UNIVERSITI PUTRA MALAYSIA

EFFECTS OF SOIL COMPACTION, OVER-TOP-FILLING AND WATERLOGGING ON GROWTH AND PHYSIOLOGY OF Azadirachta excelsa (JACK) JACOBS SEEDLINGS

NURUL NASYITAH BINTI SHUKOR

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By

NURUL NASYITAH BINTI SHUKOR

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

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DEDICATION

Subhanallah,
Alhamdulillah,
Lailahaillallah,
Allahuakbar
Lahawlawala Quwwataillabillahilaliyyilazim.

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

EFFECTS OF SOIL COMPACTION, OVER-TOP-FILLING AND WATERLOGGING ON GROWTH AND PHYSIOLOGY OF *Azadirachta excelsa* (JACK) JACOBS SEEDLINGS

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December 2014

Chairman: Hazandy Abdul Hamid, PhD

Faculty : Forestry

Urban forest tree were highly exposed to various type of environmental stress which can give negative effects to their growth. Series of experiments were conducted in investigating the toleration and adaptation of *Azadiractha excelsa* toward current common stress specifically soil compaction, over-top-filling and waterlogging. Measurement has been made in morphology changes, biomass allocation, root adaptation, and internal physiology comprising chlorophyll fluorescence, gas exchange, hydraulic conductance and water use efficiency. Study was conducted in the nursery of Faculty of Forestry. Repeated measures were used to examine the performance over time of experiment meanwhile one way ANOVA was used to test among different treatments.

In soil compaction experiment, soil bulk density of 1.2 g cm^{-3} (low), 1.4 g cm^{-3} (medium) and 1.6 g cm^{-3} (severe) were applied by compacting soil inside the pot. The result showed that severe soil compaction treatments had caused the decrease in physical growth of seedlings. Low optimal value was also found in photochemical efficiency, as well as decreased photosynthetic rate and stomatal conductance. It showed the diligently related root sensitivity of the system architecture to the high mechanical impedance of the soil. However, it still showed capability in tolerance towards compacted soil by maximizing water use a low stomatal conductance in order to have enough sugar to recover stress.

Over-top-filling experiment was done by applying a layer of top soil over normal collared seedling. Three different levels of 10 cm, 20 cm and 30 cm had given positively significant results towards performance of the seedling including growth and physiological. Evidently, seedlings in higher soil level had higher relative growth rates in both diameter and height, and also leaf area parameter. It was also found that new areas of root growth were present in higher over-top-filling. There were no significance

differences in any parameters of chlorophyll fluorescence, gas exchange and water relations were shown which indicate encourage performance.

The third study tested on different periods of time to waterlogged seedling over the 1-week, 2-weeks and 3-weeks duration. Further research was also carried out through moving seedlings out of waterlogged after 2 weeks to assess their recovery. It was found that oxygen deficiency disallow root respiration when it is flooded. Moreover, the ability to allocate more carbon during flooding also appeared to be related to flooding tolerance.

A. excelsa seedlings were found are partially tolerance in surviving under compacted soil with declined in morphology performance but still showed some high capability to survive. Instead, it also possesses good morphology and physiology modifications especially in managing photochemical efficiency, gas exchange and water relation which improved their ability to survive in stress condition such over-top-filling and waterlogging conditions. Planting or allowing this seedling to grow in locations where such stresses have the probability to take place is plausible as the trees could still have chance to survive.

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

KESAN PEMADATAN TANAH, TANAH YANG BERLEBIHAN DAN PENAKUNGAN AIR KEATAS PEMBESARAN DAN FISIOLOGI ANAK BENIH *Azadirachta excelsa* (JACK) JACOBS

Oleh

NURUL NASYITAH BINTI SHUKOR

Disember 2014

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Fakulti : Perhutanan

Pokok hutan bandar banyak terdedah dengan pelbagai jenis stres alam sekitar. Beberapa siri eksperimen telah dijalankan bagi menyiasat keupayaan toleransi dan adaptasi terhadap stres oleh *Azadiractha excelsa* di mana jenis stress tertumpu kepada pemadatan tanah, tanah yang melebih dan penakungan air. Perubahan yang terjadi pada morfologi, peruntukan biojisim, penyesuaian akar dan fisiologi dalaman yang terdiri dari pendarfluor klorofil, pertukaran gas, kekonduksian hidraulik dan kecekapan penggunaan air telah diselidik. Kajian ini telah dijalankan di nurseri Fakulti Perhutanan. Kadah pengukuran berulang telah digunakan bagi menganalisa secara saintifik prestasi sepanjang masa eksperimen sementara itu ANOVA satu hala digunakan untuk ujian perbandingan antara rawatan.

