UNIVERSITI PUTRA MALAYSIA

DISTRIBUTION AND CHARACTERISTICS OF MINERAL INCLUSIONS IN *Hopea odorata* Roxb. AND *Dryobalanops aromatic* Geartn. f.

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FH 2012 21

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By

TOONG WEI CHING

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

NOVEMBER 2012

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

DISTRIBUTION AND CHARACTERISTICS OF MINERAL INCLUSIONS IN *Hopea odorata* Roxb. AND *Dryobalanops aromatic* Geartn. f.

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Chairman: Professor Dr. Mohd. Hamami bin Sahri, PhD

Faculty: Faculty of Forestry

This study was to investigate the occurrence, distribution, morphology, and dimension of mineral inclusions (calcium crystal and siliceous inclusion) in *H. odorata* and *D. aromatica*. Specifically, this study also attempted to compare the different amount of calcium crystals with regard to its growing and age of the tree. These species were selected due to deposition of mineral inclusion which leads to caused wearing in the woodworking cutting tools which contributed to processing economic.

Siliceous inclusion deposited in *D. aromatica* has smooth and rough surface with globular, aggregate and irregular shape, and its size was ranging from 1.31 to 23.1 µm. Calcium crystal deposited was in druse form and that found

to has sizes in ranging from 7.9 to 23.1 µm. The siliceous inclusion commonly deposited in wood ray and phloem ray, and even pith, but occasionally in axial parenchyma of wood and phloem. Pith area in the branch was lacking of mineral inclusions. The amount and size of siliceous inclusion was increased toward inner part of secondary xylem. The size was decreased, while the amount was increased with the tree height. At the pith this inclusion showed a decreased in the amount and size with an increased in tree height. Calcium crystal coexisted with siliceous inclusion in phloem ray and the cortex of the barks, and commonly found in separate cells. Mineral inclusions in the trunk bark were decreased in size with an increased in tree height, while in the root bark was decreased with an increasing in depth within the soil. Siliceous inclusion was deposited in epidermis while the crystal was deposited in palisade and spongy mesophyll of the leaf blade, and in cortex of the midrib and petiole, but occasionally in the parenchyma cell adjacent to vascular bundles of the petiole. Crystal found in leaf blade had smaller size than in petiole.

H. odorata deposited the calcium crystal in form of druse and prismatic with four to eight planes, and with size ranging from 9.8 to 45.4 µm. Prismatic crystal was deposited in wood ray and the pith. The amount and the size of the crystals were increased toward inner part of secondary xylem, and decreased with an increasing in tree height. Druse crystal was commonly found in the phloem ray and the cortex, occasionally also found in wood ray

and axial phloem parenchyma. The size was decreased in size with an increasing tree height.

Crystals in young *H. odorata'* s tree showed druse and prismatic form with four to ten planes in shape, and the size ranging from 7.4 to 53.3 µm. Both crystal forms were coexisting in wood ray, but druse crystal deposited in inflated ray cell or inflated chambered ray cell. Prismatic crystal was increased in size with an increasing tree height, while druse crystal size distribution was showed a reverse pattern. The crystal found in the pith was prismatic and showing decreasing size with an increased tree height. In the branch wood, the crystal was absent. Prismatic crystal was deposited in ray cells of root wood, but druse crystal was absent. The size of crystal in root wood was decreased as it goes deeper into soil. Druse crystals was deposited in spongy and palisade mesophyll of leaf blade, in the cortex of midrib and parenchyma and cortex of petiole in which size in petiole was larger than in leaf blade. Tree planted in Selangor which was older than tree planted in Perlis was showed fewer amount of crystals than in Perlis even in the young tree.

The finding from this study, occurrence of mineral inclusions has a significant in the taxonomical characteristic and wood identification. The dimension and distribution pattern can serve as basis for investigation into wearing of woodworking cutting tools. It also filled the gap of knowledge of mineral inclusions in various tree parts.

Abstrack tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains.

TABURAN DAN CIRI-CIRI INKLUSI GALIAN DALAM *Hopea odorata* Roxb. DAN *Dryobalanops aromatic* Gaertn. f.

Oleh

TOONG WEI CHING

NOVEMBER 2012

Pengerusi: Profesor Dr. Mohd. Hamami bin Sahri, PhD

Fakulti: Fakulti Perhutanan

Penyelidikan ini dijalankan untuk mengkaji kedapatan, taburan, morfologi, dan dimensi inklusi galian seperti kristal berkalsium dan inklusi bersilika dalam *H. odorata* dan *D. aromatica*. Secara khususnya, penyelidikan ini membandingkan jumlah kalsium yang berlainan dan jumlah kristal yang mendap berhubung kait dengan faktor pengaruh iaitu lokasi dan umur pokok berkenaan.

Inklusi bersilika yang termendap dalam *D. aromatica* mempunyai permukaan yang licin atau kasar dengan kewujudan dalam bentuk bulat, berkumpulan atau tidak teratur. Saiznya berjulat antara 1.31 hingga 23.1 µm. Kristal

