm across the stem, although the length tended to increase slightly outward.

The radial variation pattern of wood fibre length was related to the radial tendency in the frequency of cell divisions in cambium rather than the age of the tree. The results of the cross-correlation function between the wood fibre increment and the climatic factors showed that its monthly increment was correlated to monthly precipitation in a few previous months rather than that in the same month. This suggests that the radial growth in the tree was active prior to increase in rainfall.

Three-dimensional analysis of wood fibre morphology using serial cross sectioning was conducted on *Shorea leprosula* Miq., for detailed analysis of the morphology without using special and expensive device.

Serial cross sectioning provides precise information on the location and the length of wood fibre in each radial file.

Comparing the wood fibre length measured using serial cross sectioning and maceration, the result obtained by the former was approximately 0.1 mm shorter than the latter. To obtain a serial cross sectioning, more precise measurement of wood fibre length in an objective lens of greater resolution power showed be used to detect the exact tip of the fibre apex.

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

VARIASI UNSUR MENEGAK PADA ARAH JEJARI DI DALAM KAYU MUDA *Acacia mangium* Willd. DAN SIRI HIRISAN PERMUKAAN RENTAS *Shorea leprosula* Miq. SEEDLINGS

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Februari 2002

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Kualiti kayu khususnya struktur kayu, sifat fizikal dan mekanikal dan kualiti lain di dalam kerja kayu (*woodworking*) banyak dipengaruhi oleh nisbah, jenis, morfologi, susunan, taburan dan ketumpatan bandingan sel xylem. Tujuan kajian ini dijalankan adalah untuk menentukan corak variasi arah jejari gentian kayu *Acacia mangium* Willd. dan *Shorea leprosula* Miq. Selain dari itu , kesesuaian teknik siri hirisan permukaan rentas untuk menentukan panjang gentian *Shorea leprosula* juga diselidik.

Dalam bahagian pertama kajian, perbezaan corak variasi arah jejari panjang gentian dan panjang elemen vesel diantara pokok *Acacia mangium* Willd. yang dominan dan *suppressed* diselidik. Selain dari itu kaitan antara

corak variasi jejari panjang gentian dengan faktor cuaca bulanan (suhu dan hujan) dalam peringkat permulaan pertumbuhan pokok juga dikaji.

Panjang gentian semakin meningkat dari empulur ke arah kulit kayu dan sekata pada jarak 3 cm hingga 4 cm daripada empulur dalam pokok dominan, manakala panjang gentian pada pokok *suppressed* meningkat pada keseluruhan batang iaitu dari empulur hingga ke arah kulit kayu pada jarak 4 cm. Purata panjang vesel lebih kurang 0.2 mm dan tidak berubah pada keseluruhan batang, walaupun panjangnya sedikit meningkat ke arah kulit.

Perbezaan bentuk panjang gentian kayu arah jejari adalah berkait dengan kecenderungan arah jejari dalam kekerapan pembahagian sel dalam kambium dan bukan umur pokok. Keputusan fungsi *cross-correlation* antara pertambahan panjang gentian dan faktor cuaca menunjukkan terdapat korelasi antara pertambahan panjang dengan kelembapan bulanan pada beberapa bulan lepas dan tidak pada bulan yang sama. Kemungkinan pertumbuhan arah jejari pada batang pokok aktif pada bulan yang banyak menerima hujan.

Analisa 3-dimensi morfologi gentian kayu menggunakan siri hirisan rentas kayu *Shorea leprosula* secara terperinci tanpa menggunakan peralatan yang mahal. Siri hirisan rentas dapat menyediakan kedudukan tepat gentian dan panjang gentian dapat ditentukan tanpa menggunakan analisa statistik seperti yang perlu dilakukan jika menggunakan kaedah maserasi *(maceration)*.

Perbandingan mengukur panjang gentian menggunakan kedua-dua kaedah iaitu siri hirisan rentas dan maserasi mendapati dengan menggunaan kaedah siri hirisan rentas panjang gentian adalah 0.1 mm lebih pendek berbanding dengan kaedah maserasi. Untuk mendapatkan ketepatan ukuran yang jitu siri hirisan permukaan rentas resolusi kanta objektif yang tinggi mesti digunakan untuk mengesan kedudukan sebenar kedua-dua hujung gentian.

ACKNOWLEDGEMENTS

I would like to express my profound gratitude to Assoc. Prof. Dr. Mohd. Hamami Sahri, the chairman of my supervisory committee, for his guidance and suggestions throughout the course of my study and in preparation of this thesis. My sincere appreciation is also extended to Dr. Zaidon Ashaari and Dr. Wong Ee Ding, members of my advisory committee, for their suggestions and comments.

My sincere appreciation goes to Prof. Dr. Fujita Minoru and Prof. Dr. Nobuchi Tadashi of Kyoto University for their kind assistance, provision of facilities, and invaluable suggestions, comments and encouragement. I am also thankful to Prof. Dr. Furukawa Ikuo of Tottori University for his support and encouragement.

Acknowledgements are also extended to Mr. Hasidin Abd. Rashid and all the staff of the Faculty of Forestry, Universiti Putra Malaysia, who have helped and provided me the facilities needed throughout the course of my studies.