Dalam eksperimen pemadatan tanah, ketumpatan pukal tanah sebanyak 1.2 g cm^{-3} (rendah) , 1.4 g cm^{-3} (sederhana) dan 1.6 g cm^{-3} (tinggi) telah diaplikasi dengan memadatkan tanah ke dalam pasu. Keputusan menunjukkan rawatan pemadatan tanah yang teruk telah menyebabkan pembantutan dalam pembesaran anak benih. Didapati juga nilai optimum rendah dalam kecekapan fotokimia, penurunan kadar fotosintesis dan pengurangan pembukaan stoma. Keputusan juga menunjukkan kepekaan oleh bahagian struktur sistem akar yang sangat sensitif dengan peningkatan mekanikal impedans tanah.

Eksperimen seterusnya adalah dengan mengisi tanah melebih dari normal kolar anak benih. Rawatan yang terdiri dari tiga tahap yang berbeza 10 cm, 20 cm dan 30 cm telah menunjukkan keputusan yang positif ke atas anak benih. Di mana, anak benih dalam rawatan tertinggi telah menunjukkan kesan pertumbuhan morfologi secara relatif yang baik dari segi diameter, tinggi dan keluasan daun. Selain dari itu, kawasan pertumbuhan akar yang baru telah ditemui pada tanah yang melebih. Tidak ada perbezaan yang

signifikan pada ukuran pendarfluor klorofil dan juga pertukaran gas bagi rawatan dengan anak benih kawalan yang menunjukkan prestasi yang mengalakkan.

Kajian ketiga pula diuji ke atas dengan anak benih yang dibesarkan pada kawasan air bertakung pada tempoh masa yang berbeza sepanjang 1 minggu, 2 minggu dan 3 minggu. Penyelidikan lebih mendalam dijalankan dengan menilai tempoh pemulihan iaitu dengan mengasingkan anak benih yang yang telah dibanjirkan kepada kawasan biasa. Keputusan menunjukkan kekurangan oksigen tidak membenarkan pernafasan akar berlaku ketika dibanjiri. Selain dari itu, sebagai menunjukkan proses toleransi terhadap banjir, anak benih berupaya untuk mengumpul lebih banyak biojiism.

Anak benih *A. excelsa* ditemui mempunyai keupayaan survival separa toleransi terhadap tanah mampat. Namun begitu, masih mampu menunjukkan keputusan yang baik dari segi morfologi dan perubahan fisiologi terutamanya dalam kecekapan fotokimia, pertukaran gas dan sistem perhubungan air sebagai tanda toleransi untuk terus mencuba kemandirian dalam tanah yang melebih dan juga dalam air yang bertakung. Oleh yang demikian, anak benih ini masih mempunyai peluang untuk terus hidup jika ditanam atau dibiarkan di kawasan yang mempunyai stres.

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Finally, I really hope that this thesis will help other researchers in their pursuit for knowledge. Let's spread the wonders of Tree, InsyaAllah.

Thank you ☺.

I certify that a Thesis Examination Committee has met on 05 December 2014 to conduct the final examination of Nurul Nasyitah Binti Shukor on her Master of Science thesis entitled "Effects of Soil Compaction, Over-Top-Filling And Waterlogging on Growth and Physiology of *Azadirachta excelsa* (Jack) Jacobs Seedlings" 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.

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Name of Chairman of Supervisory Committee	: Assoc. Prof. Dr. Hazandy bin Abdul Hamid

Signature	: ______________________
Name of Members of Supervisory Committee	: Assoc. Prof. Dr. Arifin bin Abdu

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbols/Abbreviation	**Word (Unit)**
ANOVA	analysis of variance
$AGR_{diameter}$	absolute diameter growth rate
AGR_{height}	absolute height growth rate
$RGR_{diameter}$	relative diameter growth rate
RGR_{height}	relative height growth rate
A_{net}	net photosynthesis (µmol CO_2 m^{-2} s^{-1})
ATP	adenosine triphosphate
C_i	internal CO_2 (µmol mol^{-1})
E	leaf transpiration rate (mmol H_2O m^{-2} s^{-1})
F_O	initial chlorophyll fluorescence
Fm	maximum chlorophyll fluorescence
Fv	variable chlorophyll fluorescence
Fv/Fm	maximum quantum efficiency of PSII photochemistry
G_s	stomatal conductance (µmol CO_2 m^{-2} s^{-1})
IAA	hormone auxin
WUE	water use efficiency
WUE_i	intrinsic water use efficiency
WUE_{inst}	instantaneous water use efficiency
VpdL	vapour pressure deficit in leaf (kPa)
K	hydraulic conductivity
Ψ	water potential
$\Psi_{predawn}$	predawn water potential
$\Psi_{middday}$	midday water potential

CHAPTER 1

INTRODUCTION

1.1 General Background

Trees growth is dependent towards its environmental condition in order to grow well and continue to give benefits to human and it's surrounding. Our environment consists of biotic and abiotic factors that can contribute to the advantages or obstructions of tree survival and success. One type of ecosystem with high stress level environment is the trees planted in urban area. Remarkably, urban forest trees can be defined as trees that are planted or grow nearby human activities and play important roles to the ecological structure (Clark *et al.*, 1997). These tree commonly used to satisfy environmental benefits such as reducing atmospheric carbon and also the heat island effect (Akbari, 2002).

