MORPHOLOGICAL AND GENETIC VARIATION OF Eusideroxylon zwageri Teijsm. & Binn. (BORNEO IRONWOOD) IN SARAWAK, MALAYSIA

SITI FATIMAH MD ISA

FS 2020 30

MORPHOLOGICAL AND GENETIC VARIATION OF *Eusideroxylon zwageri* Teijsm. & Binn. (BORNEO IRONWOOD) IN SARAWAK, MALAYSIA

By

SITI FATIMAH MD ISA

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

August 2020

This thesis is dedicated to:

My understanding husband and my dear son.

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

MORPHOLOGICAL AND GENETIC VARIATION OF *Eusideroxylon zwageri* Teijsm. & Binn. (BORNEO IRONWOOD) IN SARAWAK, MALAYSIA

By

SITI FATIMAH MD ISA

Augut 2020

Chairman : Rusea Go, PhD
Faculty : Science

Previously, two species were recognized as Borneo Ironwood, *Eusideroxylon zwageri* and *E. melagangai*. However, study revealed that *E. melagangai* is belonging to a new genus called *Potoxylon.* This confusion is due to the close morphological resemblance between both species. Borneo Ironwood has high demand and high market value because of its valuable and durable timber, which has put its number at risk of illegal logging. In addition to threats from illegal logging, the slow seed germination process delays their natural regeneration in the forest. It may take up to six months in their natural environment to germinate. Other than that, poor genetic matching of planting material to the planting site or using seed from small, inbred populations can result, for instance, in reducing growth, reproductive output, the ability to resist pests and capacity to adapt to environmental variation. In this project, two sampling areas were chosen (i) Nirwana Rehabilitation Forest (NRF), UPM Bintulu Campus, and (ii) fragmented area in Tatau, Bintulu, Sarawak. The aims for this study were to document morphological features of *E. zwageri* and to recognize their varieties by using conventional method based on the macro-morphology characters and to support the outcome with cladistics analysis. Subsequently, four microsatellite markers were used to analyse *E. zwageri* genetic variation and their clustering to the varieties based on allelic data. In addition, the identification of fungi isolated from the fruits of *E. zwageri* was also conducted. Three varieties of *E. zwageri* were identified namely; *zwageri*, *grandis*, and *exilis*. These varieties were recognized based on the seed, bark and leaves traits and supported with cladistics analysis and allelic data. Meanwhile, genetic study shown that 20.1% of total genetic variation corresponded to differences between populations while 79.9% was attributed by differences between individuals. The Tatau (Ho = 0.399; He =

0.563) population was observed to have relatively lower genetic diversity compared to NRF (Ho = 0.659; He = 0.739) area based on the observed (Ho) and expected (He) heterozygosity value; and both areas shown a deficiency of heterozygosity indicated by positive F_{IS} value (Tatau = 0.054; NRF = 0.165) that suggested the population undergoing inbreeding event. Furthermore, study on fungi diversity isolated from *E. zwageri* fruits identified fungi from nine taxa from Ascomycota phylum namely; *Annulohypoxylon nites, A. viridistratum, Daldinia eschscholtzii, Hypoxylon investiens, Lasiodiplodia theobromae, Trichoderma asperellum, T. crassum, T. spirale,* and *T. virens.* This data will be useful for future understanding in fungi involvement in rooted seed in *E. zwageri* species. It is hope that the results from this study will be used as baseline data in an effort to protect this vulnerable species.

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

MORFOLOGI DAN VARIASI GENETIK *Eusideroxylon zwageri* Teijsm. & Binn. (BELIAN) DI SARAWAK, MALAYSIA

Oleh

SITI FATIMAH MD ISA

Ogos 2020

Pengerusi : Rusea Go, PhD
Fakulti : Sains

Terdahulu, Belian di Borneo telah dikenal pasti mempunyai dua spesis yang dikenali sebagai*; Eusideroxylon zwageri* dan *E. melagangai.* Bagaimanapun, kajian melaporkan bahawa *E. melagangai* tergolong dalam genus baru yang dikenali sebagai *Potoxylon.* Kekeliruan ini adalah disebabkan oleh persamaan morfologi yang hampir sama antara kedua-dua spesis. Belian mempunyai permintaan yang luas dan nilai pasaran yang tinggi kerana kayunya yang berharga dan tahan lama, di mana ianya juga menjadi ancaman kepada kegiatan pembalakan haram. Selain itu, proses percambahan biji benih yang lambat menangguhkan pertumbuhan semulajadi mereka di dalam hutan. Percambahan biji benih *E. zwageri* mengambil masa selama enam bulan dalam persekitaran semulajadinya. Di samping itu, pemadanan genetik yang lemah untuk menanam benih ke tapak penanaman atau menggunakan benih dari populasi yang kecil atau mempunyai baka yang sama boleh menjejaskan pertumbuhan, pengeluaran, keupayaan untuk menentang perosak dan keupayaan untuk menyesuaikan diri dengan keadaan persekitaran. Dalam projek ini, dua kawasan pensampelan telah dipilih; (i) Hutan Pemulihan Nirwana (NRF), Kampus UPM Bintulu, dan (ii) kawasan terpencil di Tatau, Bintulu, Sarawak. Tujuan kajian ini adalah untuk mendokumenkan ciri-ciri morfologi *E. zwageri* dan mengenal pasti varieti yang terdapat di tempat kajian dengan menggunakan kaedah konvensional iaitu berdasarkan ciri-ciri makro-morfologi dan disokong dengan analisis kladistik. Seterusnya, empat penanda mikrosatelit digunakan untuk menganalisis variasi genetik mereka dan kluster mereka kepada varieti berdasarkan maklumat dari data mikrosatelit. Selain itu, pengecaman fungi yang diasingkan dari buah *E. zwageri* juga dijalankan. Tiga jenis varieti telah dikenal pasti iaitu; *zwageri*, *grandis* dan *exilis.* Varieti ini diiktiraf berdasarkan kriteria benih, kulit dan daun dan keputusan ini disokong melalui analisis kladistik dan data

mikrosatelit. Sementara itu, kajian genetik menunjukkan bahawa 20.1% daripada jumlah variasi genetik sepadan dengan perbezaan antara populasi manakala 79.9% dikaitkan dengan perbezaan antara individu. Belian di Tatau (Ho = 0.399; He = 0.563) diperhatikan mempunyai kepelbagaian genetik yang lebih rendah berbanding dengan kawasan NRF (Ho = 0.659; He = 0.739) berdasarkan pemerhatian (Ho) dan jangkaan (He) *heterozygosity;* dan kedua-dua kawasan menunjukkan kekurangan *heterozygosity* yang dikenal pasti melalui nilai positif F_{IS} (Tatau = 0.054; NRF = 0.165) yang mencadangkan populasi ini mengalami kejadian *inbreeding*. Tambahan pula, pengecaman mengenai kepelbagaian fungi yang diasingkan dari buah *E. zwageri* mengenal pasti sembilan jenis kulat dari filum Ascomycota; *Annulohypoxylon nites, A. viridistratum, Daldinia eschscholtzii, Hypoxylon investiens, Lasiodiplodia theobromae, Trichoderma asperellum, T. crassum, T. spirale,* and *T. virens.* Data ini amat berguna sebagai asas pemahaman berkaitan penglibatan spesis kulat dalam pencambahan spesis *E. zwageri* pada masa hadapan. Diharapkan hasil dari kajian ini akan digunakan sebagai data asas dalam usaha untuk melindungi spesis terancam ini.