I would like to convey my deepest thanks to my dearest family members, my father Papa san, mother Mama san and younger sister Satoko

for their constant support and unfailing encouragement. Furthermore, I wish to express my special thanks to my friends in Nepal, Phurba dai, Pasang dai, Ang Dawa san, Dendi san, Ang Pasang san, Kitemba san and all friends of Sherpa for giving me the strength and courage. Thank you very much to my friends in UPM, and especially to my housemate Kak Azilah and Kak Lailan, and my roommate Poppo for constant encouragement, and especially to Ogata Yoshiyuki, thank you so much for your assistance, suggestions, and guidance in my master's study, and to all of my dearest friends in Japan.

Finally, especially to Wong san, thank you so much for invaluable suggestions, comments and constructive criticisms which led to the completion of this thesis.

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CHAPTER ONE

INTRODUCTION

1.1 Background

The term "wood quality" refers to the texture, physical and mechanical properties of wood which in turn affect its processing properties. The indices which are frequently used for the measurement of wood quality include wood fibre length, height and distribution of ray tissue, and the proportion of vessel and ray tissue. The characteristics of these elements vary considerably among species and trees, even at different heights within a tree or across the trunk at the same height.

In addition to wood density which is generally recognised to be the most important and efficient index for wood strength, wood properties are greatly influenced by the proportion of certain types of xylem constituent cells, their arrangement and distribution. The characteristics of hardwood are basically dependent on the chemical and morphological properties of the xylem constituent cells, i.e. wood fibres, which constitute up to 60 % of the total volume of wood.

Wood fibre length, one of the most important morphological factors, generally depends on the location of the fibre within a trunk. The fibre length is usually the shortest at the pith, gradually increases outward, and finally becomes constant at a certain point (known as "stable point") within the xylem. In most of the tropical trees, very little is known about the radial and vertical variation patterns of wood fibres, hence the stable point cannot be determined, although substantial work has been conducted to determine the average length of wood fibres (Peh et al. 1986; Sahri et al. 1993; Lim and Gan 2000). In typical tropical trees, the variation pattern of wood fibre length with time is not known, since these trees do not have annual rings. It is therefore impossible to investigate the relationship between its variation pattern and climatic factors.

This study is divided into two main parts. The first part reports the radial variation pattern of the lengths of wood fibre and vessel element in young *Acacia mangium* Willd. trees, a fast growing species, followed by the establishment of correlation between the wood fibre length variation and radial growth rate based on increment of girth at breast height. Subsequently, the effects of selected climatic factors on the radial variations of fibre length, vessel element length, fibre increment and fibre elongation ratio were also established.

In the second part, a serial cross section technique was introduced to examine the wood fibre morphology in 4-year-old *Shorea leprosula* Miq., a slow growing species. Different from the conventional maceration method, this technique provides more precise information on the length of fibres corresponding to their exact location in each radial section, instead of relying on the current maceration method which only presents an approximation based on statistical means. This technique was not adopted for *A. mangium* sample trees as the xylem cells in these trees had undergone a greater degree of elongation, and the cell arrangement was too complicated for identification on the cross section.

1.2 Justification

Information on the radial variation of the length of wood fibre and vessel element in *A. mangium* and *S. leprosula*, and their correlations with the climatic factors over time, could provide a better understanding on the growth behavior of these fast/slow growing hardwood species. These fundamental data can be related to the wood properties, which can lead to more efficient timber utilisation.

Successful application of the serial cross section technique in hardwood species enables determination of wood fibre length at exact location in the radial section, instead of relying on the current maceration method which only presents an approximation based on statistical means.

1.3 Objectives

This study aims to

1. investigate the radial variation pattern of the lengths of wood fibre and vessel element in *Acacia mangium* trees and determine the wood fibre maturation point, i.e., the point at which the fibre length becomes constant.

2. compare the radial variation pattern of the lengths of wood fibre and vessel element between dominant and suppressed *Acacia mangium* trees.

3. evaluate the relationship between the radial variation in the length of wood fibres and monthly climatic factors (average temperature and precipitation) in the early stage of tree growth in *Acacia mangium*.

4. attempt and evaluate the serial cross sectioning method for measuring the dimension of wood fibre in *Shorea leprosula*.

CHAPTER TWO

LITERATURE REVIEW

2.1 Xylem Constituent Elements

Xylem constituent elements of both coniferous and dicotyledonous trees are contained almost exclusively within the secondary xylem. These elements are derived by cambial division and composed of several types of cells including conductive tissues.

The xylem in conifers is constituted of tracheid and parenchyma as axial elements, with ray tracheid and ray parenchyma as radial elements. The axial tracheids are particularly predominant, making up approximately 90% of the total axial constituent elements (Appendix 1-1). Other elements, i.e., axial and ray parenchyma and intercellular canal, account for approximately 0.9, 3.8 and 0.8%, respectively.

In general, broad-leaved trees evolved more than conifers and have various cell types for specialized functions (Furuno and Watanabe 1994). The main xylem constituents of hardwood are wood fibres, vessel elements, tracheids, and parenchyma cells (axial elements), with ray parenchyma as the predominant radial element (Appendices 1-2 and 1-3). In both Japanese and tropical broad-leaved trees, the proportion of wood fibre is generally the