NUTRITIONAL REQUIREMENTS OF *AZADIRACHTA EXCELSA* (JACK) JACOBS STAND AT LABIS, JOHORE

By

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

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Faculty : Forestry

The growth of forest is a long-term process. Studying the cycling of nutrients is important in order to understand the ecological functioning of a forest. The use of fertilizers in forest management has a profound effect on nutrient cycling processes at the plant-soil interphase. The transfer of nutrients among the various compartments or pools is a continuous process and the aim of the present study is to quantify the flow of nutrients between these pools and to identify some of the factors involved in influencing this process. A field experiment in Sungai Karas, Johore, Malaysia was initiated with the objective of evaluating growth responses and distribution of nutrients within tree compartments in *Azadirachta excelsa* (Jack) Jacobs under different fertilizer regimes. The findings should provide plantation managers with some baseline data on nutrition management in *A. excelsa* plantations. The treatments involved a factorial combination of three rates of urea N (50, 100 and 150 kg ha^{-1}), three rates of triple superphosphate P (50, 75 and 100 kg ha^{-1}) and two rates of dolomite lime (0 or 53.25 kg Ca and 30 kg Mg

ha^{-1}) applied in split (three times; 26, 30, and 34 months after planting) in a 2-year-old stand established on a degraded soil.

Slope, in association with soil depth, had the greatest influence on stand growth two years after planting. The growth parameters were negatively correlated with slope and soil exchangeable K. Soil nutrient status remained unchanged despite receiving regular fertilizer application, suggesting that higher requirement and uptake by the plants or leaching had taken place. Thus, proper site selection and fertilizer application rate are important factors to be considered when establishing *A. excelsa* stands.

Thirty-six trees were randomly selected from different treatments and harvested for biomass assessment. Based on the harvested samples, the effect of fertilizers and dolomite lime were insignificant on biomass production. This may be caused by competition from the undergrowth and low levels of fertilizer used. The aboveground biomass ranged from 3.4 to 28.4 t ha^{-1}, of which 6.6% was foliage. Equations for predicting stem volume were also developed in the present study using the data from felled trees. The equations were selected from three commonly used models and validated using data from 36 tree samples from the 4-year-old plantation. The least biased and most precise estimates of stem volume were obtained using the logarithmic equation. Regression equation using diameter at breast height as the variable was a good predictor of aboveground biomass among the prediction variables tried. Concentrations of nutrient were highest in foliage with the exception of Ca. The total nutrient contents in the aboveground biomass (in kg ha^{-1}) were 45.15 for N, 6.66 for P, 39.67 for K, 5.97 for

Mg and 11.43 for Ca. Current harvesting method of timber coupled with burning activity during site preparation would result in the removal of substantial amounts of nutrients, and may lead to degradation of site quality.

Mean increments of tree volumes (estimated using regression) in two years of observation or 51 months after planting ranged from 25.95 to 54.67 m^3 ha^{-1}. Growth of *A. excelsa* was strongly influenced by the addition of N. Foliar P concentration was increased by additions of N and P at 39 months but this was not found at 51 months. Consequently strong correlation between P foliar nutrient concentrations and growth was found at 39 months. The best growth was associated with foliar concentrations at 39 months of about 2.57% N and 0.27% P. The rather substantial decrease in growth in second half of the experiment indicates the need to continually repeat fertilizer application to sustain growth rates.

Additions of dolomite lime and fertilizers increased soil pH, and concentrations of Mg and Ca in the soil two years after the commencement of the present study. Liming led to a reduction of soil total N suggesting higher N mineralization may have taken place. Application of N and P increased soil total N and P availability in the soil.

Mean annual litterfall ranged from 4.95 to 6.60 t ha^{-1} yr^{-1}. The addition of fertilizer and dolomite lime did not result in any changes in the mass of litterfall. Leaf litter accounted for more than 88% of total litter production. The mean standing crop of leaf litter ranged from 1.26 to 3.76 t ha^{-1}. Nitrogen application increased the mass of leaf

litter accumulated on the forest floor but not the nutrient concentration of the leaf litter. Differences among the treatments were found only at the early stages of decomposition for both the decomposition rates and weight losses. Release of the nutrients at the end of the experiment was positively correlated with their initial concentration.