ACKNOWLEDGEMENTS

Alhamdulillah, in the name of Allah the Most Gracious and the Most Merciful, whom with His willing and blessing giving me the strengths and opportunity in completing the research work and compiled it in this thesis.

Sincere thanks to my supervisor, Prof. Dr. Rusea Go for the guidance, advises, and all the input throughout my research work. To my co-supervisor, Dr. Nazre, Dr. Christina and Dr. Riina thank you for your careful corrections, ideas, thoughts, comments, and time in checking my earlier draft. I am indeed very grateful. Many wonderful people who have supported and believe in my capability, in particular Mohd Akmal Mohd Raffi, Wong Wee Nee and Micheal Charles. Thank you for all your positive words and encouragement.

I am also grateful to the Forest Department of Sarawak (FDS) for the permit to conduct the study with permit No. NCCD.907.4.4 (JLD.13)-297 and park permit No. WL032/2016. I also would like to acknowledge The Ministry of Higher Education Malaysia for the award of the Fundamental Research Grants Scheme project No. FRGS/1/2015/WAB13/UPM/02/4 made available to Universiti Putra Malaysia.

Above all, I am highly indebted to my parents, Md Isa bin Saleh and Habibah binti Bakar for their continuous support. Thank you for your endless prayer, care and love. No words can described how grateful I am. Finally, I would like to thank to those indirectly or directly contributed in the successful of this research project.

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

Rusea Go, PhD
Professor
Faculty of Science
Universiti Putra Malaysia
(Chairman)

Mohd. Nazre Saleh, PhD
Associate Professor
Faculty of Forestry and Environment
Universiti Putra Malaysia
(Member)

Christina Seok Yien Yong, PhD
Senior Lecturer
Faculty of Science
Universiti Putra Malaysia
(Member)

Riina Jalonen, PhD
Scientist | Tree diversity for resilient landscapes
Alliance of Bioversity International and CIAT
Asia-Malaysia Office
(Member)

ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 10 December 2020

TABLE OF CONTENTS

				Page
ABSTRACT				i
ABSTRAK				iii
ACKNOWLEDGEMENTS				v
APPROVAL				vi
DECLARATION				viii
LIST OF TABLES				xii
LIST OF FIGURES				xiii
LIST OF APPENDICES				xv
LIST OF ABBREVIATIONS				xvi
CHAPTER				
1	**INTRODUCTION**			
	1.1	Background of Study		1
	1.2	Problem Statement		2
	1.3	Objectives of The Study		3
2	**LITERATURE REVIEW**			
	2.1	Borneo Ironwood		5
	2.2	*Eusideroxylon zwageri* Teijsm. & Binn.		8
	2.3	Status and Distribution of *Eusideroxylon zwageri*		13
	2.4	Microsatellite markers		
		2.4.1	General Characteristic of Microsatellites	15
		2.4.2	Genetic Study Using Simple Sequence Repeats (SSRs) in *Eusideroxylon zwageri*	16
	2.5	Fungi Study		
		2.5.1	Fungi and Plants	17
		2.5.2	Fungi Study Related with *Eusideroxylon zwageri*	19
3	**IDENTIFICATION OF *EUSIDEROXYLON ZWAGERI* USING MORPHOLOGICAL DATA**			
	3.1	Introduction		20
	3.2	Materials and Methods		
		3.2.1	Sampling Site	22
		3.2.2	Species Mapping	25
		3.2.3	Species Identification	25
		3.2.4	Character Matrix and Cladistics Analysis	27
	3.3	Results		
		3.3.1	Taxonomic Treatment of *Eusideroxylon zwageri*	27
		3.3.2	Species Distribution of *Eusideroxylon zwageri*	28
		3.3.3	Species Identification in The Study Site	32
		3.3.4	Cladistic Analysis	37

	3.4	Discussion	39
	3.5	Conclusion	42
4	**GENETIC VARIATION OF *EUSIDEROXYLON ZWAGERI* USING SIMPLE SEQUENCE REPEATS (SSRs) MARKERS**		
	4.1	Introduction	43
	4.2	Materials and Methods	
		4.2.1 Plant Sample Collection	44
		4.2.2 DNA Extraction	45
		4.2.3 Polymerase Chain Reaction (PCR) Amplification	46
		4.2.4 Data Analysis	48
	4.3	Results	48
	4.4	Discussion	56
	4.5	Conclusion	60
5	**FUNGI IDENTIFICATION ISOLATED FROM FRUITS OF *EUSIDEROXYLON ZWAGERI***		
	5.1	Introduction	62
	5.2	Materials and Methods	
		5.2.1 Sampling and Fungi Isolation	63
		5.2.2 DNA Extraction and PCR Amplification	63
		5.2.3 Sequence Analysis	64
	5.3	Results	
		5.3.1 Colony Features of The Isolated Fungi	64
		5.3.2 Molecular Sequence Identification of The Isolated Fungi	66
	5.4	Discussion	71
	5.5	Conclusion	73
6	**SUMMARY, CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH**		
	6.1	Summary and Conclusion	74
	6.2	Recommendation for Future Research	75
REFERENCES			77
APPENDICES			90
BIODATA OF STUDENT			108
LIST OF PUBLICATIONS			109

LIST OF TABLES

Table		Page
2.1	Varieties and their different vernacular name of Ironwood found in Indonesia.	11
3.1	Morphological characteristics guidelines was used to identify the varieties of *E. zwageri* according to Irawan et al. (2015).	26
3.2	Numbers of *E. zwageri*'s herbarium specimens selected herbaria and collected only from Sarawak.	29
3.3	The location of collected *E. zwageri* documented from herbarium specimens.	30
3.4	Summary of general morphological characteristics of *E. zwageri* found in the study area.	32
3.5	Number of *E. zwageri* tree and their varieties, habitat and types of soil according to study area.	33
4.1	Characteristics of four polymorphic microsatellite loci in *E. zwageri* (Kurokochi et al., 2014) used in the current study	47
4.2	Genetic diversity analyses over all three loci and populations based on number of allele (Na), observed (Ho) and expected heterozygosity (He), allelic richness (A_R), polymorphism information content (PIC), and *F*-statistics (F_{IT}, F_{IS} and F_{ST}).	51
4.3	Genetic diversity analyses within populations.	54
5.1	Identification of the isolated fungi based on ITS sequence against sequences in National Centre for Biotechnology Information (NCBI) using Basic Local Alignment Search Tool (BLAST).	68

