UNIVERSITI PUTRA MALAYSIA

EFFECTS OF PLANTING DENSITY AND CLONES ON THE GROWTH AND WOOD QUALITY OF RUBBER TREE (Hevea brasiliensis Muell. Arg.)

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By

HAMID REZA NAJI

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

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DEDICATIONS

First and foremost, I would like to dedicate this thesis to my beloved parents, Haji Hassan and Sareh Khatoun whose love for me knew no bounds and, who taught me the value of hard work. Thank you so much, I will never forget you.

I also want to remember my elder brother, Sadroddin Naji, whose life was cut short by a horrible accident at the tender age of 19 who left a void never to be filled in our lives. May you find peace and happiness in Paradise!

Last not least, I am dedicating to my lovely wife, Seyedeh Ameneh and sons: Sadra and Parsa for their endless kindness and understanding me during last four years.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Doctor of Philosophy

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Chairman: Professor Mohd. Hamami Sahri, PhD

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Rubberwood *(Hevea brasiliensis)* is a well-known plantation species in tropical areas. Wood properties are changed with genetic manipulation, silvicultural techniques, and site conditions. The main concern in wood utilization is the level of variation of wood properties. According the early researches, there are no adequate reports on how wood quality changes under different planting densities and clones? Understanding wood properties and its behavior under different conditions is very important for the evaluation of its products performance. Basic information on rubberwood of different clones and planting densities and their variation would be very valuable as an indicator for evaluating its suitability for diverse final uses.

This study was carried out to characterize variation of anatomical, physical and mechanical properties as well as the tree growth parameters of a 9-year-old plantation grown wood in four

different planting densities (PD); 500 (PD I), 1000 (PD II), 1500 (PD III), and 2000 (PD IV) trees ha^{-1} of two clones RRIM 2020 (I) and RRIM 2025 (II). This plantation was managed by Malaysian Rubber Board in the northeastern state of Terengganu, Peninsular Malaysia.

Diameter at basal area (DBA), diameter at breast height (DBH) and clear bole height (BH) were measured to evaluate the effect of planting density on tree growth. The DBA and DBH showed significant negative correlation with planting density. The highest values of DBAs in both clones were 27.99 cm and 24.62 cm in PD I and the lowest values of 23.92 cm and 19.98 cm in PD IV. Likewise, the highest values of DBHs in both clones were 20.22 cm and 19.96 cm in PD I and the lowest values of 17.54 cm and 15.07 cm in PD IV. The BH revealed a significant and positive correlation with the planting density that showed an ascending trend from low to high planting densities. The highest values of 1023 cm and 1026 cm were in PD IV and the lowest values were 467 cm and 738 cm in PD I from both clones. The DBA and DBH in clone II were significantly smaller than clone I while the BH performance in clone II showed better results.

The changes in fiber length and fiber wall thickness indicated a descending trend from low to high planting densities. Highest values of fiber length (1300 µm) in clone I was recorded in PD II and the lowest (1187 µm) in PD IV. The highest values of fiber length (1340 µm) in clone II was in PD I and the lowest (1272 µm) in PD III. Indefinite trends for fiber diameter and lumen diameter were seen in both clones. In clones I and II, the both features showed a decreasing trend until PD III and the increased in PD IV.

Vessel density, vessel diameter, and vessel area in clone I from starting point of PD II showed an ascending trend to high planting densities. The PD I did not follow this trend. The highest values

were in PD IV and PD I. In clone II, the trend of vessel density was ascending from the PD II. The highest value of vessel density was in PD IV and lowest value in PD II. Concerning vessel diameter and area, the trends were fluctuated. The highest values were recorded in PD I and PD III.

Regarding the ray features, ray density (mm^{-2}) and ray height showed an increasing movement from low to high planting densities. The trend of ray area indicated almost constant from low to high planting densities. The ray density in clone II was higher than clone I may relate with wood density. It was concluded that PD I and PD II can have higher quality wood in terms of longer fiber and thicker fiber wall.

The mean air-dry wood density showed a descending trend from low to high planting densities. The highest values (0.59 and 0.64 $g.cm^{-3}$) were revealed in PD I and the lowest (0.54 and 0.54 $g.cm^{-3}$) in PD IV and PD III in both clones, respectively. The planting density had highest effect on wood density. Mean longitudinal shrinkage showed an increasing but insignificant trend from low to high planting densities in both clones. The tangential, radial and volumetric shrinkages decreased from low to high planting densities. Although they showed decreasing trend from low to high planting densities, there were significant differences between the different planting densities. The lowest values of shrinkages were recorded in PD IV for both clones. In general, the samples in clone II were more stable than clone I.

