UNIVERSITI PUTRA MALAYSIA

GROWTH PERFORMANCE OF HOPEA ODORATA ROXB. AND MIMUSOPS ELENGI L. SEEDLINGS UNDER SOIL COMPACTION, WATER AND NUTRIENT STRESSES EXPERIENCED IN THE URBAN ENVIRONMENT

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By

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Thesis Submitted in Fulfilment of the Requirements for the Degree of Doctor of Philosophy in the Faculty of Forestry
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April 2000

DEDICATED TO MY LATE PARENTS

Abstracts of thesis presented to the Senate of the Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy.

GROWTH PERFORMANCE OF *HOPEA ODORATA* ROXB. AND *MIMUSOPS ELENGI* L. SEEDLINGS UNDER SOIL COMPACTION, WATER AND NUTRIENT STRESSES EXPERIENCED IN THE URBAN ENVIRONMENT

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The urban environment has a variety of biological, chemical and physical stresses that can limit tree growth. *Hopea odorata* and *Mimusops elengi* are among the most common tree species planted in parks, along roadsides and highways in urban areas. The ability of these two species in adapting to the harsh urban environment is of interest. The objective of this study was to evaluate comparatively the differences in morphological and ecophysiological responses of these two species to soil compaction, water and nutrient stresses and how these differences could contribute to an understanding of the effects of environmental stress on plant growth.

A higher reduction in the morphological and physiological growth of *H. odorata* seedlings occurred on encountering soil compaction and water stresses compared to *M. elengi* seedlings during the first 3 months of treatment. The lower reduction in the morphological growth of *M. elengi* seedlings could be due to the higher amount of nutrient available in the leaves at the start of the experiment. However, as time progressed, the reduction in the morphological and physiological growth of *M. elengi* seedlings increased due to the impeded root system that reduced the uptake of water and nutrients necessary for subsequent growth. Root growth of *H. odorata* seedlings was significantly restricted under soil compaction of bulk density > 1.6 g/cm^3 during the first 3 months of treatment but after 6 months an almost similar rate to the control was resumed until the end of the experiment. In contrast, root growth of *M. elengi* seedlings under high compaction levels (> 1.4

g/cm^3) was still confined to the upper 20-cm compacted zone indicating that bulk densities of > 1.4 g/cm^3 inhibited root penetration at all levels of watering throughout the experimental period. *H. odorata* seedlings still maintained a positive carbon gain at a leaf water potential as low as -3.5MPa whereas for *M. elengi* seedlings, photosynthesis was completely inhibited at a leaf water potential of -2.5MPa.

The increases in xylem sap ABA concentration observed in both species at high bulk densities were closely related with reductions of stomatal conductance suggesting that xylem ABA might have acted as a stress signal in the control of stomatal conductance. The inability of *M. elengi* seedlings to produce as much xylem ABA concentration compared to *H. odorata* seedlings in response to soil compaction and water stresses might have been crucial to their failure to maintain near–normal rates of leaf expansion at a certain critical level of compaction.

The application of 30g NPK fertiliser under well-watered condition greatly enhanced all the morphological and physiological parameters of *H. odorata* seedlings. In contrast, only height growth of *M. elengi* seedlings was greatly promoted by the application of 50g of fertiliser under well-watered condition but with a smaller diameter. The higher photosynthetic rates of seedlings for both species at the end of the experiment could be due to fertilisation, which reduced the impact of drought through its effect on stomatal control.

In conclusion, *H. odorata* seedlings had the ability to acclimatise, combining morphological and physiological modifications which improved their capacity to survive soil compaction, water and nutrient stresses and thus could survive better in urban areas compared to *M. elengi* seedlings. The practical implications of this study are discussed.