LIST OF FIGURES

Figure		Page
2.1	*Potoxylon melagangai* (Sym.) Kosterm. 1-Leaf. 2-Racemes. 3-Flower. Details of the description can be found in Appendix 1. (Adopted from Kostermans, 1978).	7
2.2	Seed shapes of *E. zwageri* varieties. From left to right: var. *exilis*, var. *ovoidus,* var. *zwageri*, and var. *grandis.* (Adopted from Irawan et al., 2015).	8
2.3	*Eusideroxylon zwageri* Teijsm. & Binn. A. A part of flowering branch with the tip. Details of the description can be found in Appendix 2. (Adopted from Teijsmann & Binnendijk, 1863).	9
2.4	*Eusideroxylon zwageri* Teijsm. & Binn. B. A twig with a young fruit. Details of the description can be found in Appendix 2. (Adopted from Teijsmann & Binnendijk, 1863).	10
2.5	Distribution map of *E. zwageri*. A. Distribution of *E. zwageri* in Malaysia and Indonesia. B. Distribution of *E. zwageri* in the Philippines. (Source: Global Biodiversity Information Facility (GBIF)).	14
3.1	Anthropogenic activities in Tatau sampling site.	21
3.2	Field sampling location at UPM Bintulu Campus and Tatau, Bintulu, Sarawak.	23
3.3	UPM Bintulu Campus sampling area.	24
3.4	Tatau, Bintulu sampling area.	24
3.5	Seedling of Belian tree growth in the nursery.	26
3.6	Species distribution of *E. zwageri* in Sarawak by using DIVA-GIS software version 7.5 on the land cover in 2010.	31
3.7	Number of standing tree according to the diameter at breast height (dbh) found in Nirwana Rehabilitation Forest (NRF), UPM Bintulu Campus and Tatau, Bintulu.	34
3.8	One of the *E. zwageri* tree with dbh more than 55.00 cm in Tatau, Bintulu, Sarawak.	35
3.9	Color and form of bark of *E. zwageri* varieties.	36

3.10	Seed variations in *E. zwageri.*	36
3.11	A majority rule consensus of 100 equally parsimonious trees of *E. zwageri* varieties based on morphological sequence data.	38
4.1	Microsatellite marker for primer Ez_05 with 17 repeat motifs of (GA).	49
4.2(A)	Allele frequencies for locus Ez_05 in NRF and Tatau.	52
4.2(B)	Allele frequencies for locus Ez_07 in NRF and Tatau.	52
4.2(C)	Allele frequencies for locus Ez_09 in NRF and Tatau.	53
4.3	Unweigthed neighbor-joining trees using simple matching similarity coefficient based on three microsatellite markers for the 52 taxa of *E. zwageri f*rom NRF and Tatau, Bintulu.	55
4.4	Complexity of peak pattern of locus Ez_04.	57
5.1	Colony features and pigmentation of the fungal isolated on Potato Dextrose Agar plate.	66
5.2	Banding patterns of ITS gene fragments of fungi isolated from fruit of *E. zwageri*	69
5.3	Maximum Likelihood (ML) tree, showing the relationship of fungal isolated from Belian fruits inferred from ITS region.	70

LIST OF APPENDICES

Appendix		Page
1	Details description of Figure 2.1	90
2	Details description of Figure 2.3	90
3	Details description of Figure 2.4	91
4	Soil texture of Nirwana Rehabilitation Forest (NRF), UPM Bintulu Campus, Sarawak	92
5	Soil texture of Tatau, Bintulu, Sarawak	94
6	Soil pH	96
7	Weighted (W) and unweight (UW) allele frequencies per locus and per population.	97
8	NCBI GenBank dataset	98

LIST OF ABBREVIATION

NRF	Nirwana Reserved Forest
Pers. comm.	Personal communication

CHAPTER 1

INTRODUCTION

1.1 Background of Study

In Sarawak, Borneo Ironwood (*Eusideroxylon zwageri* Teijsm. & Binn.) is known locally as Belian. It is the most treasured timber of Borneo, and has been exploited widely. The species remained threatened by illegal logging despite harvesting and export restrictions in Borneo. In 2008, the Malaysian National Workshop on Forest Genetic Resources Conservation and Management identified the species amongst 30 plants as priority species for forest genetic resources conservation and categorized them as having economic importance. In Section 24 of The Sarawak Timber Industry (Registration) Regulations and Section 95 of The Forest Rules, Borneo Ironwood sawn timber were clearly defined and classified as marketable trees, and export in any form is not allowed without permission. Felling is allowed for trees above 60 cm in diameter for communities living surrounding the forest, but prohibited for concession holders and export of Ironwood is permitted only for processed wood products.

Besides that**,** International Union for Conservation of Nature (IUCN) Red List of Threatened Species (2019) listed this species as Vulnerable (VU). However, the species was last assessed in 1998 and the status would have change following the rapid industrial development and current global situations such as global warming. Several threats that threatened the number of the species in the forest mainly caused by uncontrolled logging and wood harvesting, residential and commercial development and agriculture and aquaculture activities (IUCN, 2019). This species is likely to become endangered unless the circumstances that are threatening its survival and reproduction are improved. Slow growth with mean radial growth rate 0.058 cm per year (Kurokawa, Yoshida, Nakamura, Lai, & Nakashizuka, 2003) and slow regeneration in the logging area is another biological reason contributing to the lower number of the species in the forest.

Other than that, ignorance, unawareness attitude and lack of knowledge about the status and importance of the Borneo Ironwood to our forest ecosystem give opportunity to illegal loggers to cut down the species without following rules and regulation. These could contribute to one of the cause the species to become nearly extinct in the forest. On July 19, 2018, Independent National Newspaper of East Malaysia (Daily Express) reported a major logging scandal that involved 40,161 logs involving Borneo Ironwood that have not been taxed and was also found with measurement less than 40 cm which was against the provisions under the Forest Enactment 1968. If this situation is not prevented and not addressed to the public, it will cause more serious forest destruction and threaten the number of Borneo Ironwood species in the forest.