The mechanical properties showed a descending trend from low to high planting densities. The highest values of MOR (87.18 Mpa and 98.22 Mpa) in both clones were in PD I, while the lowest values (83.10 Mpa and 85.43 Mpa) were evidenced in PD IV and PD III of clones I and II

respectively. The MOE also showed a descending trend from low to high planting density. The compression parallel to grain followed a fluctuated trend that the highest value in clone I and clone II were in PD II and in PD IV respectively. The lowest values were in PD IV and PD III. The hardness in both clones had a little sway in PD II of clone I and PD III of clone II but it follows a decreasing trend. Among the two clones, PD I of clone II showed highest quality in strength. The shear parallel to grain like the hardness showed a decreasing trend toward high planting density but with a little sway in PD III of both clones. In general, the mechanical properties in clone II showed the better performance compared to clone I.

On the whole, PD I and PD II shall produce higher quality of wood, with regards to longer fiber, thicker fiber wall and higher wood density. These factors greatly affect the wood quality. PD I of clone II exhibits the highest evidences being the best planting density.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KESAN KEPADATAN PENANAMAN DAN KLON KE ATAS KUALITI KAYU GETAH (*Hevea brasiliensis* Muell. Arg.)

Oleh

HAMID REZA NAJI

February 2013

Pengerusi: Profesor Dr. Mohd. Hamami Sahri, PhD

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Perladangan hutan memainkan peranan yang semakin penting dan kritikal untuk memenuhi keperluan bekalan kayu balak negara. Kayu getah *(Hevea brasiliensis)* merupakan antara spesis perladangan hutan yang sangat dikenali, walaubagaimanapun ciri-ciri kayu ini masih belum sepenuhnya dikaji. Kefahaman mengenai ciri-ciri dan perilaku kayu sesungguhnya amat penting untuk menilai prestasi sesuatu produk.

Kajian ini dijalankan untuk menentukan variasi sifat-sifat anatomi, fizikal dan mekanikal, serta parameter pertumbuhan pokok getah yang berumur 9 tahun dari sebuah ladang di Timur Laut negeri Terengganu, Semenanjung Malaysia. Pokok getah di ladang ini mempunyai empat (4)

kepadatan penanaman (PD) yang berbeza iaitu: 500 (PD I), 1000 (PD II), 1500 (PD III), dan 2000 (PD IV) pokok.ha-1 daripada dua klon RRIM 2020 (I) dan RRIM 2025 (II). Perladangan ini dikendalikan oleh Lembaga Getah Malaysia (LGM).

Diameter luas pangkal (DBA), diameter ketinggian paras dada (DBH) dan tinggi batang (BH) diukur bagi menilai kesan kepadatan penanaman kepada pertumbuhan pokok. DBA and DBH menunjukkan perkaitan negatif dengan kepadatan penanaman. Nilai tertinggi DBA pada kedua-dua klon masing-masing 27.99 cm dan 24.62cm dalam PD I dan nilai- terendah ialah 23.92 cm dan 19.98 cm dalam PD IV. Begitu juga dengan nilai tertinggi DBH dalam kedua-dua klon masing- masing 20.22 cm dan 19.96 cm pada PD I dan nilai terendah ialah 17.54 cm dan 15.07 cm dalam PD IV. BH menunjukkan perkaitan positif dan signifikan dengan kepadatan penanaman pokok dengan tren menaik dari untuk kepadatan penanaman. Nilai tertinggi iaitu 1023 cm dan 1026 cm dalam PD IV dan nilai terendah adalah 467 cm dan 738 cm dalam PD I untuk kedua-dua ~~jenis~~ klon. DBA dan DBH untuk klon II adalah lebih kecil daripada klon I manakala prestasi BH pada klon II menunjukkan hasil yang lebih baik.

Panjang gentian dan ketebalan dinding gentian menunjukkan perubahan menurun bagi kepadatan penananam. Nilai tertinggi bagi panjang gentian bagi klon I ialah1300 µm pada PD II dan yang terendah 1187 µm adalah pada PD IV. Nilai terpanjang untuk gentian untuk klon II ialah 1340 µm pada PD I manakala yang terpendek ialah 1272 µm pada PD III. Corak yang tidak menentu bagi diameter gentian dan diameter lumen terdapat pada kedua-dua klon. Pada klon I dan II, kedua-dua sifat menunjukkan corak menurun sehingga PD III dan menaik pada PD IV. Dapat disimpulkan bahawa PD I dan PD II dapat menunjukkan kualiti kayu yang tinggi berteraskan panjang gentian dan ketebalan dinding gentian.