berkalsium wujud dalam bentuk druse yang termendap mempunyai saiz berjulat diantara 7.9 kepada 23.1 μm. Inklusi bersilika disimpan dalam xilem dan floem ruji , dan empulur, tetapi kadang-kalanya inklusi bersilika juga terdapat dalam kayu dan parenkima aksial floem. Empulur pada batang pokok tidak mempunyai inklusi galian. Jumlah dan saiz inklusi bersilika meningkat ke arah bahagian dalaman xilem. Walaupun saiznya telah mengecil, tetapi jumlahnya meningkat pula secara keseluruhan dengan peningkatan ketinggian pokok. Empulur menunjukkan penurunan jumlah dan pertambahan saiz dengan peningkatan kepada ketinggian pokok. Kristal berkalsium dan inklusi bersilika wujud bersama di floem ruji dan korteks kulit kayu serta sering berasingan dan agak jarang wujud di dalam sel tunggal. Saiz inklusi galian dalam kulit batang mengecil dengan peningkatan ketinggian pokok. Manakala, pada dalaman kulit akar pula saiznya berkurang dengan pertambahan panjang akar kedalam tanah. Inklusi bersilika yang termendap dalam epidermis dan kristal berkalsium yang termendap dalam jaringan mesofil tiang dan jaringan mesofil bunga karang pula adalah pada helaian daun, dan dalaman korteks pada tulang daun, serta tangkai daun. Akan tetapi, kadang-kala kandungan ini juga termendap dalam sel parenkima bersebelahan dengan berkas vaskular dalam petiol. Kristal berkalsium yang termendap pada daun mempunyai saiz yang lebih kecil berbanding dalam petiol.

H. odorata memendapkan kristal berkalsium dalam bentuk druse dan prisma yang mempunyai 4 hingga 8 permukaan serta dengan saiz antara 9.8 hingga

45.4 µm. Kristal prisma termendap pada ruji kayu dan empulur. Jumlah dan saiz kristal meningkat ke arah bahagian dalaman xilem, dan berkurangan dengan peningkatan ketinggian pokok. Druses kristal biasanya ditemui di dalam floem ruji dan korteks kulit kayu, kadang-kadang ditemui dalam ruji kayu dan parenkima aksial floem. Saiznya berkurang dengan peningkatan ketinggian pokok.

Kristal dalam *H. odorata* muda wujud dalam bentuk druse dan prisma dengan 4-10 permukaan dan saiznya di antara 7.4 hingga 53.3 µm. Kedua-dua bentuk kristal ini wujud bersama dalam ruji kayu, tetapi kristal druse yang termendap dalam sel ruji yang mengembung atau pada sel ruji bersenggat. Saiz Kristal prisma meningkat dengan peningkatan ketinggian pokok, manakala kristal druse menunjukkan tren sebaliknya. Kristal yang mendap dalam empulur adalah prisma yang mengecil dengan ketinggian pokok. Pada bahagian cabang, tiada kewujudan sebarang kristal. Kristal prisma termendap dalam sel ruji kayu akar, tetapi tiada mendapan kristal druse. Saiz kristal dalam akar kayu mengecil pada bahagian akarnya yang lebih mendalam ke dalam tanah. Kristal druse juga termendap dalam jaringan mesofil tiang dan jaringan mesofil bunga karang pada helaian daun, korteks pada tulang daun, serta parenkima dan korteks pada tangkai daun yang bersaiz lebih besar daripada dalaman helaian daun. Pokok yang ditanamkan di Selangor adalah lebih tua berbanding pokok yang ditanamkan di Perlis. Pokok yang ditanamkan di Selangor mempunyai jumlah kristal yang

kekurangan berbanding dengan pokok yang ditanamkan di Perlis walaupun saiznya adalah kecil.

Dari penyelidikan ini, ia dapat mengimpulkan kewujudan inklusi galian yang mempunyai kepentingan dalam taxonomi tumbuhan. Sementara itu, dimensi dan taburannya boleh digunakan sebagai asas untuk mengkaji kehausan dan sebab ketumpulan kepada alat-alat pemotong kayu. Malahan, ini juga mampu mengisi kekurangan pengetahuan mengenai inklusi galian dalam bahagian pokok.

ACKNOWLEDGEMENTS

I desire to express my sincere appreciation to Prof. Dr. Mohd. Hamami Sahri, who is the chairman of my supervisory committee, for his mentoring and precious suggestions throughout this study. My grateful thanks also to Assoc. Prof. Dr. Mohd. Zin Jusoh, who is members of my advisory committee, for his suggestions and comments.

My warmest regards due to Prof. Dr. Tadashi Nobuchi for his concept and invaluable suggestion which made this study possible. I am also like to thank Dr. Rasmina Halis for her suggestion in improving the chemical analysis of this study. Special thanks are due to Dr. Mohamad Roslan Mohamad Kasim for his guidance in statistical analysis.

I desire to convey my deepest appreciation to my dearest family members for their warm support and encouragement. My appreciation from bottom of my heart to Son Mei Teng who consistently and unfailingly in giving encouragement and always for be there for me during my difficulty. I also wish to thanks to my friend Abdirizak for giving me hope and strength.

I certify that a Thesis Examination Committee has met on (insert **01 November 2012**) to conduct the final examination of Toong Wei Ching on his thesis entitled "**Distribution and characteristics of mineral inclusions in *Hopea odorata* and *Dryobalanops aromatica***" 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 Thesis Examination Committee were as follows:

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the **Master degree of Science**. The members of the supervisory Committee were as follows:

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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 at any other institution.

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TOONG WEI CHING

Date: 1 NOVEMBER 2012

LIST OF TABLES

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LIST OF ABBREVIATIONS

ANOVA	analysis of variance
°C	degree Celsius
cm	centimeter
EDX	energy disperse X-ray
g	gram
IAWA	International Association of Wood Anatomists
IUCN	International Union for Conservation of Nature
kg	kilogram
m	meter
m^2	square meter
m^3	cubic meter
µm	micrometer
mm	millimeter
%	percentage
SEM	scanning electron microscope
SPSS	Statistical Package for the Social Sciences
t-test	Student's t test
yr	year

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