This protected tree can reach a height of up to 50 meter and may live up to over 1,000 years. Mature trees produce large fruits that, although poisonous to humans, are important food source for foraging animals. The species is also valued for cultural reasons. The wood is dense (0.85 – 1.1 g/cm^3) (Wahyuni, 2011), strong and resistant to decay, that indigenous people of Borneo prefer to utilize it to build their houses. Dayak people of Borneo believed that these trees protect them from dangerous animals, while Murut (Borneo headhunter) used it to make blowpipe and Dusun ancestors used it to make coffin. Until today black pepper industry in Borneo used Belian wood as support to grow the creeping herbs and Murut Cultural Center is also supported by Belian wood pillars.

1.2 Problem Statement

Scientifically, there are two genera known as Borneo Ironwood; *Eusideroxylon zwageri* Teijsm. & Binn. and *Potoxylon melagangai* (Sym.) Kosterm and in this study, was focused more on *E. zwageri.* It is challenging to identify *E. zwageri* with *P. melagangai* in the field without proper training and experiences because of the close similarity in their vegetative structure. Besides, several varieties in *E. zwageri* have been informally recognized by local people, which make it more difficult in making affirmative identification. Thus, it is desirable to study the delimiting characters used to distinguish this species.

Eusideroxylon zwageri is valued as one of most durable timber tree in Malaysia and has high market value especially in the construction and furniture industries. It has high interest for restoration practitioners yet; efforts to restore the species populations through tree planting are hindered by the lack of information, especially knowledge on their genetic variation. Factors such as declining in population size through illegal logging, isolation of the population that cause by anthropogenic activities and genetic drift can cause severe genetic bottleneck for the species, which can lead to decline in the genetic variation of the species (Peery, 2012; Finlay, Bradley, Preston, & Provan, 2017). This scenario may contribute to the difficulty of getting a good quality of tree with a high chance of survival.

Besides that, the germination of *E. zwageri* seeds may take up to six months in their natural environment. Review on *E zwageri* germination process has shown that mechanical seed scarification method is a standard technique used to promote germination of *E. zwageri* seedling owing to their thick and hard endocarp layer (Irawan, 2012). Likewise, the seeds are susceptible to pathogen attack, which will hinder the sprouting of the *E. zwageri* seedling. This also will affect the regeneration process of the species where there are not enough young seedlings that will take the place of older trees that will eventually die. Hence, it is also important to study and identify fungi diversity on *E. zwageri* seeds or fruits to aid in future study on their symbiotic roles.

In particular, information and report on *E. zwageri* in the selected study areas in Sarawak are very limited. UPM Bintulu Campus has been closed for almost seven years thus the documentation activity in the Nirwana Rehabilitation Forest (NRF) is believed was also abandoned at that time (Marzuki pers. comm., 2017). In addition, after almost 28 years it is also perhaps that this study could provide an overview of *E. zwageri* genetic variation that has been preserved as a result from the restoration effort done in NRF. Meanwhile, fragmented area in Tatau, Bintulu that is believed resulted from anthropogenic activities (palm oil plantation) in the surrounding area could be considered to be the greatest threats to *E. zwageri* species residing in that area. Thus, the motivation to study and document the existence of the species in the chosen area is urgently needed before it vanishes.

1.3 Objectives of The Study

This study was carried out to identify Sarawak's *Eusideroxylon zwageri* and their varieties in selected areas, to analyze their genetic variation and to identify fungi isolated from their fruits. This information will be used in order to protect the species, to develop a future plan for enhancing their genetic diversity and to ensure optimal restoration practices and outcome. This fundamental study is necessary before more complexity work is implemented. Thus, the objectives of the study are as follows:

1. To identify species and the variety of *Eusideroxylon zwageri* in the selected study area (UPM Bintulu Campus and fragmented area in Tatau, Bintulu) using morphological approaches with support from cladistics analysis,

2. To analyze genetic variation by using specific marker that has been developed for *Eusideroxylon zwageri* and to further verify the clustering of *E. zwageri* to the varieties based on the allelic data,

3. To identify species of fungi isolated from *Eusideroxylon zwageri*'s fruits by using molecular technique to contribute to

the latest knowledge on the species of fungi isolated from *E.zwageri.*

REFERENCES

Ariff, I. A., Khan, H. A., Shobrak, M., Al Homaidan, A. A., Al Sadoon, M., Al Farhan, A. H., & Bahkali, A. H. (2010). Interpretation of electrophoretograms of seven microsatellite loci to determine the genetic diversity of the Arabian Oryx. *Genetics and Molecular Research 9*(1), 259 – 265.

Ahloowalia, B. S., Prakas, J., Savangikar, V. A., & Savangikar, C. (2002). Plant tissue culture in Proceedings of a Technical Meeting organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. Vienna.

Alghamdi, S. A. (2019). Influence of mycorrhizal fungi on seed germination and growth in terrestrial and epiphytic orchids. *Saudi Journal of Biological Sciences* 26, 495-502.

Ashton, P. S. (1981). The need for information regarding tree age and growth in tropical forests. In: Bormann, F. H., Berlyn, G., (eds). *Age and Growth Rate of Tropical Trees: New Directions for Research*. New Haven: Yale University Press. p. 3-6

Avise, J. C. (2004). Molecular markers, natural history, and evolution. 2nd edition. Sinauer Associates, Inc. Publishers. Sunderland, Massachusetts. p 92 – 253.

Barnes, E. C., Jumpathong, J., Lumyong, S., Voigt, K., & Hertweck, C. (2016, In press.). *Daldinion*, an unprecedented binaphytyl derivative, and diverse polyketide congeners from fungal ordhic endophyte. *Chemistry.*

Brown, F. G. (1955). *Forest Trees of Sarawak and Brunei and their products.* Government Printing Office, Sarawak. p. 369.

Buchanan, P., Johnston, P., Pennycook, S., McKenzie, E., & Beever, R. (2002). *Data-deficient 2002, rare and endangered fungi, landcare research*. Retrived June 12, 2017, from http://www.landcareresearch.co.nz/science/plants-animals-fungi/fungi/rare-and-endagered-fungi/data-deficient-2002.

Butler, J. M. (2015). Trouble shooting data collection. *Advanced topics in forensic DNA typing: Interpretation*, 183-210. https://doi.org/10.1016/B978-0-12-405213-0.00008-7.

Borsa, P., Zainuri, M., & Delay, B. (1991). Heterozygote deficiency an population structure in the bivalve *Ruditapes decussatus. Heredity 86*, 1-9.

Centre for Agriculture and Bioscience Internatinal (CABI). (2019). Invasive species compendium *Eusideroxylon zwageri.* Retrieved March 18, 2019, from https://www.cabi.org/isc/datasheet/23535.

Carris, L. M., Little, C. R., & Stiles, C. M. (2012). Introduction to Fungi. *The Plant Health Instructor.* Doi:10.1094/PHI-I-2012-0426-01.