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

TINDAKBALAS PERTUMBUHAN ANAK BENIH *HOPEA ODORATA* ROXB. DAN *MIMUSOPS ELENGI* L. TERHADAP KEMAMPATAN TANAH, KEKURANGAN AIR DAN NUTRIEN YANG DIALAMI DI PERSEKITARAN BANDAR

oleh

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Persekitaran bandar mempunyai tekanan biologi, kimia dan fizikal yang boleh menghadkan pertumbuhan pokok. *Hopea odorata* dan *Mimusops elengi* merupakan spesies yang lazim di tanam di taman, sepanjang jalan dan lebuhraya. Kemampuan kedua-dua spesies ini untuk menyesuaikan diri dengan persekitaran bandar adalah perkara yang menarik untuk dikaji. Objektif penyelidikan ini adalah untuk menilai perbezaan secara komparatif dari segi morfologi dan ekofisiologi kedua-dua spesies ini terhadap tekanan persekitaran seperti kemampatan tanah, kekurangan air dan nutrien dan bagaimana perbezaan ini dapat memberi kefahaman terhadap kesan tekanan persekitaran keatas pertumbuhan pokok.

Pengurangan yang tinggi dari segi pertumbuhan morfologi and fisiologi berlaku apabila anak benih *H. odorata* didedahkan kepada keadaan kemampatan tanah dan kemarau dibandingkan dengan anak benih *M. elengi* pada 3 bulan pertama rawatan. Pengurangan yang rendah di dalam semua pertumbuhan yang disukat bagi anak benih *M. elengi* adalah kerana kandungan nutrien yang tinggi di dalam daun. Walau bagaimanapun lama-kelamaan, pengurangan dalam semua pertumbuhan morfologi dan fisiologi semakin meningkat kerana sistem akarnya yang terbantut yang menghalang pengambilan air dan nutrien. Pertumbuhan akar anak benih *H. odorata* adalah terbantut di bawah kemampatan tanah > $1.6 g/cm^3$ dalam tempoh tiga bulan pertama rawatan tetapi selepas 6 bulan, pemanjangan akar kembali pada kadar yang hampir sama dengan pertumbuhan anak benih kawalan. Sebaliknya,

pemanjangan akar anak benih *M. elengi* masih terbantut kepada 20-cm tanah yang keatas dan ini menunjukkan kemampatan tanah > 1.4g/cm^3 menghadkan pemanjangan akar pada semua kadar penyiraman dalam tempoh uji kaji. Anak benih *H. odorata* masih boleh menjalankan proses fotosintesis pada potensi air daun serendah – 3.5MPa tetapi proses fotosintesis ini adalah terhad pada potensi air daun – 2.5MPa bagi anak benih *M. elengi*.

Peningkatan ABA sap xilem kedua dua spesies pada kemampatan tanah yang tinggi adalah berkait rapat dengan pengurangan konduktans stomata dan ini menunjukkan bahawa ABA sap xilem mungkin bertindak sebagai amaran tekanan dalam pengawalan konduktans stomata. Ketidakupayaan anak *M. elengi* untuk mengeluarkan lebih banyak kepekatan ABA sap xilem berbanding dengan anak benih *H. odorata* bagi tindakbalas kepada kemampatan tanah dan kekurangan air yang mungkin menyebabkan kegagalan untuk mengekalkan perkembangan daun pada tahap kemampatan yang kritikal.

Rawatan 30g baja NPK di bawah tahap lapangan sangat menggalakan pertumbuhan morfologi dan fisiologi anak benih *H. odorata*. Sebaliknya, rawatan 50g baja cuma mengakibatkan kelebihan ketinggian anak benih *M. elengi* di bawah tahap lapangan tetapi bersaiz diameter kecil. Kadar fotosintesis yang tinggi untuk kedua-dua speseis diakhir eksperimen adalah kerana pembajaan yang mengurangkan kesan kemarau melalui penutupan stomata.