Kepadatan saluran, diameter saluran dan luas saluran di PD II pada klon I menunjukkan nilai menaik dengan kepadatan penanaman. Walaubagaimanapun, PD I tidak menunjukkan corak serupa. Nilai tertinggi di catat pada PD IV dan PD I. Pada klon II pula, corak bagi kepadatan saluran adalah menaik mulai PD II. Nilai tertinggi kepadatan saluran dicatat pada PD IV dan nilai terendah adalah pada PD II. Untuk diameter dan luas saluran pula, coraknya berubah-ubah. Nilai tertitinggi dicatatkan pada PD I dan PD III.

Untuk ciri-ciri ruji pula ketumpatan ruji (mm^{-2}) dan ketinggian ruji menunjukkan pergerakan menaik daripada kepadatan penanaman yang rendah kepada yg tinggi. Corak luas ruji pula menunjukkan ia malar daripada kepadatan penanaman yang rendah kepada tinggi.

Purata ketumpatan bagi kayu kering udara menunjukkan corak menurun untuk kepadatan penananam rendah kepada kepadatan tinggi. Nilai tertinggi (0.59 and 0.64 $g.cm^{-3}$) terdapat pada PD I dan yang terendah (0.54 and 0.54 $g.cm^{-3}$) terdapat pada PD IV dan PD III di kedua-dua klon. Kepadatan penanaman mempunyai perkaitan tinggi dengan ketumpatan kayu. Purata pengecutan Memanjang menunjukkan kenaikan signifikan bagi kepadatan penanaman dalam kedua-dua klon. Nilai kecutan Tengen, kecutan Jejari dan kecutan Isipadu semakin menurun daripada kepadatan penanaman rendah kepada kepadatan penanaman tinggi. Walaupun ia menunjukkan corak yang menurun daripada kepadatan penanaman rendah kepada kepadatan penanaman tinggi, perbezaan signifikan terdapat pada kepadatan penanaman yang berbeza. Nilai pengecutan tertinggi terdapat pada PD IV untuk kedua-dua klon. Secara amnya, sampel pada klon II adalah lebih setabil berbanding klon I.

Sifat mekanikal menunjukkan corak menurun daripada kepadatan penanaman rendah kepada kepadatan penanaman tinggi. Nilai yang tinggi bagi MOR (87.18 Mpa and 98.22 Mpa) bagi kedua-dua klon adalah pada PD I, manakala nilai yang terendah (83.10 Mpa and 85.43 Mpa) terdapat masing-masing pada PD IV dan PD III bagi klon I and II. Nilai MOE juga menunjukkan tren menurun dari kepadatan penanaman rendah kepada kepadatan penanaman tinggi. Mampatan selari ira mengikuti satu tren aliran turun naik dimana nilai tertinggi dalam klon I dan klon II ditunjukkan oleh PD II dan dalam PD IV. Nilai yang terendah pula dicatatkan pada PD IV dan PD III. Nilai kekerasan ditunjukkan oleh PD II bagi klon I dan PD III bagi klon II tetapi ia mengikut corak menurun. PD I bagi klon II menunjukkan kualiti kekuatan yang tinggi. Ricih selari dengan ira seperti kekerasan menunjukkan corak menurun terhadap kepadatan penanaman yang tinggi ke atas PD III untuk kedua-dua klon. Secara amnya, sifat mekanikal bagi klon II menunjukkan prestasi yang lebih baik berbanding klon I.

Secara keseluruhan. PD I dan PD II akan dapat mengeluarkan kayu yang berkualiti tinggi dengan gentian yang panjang, dinding gentian yang lebih tebal dan ketumpatan kayu yang tinggi. Faktor-faktor ini akan mempengaruhi nilai kekuatan kayu secara keseluruhan. PD I daripada klon II telah membuktikan kepadatan penanaman getah yang terbaik.

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Approval

This thesis was submitted to the senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirements for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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DECLARARTION

I declare that the thesis is my original work except for quotations and citation which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Putra Malaysia or at any other institution.

_____

HAMID REZA NAJI

Date: 27.02.2013

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