Castric, V., Bernantchez, L., Belkhir, K., & Bonhomme, F. (2002). Heterozygote deficiencies in small lacustrine populations of brook charr *Salvelinus fontinalis* Mitchill (Pisces, Salmonidae): a test of alternative hypotheses. *Heredity 89*, 27-35.

Chareprasert, S., Piapukiew, J., Thienhirun, S., Whalley, A. J. S. & Sihanonth, P. (2006). Endophytic fungi of teak leaves *Tectonia grandis* L. and rain tree leaves *Samanea saman* Merr. *World Journal of Microbiology and Biotechnology 22*(5), 481-486.

Cheng, M. S. J. (2017). Effects of mycorrhizal fungi on*Vigna radiata* growth in soil differing in fertilizer concentration. *Pursuit-The Journal of Undergraduate Research at the University of Tennessee* 8(1): 47-56.

Chutima, R., Dell, B., & Lumyong, S. (2011). Effects of mycorrhizal fungi on symbiotic seed germination of *Pecteilis sisannae* (L.) Rafin (Orchidaceae), a terrestrial orchid in Thailand. *Symbiosis* 53, 149-156.

Dance, A. (2017). Inner Workings: Special relationship between fungi and plants may have spurred changes to ancient climate. *Proceedings of the National Academy of Sciences of the United States of America* 114(46), 12089-12091.

David, M. (2016). David Moore's World of Fungi: where mycology starts. Retrieved on 13 September, 2020 from www.davidmoore.org.uk

De Guzman, E. D. (1975). Conservation of vanishing timber species in the Philipines. In: Williams, J., Lamourak, C. H., & Wulijarni-Soetjipto, N. (eds.), South-East Asian plant genetic resources. Symposium Proceeding Bogor, Indonesia, March 1975. IBPGR, Bogor.

De Wit, H. C. D. (1949). *Spicilegium malaianum*. *Bulletin of the Botanical Gardens Buitenzorg III* (18), 181-212.

Dharmarajan, G., Beatty, W. S., & Rhodes Jr., O. E. (2012). Heterozygote deficiencies causesd by a Wahlund effect: Dispelling unfounded expectations. *The Journal of Wildlife Management 77*(2), 226-234.

Dickinson, M. B., Whigham, D. F., & Hermann, S. M. (2000). Tree generation in felling and natural treefall disturbance in semideciduous tropical forest in Mexico. *Forest Ecology and Management 134,* 137-151.

Doyle, J. J., & Doyle, J. L. (1987). A rapid DNA isolation procedure for small quantities of fresh leaf tissue. *Phytochem Bulletin 19*, 11-15.

Dulymamode, R., Cannon, P.F., & Peerally, A. (2001). Fungi on endemic plants of Mauritius. *Mycological Research 105*(12), 1472-1479.

Finlay, C. M. V., Bradley, C. R., Preston, S. J., & Provan, J. (2017). Low genetic diversity and potential inbreeding in an isolated population of alder buckthorn (*Frangula alnus*) following a founder effect. *Scientific Report 7*(3010), 1-8.

Ferlian, O., Biere, A., Bonfante, P., Buscot, F., Eisenhauer, N., Fernandez, I., Hause, B., et al. (2018). Growing research networks on mycorrhizae for mutual benefits. *Trends in Plant Science* 23(11), 975-984.

Fournier, J., & Lechat, C. (2016). Some *Annulohypoxylon* spp. (Xylariaceae) form French Guiana, including three new species. *Ascomycete 8*(1), 33-53.

Fuchs, B., & Haselwandter, K. (2008). Arbuscular mycorrhiza of endangered plant species: Potential impacts on restoration strategies. *Mycorrhiza*: *State of the art, genetics and molecular biology, eco-foundation, biotechnology, eco-physiology, structure and systematics* (3rd ed.) (pp. 565-579). Heidelberg, Germany: Springer.

Gaertner, E. E. (1964). Tree growth in relation to the environment. *The Botanical Review 30*(3), 393-436. ISSN 1874-9372.

Gauli, A., Gailing, O., Stefenon, V. M., & Finkeldey, R. (2009). Genetic similarity of natural populations and plantations of *Pinus roxburhii* sarg. In Nepal. *Annuals of Forest Sciences 66,* 703. DOI: 10.1051/forest/2009053.

Gibson, E., & Rebicca, E. (2016). A preliminary study on the induction of somatic embryogenesis of *Eusideroxylon zwageri* Teijsm. & Binn. (Borneo Ironwood) from leaf explant. *Advances in Plant and Agriculture Research* 5 (4), 557-559.

Gibson, E., & Rebicca, E. (2017a). Induction of indirect somatic embryogenesis in Borneo ironwood. *Communications in Plant Sciences,* 15-19. ISSN 2237-4027.

Gibson, E., & Rebicca, E. (2017b). Induction of shoot buds multiplication of *Eusideroxylon zwageri* Tesym. And Binned (Borneo Ironwood) by using nodal explants. *Biotech Today 6*(1), 7-12. doi:10.5958/2322-0996.2016.00001.6.

Glucher, J. (2012). Microsatellite markers for linkage and association studies. *Cold Spring Harbor Protocols* (4), 425-432.

Goudet, J. (1995). FSTAT (version 1.2). a computer program to calculate *F*-statistics. *Journal of Heredity 86*, 485-486.

Guries, R. P. & Ledig, F. T. (1981). Genetic structure of populations and differentiation in forest trees. InProc.:IsozymesofNorthAmericanforest tree and forest insects. USDAFor.Servo Gen.Tech.Rep.PSW-46,p.30-37.

Global Biodiversity Information Facility (GBIF). Retrieved on 15 April, 2019, from www.gbif.org.

Hardoim, P. R., van Overbeek, L. S., Berg, G., Pirttila, A. M., Compant, S., Campisano, A., Doring, M. & Sessitsch, A. (2015). The hidden world within plants: Ecological and evolutionary considerations for defining functioning of microbial endophytes. *Microbiology and Molecular Biology Reviews 79*(3), 293-320.

Harkingto, Purwantoro, A., Prajitno, D., & Widyatmoko, A. (2006). Genetic Variation of five ironwood populations in East Kalimantan revealed by RAPD marker. *Ilmu Pertanian 1*3(1), 1-10.

Hayward, A. C., Tollenaere, R., Dalton-Margon, J., & Batley, J. (2015). Molecular markers applications in plants. In: Batley, J. editor. Plant Genotyping. Springer, New York. p. 13-27.

Heijden, M. G. A. (2016). Underground networking. *Science* 352(6283), 290-291.

Hijmans, R. J. Guarino, L., & Mathur, P. (2012). DIVA-GIS version 7.5 manual. Retrieved on 12 April, 2018, from www.diva-gis.org.