Pada kesimpulannya, anak benih *H. odorata* mempunyai kemampuan kesesuaian dengan kombinasi perubahan morfologi dan fisiologi dan seterusnya mempunyai keupayaan untuk terus hidup dalam keadaan kemampatan tanah, kekurangan air dan nutrien dalam kawasan bandar dibandingkan dengan anak benih *M. elengi*. Implikasi praktikal hasil penyelidikan ini juga dibincangkan.

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LIST OF ABBREVIATIONS

Symbol		Unit
ABA	Abscisic acid	
gs	Stomatal conductance to CO_2	μmol m^{-2} s^{-1}
MPa	Megapascal	
P	Photosynthesis	μmol m^{-2} s^{-1}
PAR	Photosynthetic Active Radiation	μmol m^{-2} s^{-1}
LWP	Leaf Water Potential	MPa
WUE	Water Use Efficiency	
ε	Bulk modulus elasticity	
$\Psi\pi_{100}$	Osmotic potential at full turgor	MPa
Ψs	Soil water potential	MPa

CHAPTER 1

INTRODUCTION

Functions of Urban Forests

Urban forests play a pivotal role in the environmental, aesthetic, architectural and engineering functions of a landscape (Clark and Matheny, 1994; David, 1996; Grey and Deneke, 1986; Duryea *et al*., 1996; Souch and Souch, 1993; Templeton and Goldman, 1996). It can be viewed as a "living technology", an essential component of the urban infrastructure that helps maintain a healthy environment for urban dwellers (Dwyer *et al.*, 1992). They are able to modify urban microclimates, which in turn affect human comfort and interior energy budgets (Barro *et al.*, 1996; Laverne and Lewis, 1996; Miller, 1988; McPherson and Luttinger, 1998; Simpson and McPherson, 1996; Summit and McPherson, 1996). The presence of urban trees and forests can make the urban environment a more pleasant place to live, work, and spend leisure time. Studies of urbanite preferences and behaviour confirm the strong contribution that trees and forests make to the quality of life in urban areas. However, the effectiveness of urban trees and forests in providing benefits to people depends on their species composition, diversity, age and location with respect to people and other elements in the landscape (Dwyer *et al.*, 1992).

Urban forest environments provide aesthetic surroundings, increased enjoyment of everyday life, and a greater sense of meaningful connection between people and the natural environment. Urban forests can also enhance the quality of life by providing restorative environments for reducing the mental fatigue of the urban residents (Ulrich, 1984). Hence, reduced stress and improved physical health for urban residents have been associated with the presence of urban trees and forest (Dwyer *et al.*, 1992).

Trees are able to intercept up to 90% of solar energy and provide substantial reduction in interior temperatures (Dwyer *et al.*, 1992). Projections from computer simulations indicate that 100 million mature trees in the United States of America cities (three trees for every other single family home) could reduce annual energy use by 30 billion kWh, saving about 2 billion dollars in energy costs (Dwyer *et al.*, 1992). Annual cooling savings are approximately 157GWh (US18.5 million) per year which is about 12% of the total air conditioning in the country (Simpson, 1998). Urban forests can also act as pollution filters and 'sinks' by trapping air pollutants such as oxides of sulphur, nitrogen and tropospheric ozone (Dwyer *et al.*, 1992). However, the rate at which trees remove gaseous pollutants depends primarily on the amount of foliage, number and condition of stomata and the meteorological conditions. For example, Sacramento's Urban Forest, California of 6 million trees are known to sequester 238,000t of carbon dioxide annually (McPherson, 1998) and approximately 1,457 metric tons of air pollutant are absorbed annually at US$28.7 million.

Trees can also be use to intercept solar energy directly by providing shade in areas where it is desired and by cooling the atmosphere through transpiration of water from the leaves (Akbari *et al.*, 1992; Landsberg, 1981; Miller, 1987). They can also be combined with landforms and structures to serve as wind breakers and be designed to slow the velocity of wind by filtration (Simpson and McPherson, 1996). Vegetation can increase relative humidity (Miller, 1987) and the impact of trees on