Urban trees mitigate many impacts of urban development by controlling rainfall runoff and flooding, conserving energy, improving air quality, lowering noise levels and enhancing attractiveness of cities (Day, 1999; Huang *et al.*, 2013). However, trees planted in urban areas are commonly exposed to numerous environmental stresses that occur instantaneously. These compounding stresses can be more unfavourable to the tree growth and survival even if stress when encountered alone. On the other hand, it has been proven that higher plasticity attributes were found for tropical forest trees and this can be recognized as a major advantage for the trees to adapt with various environmental conditions in the tropics (Day, 1999). If it can adapt to the extreme conditions, we need to figure out the qualitative description to prove the tropical trees abilities.

Hence, this study was conducted to examine the growth and physiological characteristics of *Azadiractha excelsa* grown in three major stresses conditions namely soil compaction, over-top-filling and waterlogging. There were three levels of treatments for each stress condition used for each stress experiment imposed to the seedlings. At the end of this experiment, conclusions were made to identify any correlation between plant growth and internal physiological processes which can help in understanding the adaptation of tropical trees towards environmental stresses.

Besides that, parameter comprising growth performance, biomass allocation, gas exchange including net photosynthesis (A_{net}), stomata conductance (G_s), transpiration (E), hydraulic conductance (K) and water use efficiency (WUE) can be interpreted to determine whether the *A. excelsa* is able to undergo stress or not. This is because trees express their tolerance and adaptation by observing both their growth and physiology performances. These performances can only be examined by applying appropriate equipment to the trees which were used throughout the experiment. As consequence, this study expects that *A. excelsa* species will respond depressingly towards the imposed stresses through the capability to alter its physiological attributes and performance that leads to stunted tree growth.

1.2 Problem Statement

It was recognized that from an ecological perspective, urban tree ecology differs profoundly from its natural habitats. The differences arrive from any prospective of soil characteristics, species composition, animal association and also environmental climate. Often ironic, species selection and composition is the deliberate choice of landscape architects, planners, block associations contractor, and others based on the visual effects, availability, and ultimately the cost. Thus, intriguing dilemma has been raised on the capability of planting species to be suited with urban environment plus numerous conditions are potentially lethal such as high soil pH, soil compaction, waterlogging, lack of water, air pollution, and vandalism. However, serious investigation to these environmental limits is frequently dismissed by assuming that the science is complete.

Therefore, to cover one spectrum on the urban tree stress studies, a quantitative description on gas exchange, chlorophyll fluorescence, hydraulic conductance, and growth performance of *A. excelsa* were studied. This species was selected because it was one of many common tree species planted along the roadside in the urban area which is highly exposed to environmental stress. Other than that, as a fast growing species, this species was expected to tolerate quickly towards the stresses casted upon it. The stresses studied are soil compaction, over-top-filling and soil compaction which were applied after the seedling acclimatized to the nursery surroundings.

Trees along highway or road side are prone to have compacted soil which occur by force from heavy vehicles and frequent rainfall dropping to soil structure. The force can change the structure of pores and soil particles which then give result of stunting the tree roots. Other than that, due to inappropriate management during planting, over-top-filling of soil above the tree collar can occur which also lead to effect tree growth. Improper drainage management and also heavy rainfall may have caused trees to be waterlogged. In order to survive and also to continue giving their benefits to surrounding environment, tree respond to these stresses is by adapting and tolerating to the stresses.

The respond of internal process in a tree including in handling cell activities, controlling enzyme and hormone as well as cell expanding will influence the efficiency of multiple main processes of tree. The main processes involved are photosynthesis, carbon storage, transpiration, and growth of tree parts can measure the stress level. Consequently, the information on how this species manage the stress from physiological aspects as well as morphological aspects can reveal on how tree respond to environmental stresses. Through this information, management of urban landscape tree by arborists, landscape architects and also forester will be more proficient. These observational studies of both the environment and plants will provide limits for cultivar screenings. It can reduce the amount of field material and possibilities on death to individual tree. Other than that, through this baseline knowledge and approach, the appropriate procedure can be designed for implementation on a large scale.

1.3 Research Questions

a) What are the effects on the morphological performance of *A. excelsa* planted in compacted soil, over top filled and waterlogged condition?
b) How well *A. excelsa* does tolerates physiologically in the stress conditions?
c) By all means, how does the relationship between selected parameters can explain the stress *A. excelsa* endured?

1.4 Objectives

The overall objective of this study is to determine comparatively the differences in growth measurement and physiological characteristics of *A. excelsa* during the period of six months planted in environmental stresses. The general aims are divided in several specific objectives which are explained extensively in the experimental chapters.

1.5 Hypothesis

Thus, the hypotheses tested are

a) *A. excelsa* seedlings performance in morphological and physiological characteristics decrease when planted in higher compacted soil.
b) The greater the height of soil increased above the normal collar against a seedling's stem, the greater would be the decline in the seedling's performance.
c) The longer time seedlings were waterlogged, the seedling performance will decrease.

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