Hidayat. (2007). Induksi pertumbuhan eksplan endosperm ulin dengan IAA dan Kinetin. *Agritop 26*, 147-152.

Hilderbrand, C. E., Torney, D. C., & Wagner, R. P. (1994). Informativeness of polymorphic DNA markers. In *The Human Genome Project: Deciphering The Bluepring of Heredity, Cooper, N. G. (ed.).* Universiti Science Books. Mill Valley, California. p. 360.

Hong, T. S. (2005). *Thesis*. Identification of genomic markers for Belian using RAPD. Faculty of Resource Science and Technology, Universiti Malaysia Sarawak.

Hoyos-Carvajal, L., Orduz, S., & Bissett, J. (2009). Genetic and metabolic biodiversity of *Trichoderma* from Colombia and adjacent neotropic regions. *Fungal Genetic Biology 46*(9), 615-631.

Ikeda, A., Matsuko, S., Masuya, H., Mori, A. S., Hirose, D., & Osono, T. (2014). Comparison of the diversity, composition, and host recurrence of xylariaceous endophytes in subtropical, cool temperate, and subboreal regions in Japan. *Population Ecology 56*(2), 289-300.

International Union for Conservation of Nature. (2019). *The IUCN Red List of Threatened Species.* Eusideroxylon zwageri (*Version 2019.2*). Retrieved January 20, 2019, from http://www.iucnredlist.org.

Irawan, B. (2005). Ironwood (*Eusideroxylon zwageri* Teijsm. & Binn.) and its varieties in Jambi Indonesia. Cuvillier, Goettingen. p. 159.

Irawan, B. (2012). Growth performance of one year old seedlings of Ironwood (*Eusideroxylon zwageri* Teijsm. & Binn.) varieties. *Jurnal Manajemen Hutan Tropika vol. XVII*(3), 184-190.

Irawan, B., & Gruber, F. (2003). A study on tree diversity in association with variability of ironwood (*Eusideroxylon zwageri* Teijsm. & Binn.) in Jambi, Indonesia. Deutscher Tropentag 2003 Georg-August-University Gottingen, October 8-10, 2003. http://www.tropentag.de/2003/abstracts/full/96.pdf.

Irawan, B., & Gruber, F. (2004). Morphological variability of ironwood (*Eusideroxylon zwageri*) in natural forests. *Journal of Agriculture and Rural Development in the Tropics and Subtropics* 80.

Irawan, B., Gruber, F., Finkeldey, R., & Gailing, O. (2015). Linking indigenous knowledge, plant morphology, and molecular differentiation: the case of ironwood (*Eusideroxylon zwageri* Teijsm. et Binn.). *Genetic Resources Crop Evolution.* doi:10.1007/s10722-015-0317-4.

Jamieson, I. G., Grueber, C. E., Waters, J. M., & Gleeson, D. M. (2008). Managing genetic diversity in threatened populations: a New Zealand perspective. *New Zealand Journal of Ecology 32*(1), 130-137.

Johnston, H .R., Keats, B. J. B., & Sherman, S. L. (2019). Population Genetics. In: Emery and Rimoin's Principles and Practice of Medical Genetics and Genomics (7th ed.). Elsevier Inc. p. 359-373

Kalinowski, S. T., Taper, M. L., & Marshall, T. C. (2007). Revising how the computer program CERVUS accommodates genotyping error increases success in paternity assignment. *Molecular Ecology 16*, 1099-1106.

Karnchanatat, A., Petsom, A., Sangvanich, P., Piaphukiew, J., Whalley, A. J., Reynolds, C. D., & Sihanonth, P. (2007). Purification and biochemical characterization of an extracellular beta-glucosidase from the wood-decaying fungus *Daldinia eschscholzil. FEMS Microbiology Letter 270*(1), 162-170.

Keats, B. J. B., & Sherman, S. L. (2013). Population Genetics. In: Emery and Rimoin's Principles and Practice of Medical Genetics and Genomics (6th ed.). Elsevier Inc. p. 1-12.

Killham, K., & Prosser, J. I. (2015). Chapter 3 – The Bacteria and Archae in *Soil Microbiology, Ecology and Biochemistry* 4th ed. Academic Press. p 41-76

Kim, D. H. (2019). Practical methods for rapid seed germination from seed coat-imposed dormancy of *Prunus yedoensis*. *Scientia Horticulture* 243, 451-456.

Kiyono, Y., & Hastaniah. (2000). Growth of *Eusideroxylon zwageri* seedlings and silvicultural changes in logged-over and burned forests of bukit Soeharto, East Kalimantan, Indonesia. *Japan Agricultural Research Quarterly 34*(1), 63-67.

Koopman, M. J. F., & Verhoef, L. (1938). *Eusideroxylon zwageri,* the ironwood of Borneo and Sumatra. *Tectona 31*, 381-399.

Kostermans, A. J. G. H. (1978). *Potoxylon.* A new Borneon genus of Lauraceae. *Malayan Nature Journal 32*, 143-148.

Kostermans, A. J. G. H., Sunarno, B., Martawijaya, A., and Sudo, S. (1994). *Eusideroxylon* Teijsm. & Binned. In: Plant Resources of South-East Asia 5(1). Timber trees: major commercial timbers (Soerianegara, I., & Lemmens, R. H. M. J. eds). PROSEA. Bogor Indonesia. pg. 211-215.

Kouame, K. G., Glomerellaceae, S., Abo, K., Dick, E., Bomisso, E. L., Kone, D., & Yatty, J. (2010). Artificial wounds implication for the development of mango (*Mangifera indica* L. Anacadiaceae) fruit disease caused by *Colletotrichum*. *International Journal of Biological and Chemical Science 4*(5), 1621-1628.

Krane, D. E. (2012). Artifacts and noise in DNA profiling. https://corescholar.libraries.wright.edu/biology/243.

Kuhnert, E., Fournier, J., Persoh, D., Luangsa-Ard, J. J., & Stadler, M. (2014). New *Hypoxylon* species from Martinque and new evidence on the molecular phylogeny of *Hypoxylon* based on ITS rDNA and Beta-tubulin data. *Fungal Diversity 64*(1), 181-203.

Kuhnert, E., Sir, E. B., Lambert, C., Hyde, K. D., Hladki, A. I., Romero, A. I., Rohde, M., & Stadler, M. (2017, In press.). Phylogenetic and chemotaxonomic resolution of the genus *Annulohypoxylon* (Xylariaceae) including four new species. *Fungal Diversity.*

Kumar, R., Tapwal, A., Pandey, S., Borah, R. K., Borah, D., & Borgohain, J. (2013). Macro-fungal diversity and nutrient content of some edible mushrooms of Nagaland, India. *Nusantara Bioscience 5*(1), 1-7.