The results highlight the importance of understanding nutrient fluxes before recommending a fertilization regime aimed at increasing productivity of *A. excelsa* plantations. General fertilizer prescriptions and management practices of *A. excelsa* plantation are presented. However, detailed assessments of fertilizer requirements are required if soil types other than those described here are used.

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

KEPERLUAN PEMAKANAN DIRIAN *AZADIRACHTA EXCELSA* (JACK) JACOBS DI LABIS, JOHOR

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Pertumbuhan hutan merupakan satu proses jangka panjang. Kajian kitaran nutrien adalah penting bagi memahami fungsi ekologi sesebuah hutan. Penggunaan baja dalam pengurusan hutan mempunyai kesan yang ketara ke atas proses-proses kitaran nutrien di peringkat tumbuhan-tanah. Pemindahan nutrien di antara komponen atau tempat simpanan yang berbeza merupakan satu proses yang berterusan dan kajian yang dijalankan kini adalah untuk mengetahui kadar pengerakan nutrien di antara komponen dan mengenalpasti beberapa faktor yang terlibat mempengaruhi proses ini. Satu kajian lapangan diwujudkan di Sungai Karas, Johor, Malaysia dengan objektif untuk menilai tindakbalas pertumbuhan dan taburan nutrien di dalam komponen pokok *Azadirachta excelsa* (Jack) Jacobs yang diberi kadar baja yang berlainan. Penemuan baru diharap akan memberikan serba sedikit maklumat asas kepada pengurus-pengurus ladang mengenai pengurusan permakanan ladang-ladang *A. excelsa*. Rawatan melibatkan kombinasi faktoria dengan tiga kadar urea N (50, 100 and 150 kg ha^{-1}), tiga kadar triple superphosphate P (50, 75 and 100 kg ha^{-1}) and dua kadar kapur dolomite (0 or 53.25 kg

Ca and 30 kg Mg ha^{-1}) yang diberikan secara berasingan (sebanyak tiga kali; pada bulan 26, 30, and 34 selepas penanaman) di sebuah ladang yang berusia dua tahun yang ditanam di atas tanah yang kurang subur.

Kecerunan tapak, yang berkait rapat dengan kedalaman tanah, mempengaruhi pertumbuhan dirian dua tahun selepas ditanam. Status nutrien tanah tidak berubah walaupun menerima pembajaan yang berterusan, ini menunjukkan bahawa permintaan dan pengambilan yang tinggi oleh pokok atau berlakunya larut resap. Oleh itu, pemilihan tapak yang sesuai dan kadar pembajaan adalah faktor yang utama yang perlu dipertimbangan apabila menubuhkan dirian *A. excelsa*.

Tiga puluh enam pokok telah dipilih secara rawak dari rawatan yang berbeza dan ditebang untuk penentuan biojisim. Berdasarkan sampel yang diperolehi, kesan baja dan kapur ke atas pengeluaran biojisim adalah tidak bererti. Ini mungkin disebabkan oleh persaingan di antara pokok dan tumbuhan lantai hutan serta kadar penggunaan baja yang rendah. Biojisim atas tanah berada dalam lingkungan 3.4 hingga 28.4 t ha^{-1}, di mana 6.6% adalah daun. Persamaan untuk menganggar isipadu batang juga diwujudkan pada kajian ini menggunakan data dari pokok-pokok yang ditebang. Persamaan yang digunakan dipilih dari tiga model yang biasa digunakan dan disahkan menggunakan data dari 36 pokok sampel yang berusia empat tahun. Anggaran isipadu batang yang paling tepat dan kurang bias diperolehi menggunakan persamaan logaritmatik. Persamaan regresi menggunakan diameter pada paras dada sebagai pembolehubah merupakan penganggar terbaik untuk biojisim atas tanah di kalangan persamaan yang dicuba.