Kumar, S., Stecher, G., & Tamura, K. (2016). MEGA7: Molecular Evolutionary Genetics Analysis version 7.0 for bigger dataset. *Molecular Biology and Evolution 33*(7), 1870-1874.

Kurokawa, H., Yoshida, T., Nakamura, T., Lai, J., & Nakashizuka, T. (2003). The age of tropical rain-forest canopy species. Borneo ironwood (*Eusideroxylon zwageri*), determined by ^{14}C dating. *Journal of Tropical Ecology 19*, 1-7.

Kurokochi, H., Tan. E., Asakawa, S., Sukartiningsih, Saito, Y., Ide, Y. (2014). Development of 16 microsatellite markers in *Eusideroxylon zwageri* by next-generation sequencing. *Conservation Genetic Resources 6*, 593-595.

Kurokochi, H., Nurtjahjaningsih, I. L. G., Sukartiningsih, Tan, E., Asakawa, S., Saito, Y., & Ide, Y. (2015). Development of polymorphic chloroplast DNA markers for the endangered tree *Eusideroxylon zwageri* through chloroplast isolation and next-generation sequencing. *Conservation Genetic Resources 7*, 845-850.

Lateef, A. A., Muid, S., Mohamad, H. B., & Mansor, W. Z. (2015). Short Communication: Microfungal diversity on leave of *Eusideroxylon zwageri,* a threatened plant species in Sarawak, Northen Borneo. *Biodiversitas 16*(2), 264-268.

Leonardi, S., Piovani, P., Scalfi, M., Piotti, A., Giannini, R., & Menozzi, P. (2012). Effect of habitat fragmentation on the genetic diversity and structure of peripheral populations of bech in Central Italy. *Journal of Heredity 103*(3), 408-417.

Leslie, J. F., & Summerell, B. A. (2006). *The Fusarium laboratory manual*. Ames, USA: Blackwell Publishing Professional. p. 388.

Lopes, F. A., Steindorff, A. S., Geraldine, A. M., Brandao, R. S., Monteiro, V. N., Lobo, M. Jr., Coelho, A. S., Ulhoa, C. J., & Silva, R. N. (2012). Biochemical and metabolic profiles of *Trichoderma* strains isolated from common bean crops in the Brazillian Cerrado, and potential antagonism against *Sclerotinia sclerotiorum. Fungal Biology 116*(7), 815-824.

Lowe, A. J., Boshier, D., Ward, M., Bacles, C. F. E., & Navarro, C. (2005). Genetic resource impacts of habi-tat loss and degradation; reconciling empirical evi-dence and predicted theory for neotropical trees. *Heredity 95*, 255–273.

MacKinnon, J., & Artha, B. M. (1981). National Conservation Plan for Indonesia, vol. V. Kalimantan. Field Report 17 of FAO Project INS/78/061. Bogor, Indonesia.

MacKinnon, J., & MacKinnon, K. (1986). Review of protected area system in the Indonesia Malayan Realm. IUCN, Gland. p. 284.

MacKinnon, K., Hatta, G., Halim, H., & Mangalik, A. (1996). *The ecology of Kalimantan.* Singapore: Periplus. (The Ecology of Indonesia Series 3). p. 802.

Maddison, W. P. & Maddison, D. R. (2016) Mesquite: a modular system for evolutionary analysis. Version 3.11 [Online]. Available from: http://mesquiteproject.org. USA: Boston.

Madesis, P., Ganopoulos, I, & Tsaftaris, A. (2013). Microsatellite: evolution and contribution. *Methods in Molecular Biology* (1006), 1-13.

Mohammadi, K., Khalesro, S., Sohrabi, Y., & Heidari, G. (2011). A review: Beneficial effects of the mycorrhizal fungi for plant growth. *Journal of Applied Environmental And Biological Sciences* 1(9), 310-319.

Majiol, A. R., Maid, M., & Kodoh, J. (2014). *Potoxylon melagangai* (Symington) Kosterm., 1978*. Enzyklopadie der Holzgewachse Handbuch und Atlas der Dendrologie 64,* 1-11.

Marshall, T. C., Slate, J., Kruuk, L. E. B., & Pemberton, J. M. (1998). Statistical confidence for likelihood-based paternity inference in natural populations. *Molecular Ecology 7*, 639-655.

Martin, K., & Rygiewicz, P. T. (2005). Fungal-specific 95 PCR primers developed for analysis of the ITS region of environmental DNA extracts. *BMC Microbiology Journal 5*(28), 1-11. doi:10.1186/1471-2180-5-28.

Mason, A. S. (2015). SSR Genotyping. In: Batley, J. editor. *Plant Genotyping*. Springer, New York. p. 77-89.

Mehl, J. W. M., Wingfield, M. J., Roux, J., & Slippers, B. (2017). Invasive everywhere? Phylogeographic analysis of the globally distributed tree pathogen *Lasidioplodia theobromae. Forest 8*(5), 1-22.

Meressal, A. A. K. A. (2003). Kajian kerentangan kayu *Eusideroxylon zwageri* dan *Potoxylon melagangai* terhadap serangan anai-anai *Coptotermes* sp. Universiti Malaysia Sarawak. p.1-14

Matute, D. R. (2013). The role of founder effects on the evolution of reproductive isolation. *Journal of Evolutionary Biology 26,* 2299-2311.

Miyawaki, A. (1999). Creative ecology: restoration of native forests by native trees. *Plant Biotechnology 16*, 15-25.

Mostacedo, B., Putz, F. E., Fredericksen, T. S., Villca, A., & Palacios, T. (2009). Contributions of root and stump sprout to natural regeneration of a logged tropical dry forest in Bolivia. *Forest Ecology and Management 258*, 978-985.

Mueller, G. M., & Bill, G. F. (2004). Introduction. In G. M. Mueller, G. F. Bill, & M. S. Foster (Eds.), *Biodiversity of fungi: Inventory and Monitoring Methods*. San Diego, USA: Elsevier Academic Press. p. 1-6.

Nair, D. N. & Padmavathy, S. (2014). Impact of endophytic microorganisms on plants, environment and humans. *The Scientific World Journal* (Article ID 250693), 1-11.

Nei, M., Maruyama, T. & Chakraborty, R. (1975). The bottleneck effect and genetic variability in populations. *Evolution 29,* 1–10.

Ottenheim, C., Meier, K., Zimmermann, W., & Wu, J. C. (2015). Isolation of filamentous fungi exhibiting high endoxylanase activity in lignocellulose hydrolysate. *Applied Biochemistry and Biotechnology 175*(4), 2066-2074.

Pandey, M., Gailing, O., Leinemann, L., & Finkeldey, R. (2004). Molecular markers provide evidence for long-distance planting material transfer during plantation establishment of *Dalbergia sissoo* Roxb. In Nepal. *Annals of Forest Science 61*, 603-606.