Kepekatan nutrien yang paling tinggi dijumpai dalam daun kecuali Ca. Jumlah kandungan nutrien (dalam kg ha^{-1}) di dalam biojisim atas tanah adalah 45.15 untuk N, 6.66 untuk P, 39.67 untuk K, 5.97 untuk Mg dan 11.43 untuk Ca. Kaedah penuaian masa kini ditambah pula dengan aktiviti pembakaran semasa penyediaan tapak akan mengakibatkan kehilangan jumlah nutrien yang banyak, dan ini akan menyebabkan penurunan kualiti tapak.

Purata peningkatan dalam isipadu pokok (dianggarkan menggunakan persaaam regresi) dalam tempoh dua tahun atau 51 bulan selepas ditanam berada dalam lingkungan 25.95 ke 54.67 m^3 ha^{-1}. Pertumbuhan dirian *A. excelsa* dipengaruhi oleh penambahan N. Kepekatan P dalam daun meningkat akibat penambahan N dan P pada bulan ke 39 tetapi kesan ini tidak dapat diperhatikan di bulan ke 51. Hubungan korelasi yang tinggi juga dikesan di antara kepekatan P dalam daun dengan pertumbuhan pokok pada bulan ke 39. Pertumbuhan pokok yang paling tinggi pada bulan ke 39 berhubungkait dengan kepekatan nutrien daun di mana N adalah 2.57% dan P pada 0.27%. Penurunan kadar pertumbuhan yang agak mendadak pada tahun kedua kajian menunjukkan perlunya pembajaan yang berterusan untuk mengekalkan kadar pertumbuhan.

Penambahan kapur dan baja meningkatkan pH tanah, dan kepekatan Mg dan Ca di dalam tanah dua tahun selepas kajian dimulakan. Pengapuran menyebabkan penurunan dalam jumlah N di dalam tanah menunjukkan kemungkinan kadar mineralisasi N yang tinggi telah berlaku. Penggunaan N and P meningkatkan jumlah N dan kedapatan P di dalam tanah.

Purata tahunan luruhan sarap berada dalam lingkungan 4.95 hingga 6.60 t ha^{-1} th^{-1}. Penambahan baja dan kapur tidak menyebabkan perubahan dalam berat sarap yang diperolehi. Sarap daun merupakan 88% dari jumlah luluhan sarap yang dihasilkan. Purata sarap tanaman dirian untuk daun berada dalam julat 1.26 ke 3.76 t ha^{-1}. Pengunaan N meningkatkan berat sarap daun yang terkumpul di atas permukaan lantai hutan tetapi tidak mempengaruhi kepekatan nutriennya. Perbezaan di antara rawatan hanya dijumpai pada peringkat awal penguraian bagi kadar penguraian dan kehilangan dalam berat. Pembebasan nutrien-nutrien di peringkat akhir kajian berhubungkait secara positif dengan kepekatan mereka di peringkat awal.

Keputusan-keputusan yang diperolehi menunjukkan pentingnya untuk memahami pergerakan nutrien sebelum mencadangkan kadar pembajaan yang bertujuan untuk meningkatkan produktiviti *A. excelsa* di ladang. Garis panduan untuk pembajaan dan pengurusan ladang *A. excelsa* diberikan. Akan tetapi penilaian keperluan baja diperlukan jika jenis tanah yang berbeza digunakan berbanding dengan jenis tanah yang dihuraikan dalam kajian kali ini.

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I certify that an Examination Committee met on 6th August 2004 to conduct the final examination of Ong Kian Huat on his Doctor of Philosophy thesis entitled "Nutritional Requirements of *Azadirachta excelsa* (Jack) Jacobs Stand at Labis, Johore" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Member of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirements for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

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ONG KIAN HUAT

Date:

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