Peakall, R., & Smouse, P. E. (2012). GenAlex 6.5: genetic analysis in Excel. Population genetic software for teaching and research-an update. *Bioinformatics 28*, 2537-2539.

Peery, M. Z. (2012) Reliability of genetic bottleneck tests for detecting recent population declines. *Molecular Ecology 21,* 3403–3418.

Perrier, X., & Jacquemoud-Collet J. P. (2006). DARwin software accessed from http://darwin.cirad.fr/

Posada, F., & Vega, F. E. (2006). Inoculation and colonization of coffee seedlings (*Coffea arabica* L.) with the fungal entomopathogen *Beauveria bassiana* (Ascomycota: Hypocreales). *Mycoscience 47*(5), 284-289.

Raven, P. H., Evert, R. F., & Eichhorn, S. E. (2005). Fungi. In: *Biology of Plants* 7 ed. W. H. Freeman. p. 290.

Rimbawanto, A., Widyatmoko, A. Y. P. B. C., & Harkingto. (2006). Population diversity of *Eusideroxylon zwageri* in East Kalimantan revealed by RAPD markers. *Jurnal Penelitian Hutan Tanaman 3*(3), 201-208.

Rocha, I., Duarte, I., Ma, Ying, Souza-Alonso, P., Latr, A., Vosatka, M., Freitas, H., & Oliveira, R. S. (2019). Seed coating with arbuscular mycorrhizal fungi for improved field production of chickpea. *Agronomy* 9 (471), 1-11.

Rodriguez, R. J., White, J. F., Arnold, A. E. & Redman, R. S. (2008). Fungal endophytes: diversity and functional roles. *New Phytologist 182*, 314-330.

Rostami, A. A., & Shasaver, A. (2009). Effects of seed scarification on seed germination and early growth of olive seedlings. *Journal of Biological Sciences 9*(8), 825-828.

Sabah Tourism Board. (2019). Imbak Canyon Conservation Area. Retrieved 23 March, 2019, from www.sabahtourism.com/destinas/inabk-canyon-conservation-area/.

Schmidt, J., Wilhelm, E., & Savangikar, V. A. (2002). Diseases detection and elimination in Proceedings of a Technical Meeting organized by the Joint FAO/IAEA Division of Nuclear Techniques in Food and Agriculture. Vienna.

Seng, H. W., Siew, Y. A., Mei, L. S., Tawan, C., Ipor, I., Ling, P. S., Abdullah, J. (2014). DNA genotyping of Borneo Ironwood using M13 universal primer and SCAR marker development in *Eusideroxylon zwageri. Acta Biologica Malaysiana 3*(1), 10-15.

Siew, Y. A. (2005). *Thesis*. Genotyping of *Eusideroxylon zwageri* Teijsm & Binn. and *Potoxylon melagangai* Kosterm. (Borneo Ironwood) by using M13 universal primer. Faculty of Resource Science and Technology, Universiti Malaysia Sarawak.

Silk, J. W. F. (2009). Plants of Southeast Asia. Retrieved 12 February, 2019, from www.asianplant.net.

Snaddon, J. L., Turner, E. C., Fayle, T. M., Khen, C. V., Eggleton, P., & Foster, W. A. (2012). Biodiversity hanging by a thread: The importance of fungal litter-trapping systems in tropical rainforests. *Biology Letters, 8*(3), 397-400.

Soerianegara, I., & Lemmens, R. H. M. J. (1994). PROSEA, Plant Resources of South East Asia 5 (1) Timber Trees: Major commercial timbers. PROSEA. Bogor. p. 610.

Sotomayor-Leon, E. M., & Cabalero, J. M. (1990). An easy method of breaking olive stones to remove mechanical dormancy. *Acta Hortic 286*, 113-116.

Suwannasai, N., Martin, M. P., Phosri, C., Sihanonth, P., Whalley, A. J. S., & Spouge, J. L. (2013). Fungi in Thailand: A case study of the efficacy of an ITS barcode for automatically identifying species within the *Annulohypoxylon* and *Hypoxylon* genera. *PloS ONE 8*(2), 1-8.

Teijsmann, J. E. (1858). Botanische reis over banka en in de palembansche binnenlanden. *Natuurkunding tijdschrift voor Nederlandsch-Indie 18*, 1-96.

Teijsmann, J. E., & Binnendijk, S. (1863). Translation version of Bijdrage tot de kennis can het Echte Ijzerhout (*Eusideroxylon zwageri* T. et B.). *Natuurkundig tijdschrift voor Nederlandsch-Indie 25*, 288-294.

Tefera, T., & Vidal, S. (2009). Effect of inoculation method and plant growth medium on endophytic colonization of sorghum by the entomopathogenic fungus *Beauveria bassiana*. *Biocontrol 54*(5), 663-669.

The Plant List. (2013). *Eusideroxylon* zwageri (*Version 1.1*). Published on the Internet; Retrieved 12 February, 2019, from http://www.theplantlist.org/.

Toonen, R. J., & Hughes, S. (2001). Incresed throughput for fragment analysis on an ABI Prism 377 automated sequencer using a membrane comb and STRand software. *BioTechniques* 31, 1320-1324.

UNEP-WCMC. (2007). State of the world's protected areas 2007. Retrieved March 15, 2019, from www.unep-wcmc.org.

User Guide Applied Biosystems by Life Technologies. (2014). DNA fragments analysis by capillary electrophoresis. Thermo Fisher Scientific Incorporation.

U'ren, J. M., Dalling, J. W., Gallery, R. E., Maddison, D. R., Davis, E. C., Gibson, C. M., & Arnold, A. E. (2009). Diversity and evolutionary origins of fungi associated with seeds of a neotropical pioneer tree: A case study for analysing fungal environmental samples. *Mycological Research 111*(4), 432-449.

U'ren, J. M., Miadlikowska, J., Zimmerman, N. B., Lutzoni, F., Stajich, J. E., & Arnold, A. E. (2016). Contribution of North American endophytes to the phylogeny, ecology, and taxonomy of Xylariaceae (Sordariomycetes, Ascomycota). *Molecular Phylogenetic and Evolution 98*, 210-232.

Vieira, M. L. C., Santini, L, Dinis, A. L., & Munhoz, C. F. (2016). Microsatellite markers: what they mean and why they are so useful. *Genetics and Molecular Biology 39*(3), 312-328.

Waples, R. S. (2015). Testing for Hardy-Weinberg proportions: have we lost the plost?. *Journal of Heredity 106*, 1-19.

Wahyuni, T. (2011). Can traditional foret management protech and conserve ironwood (ulin) stands?. An option and approach in East Kalimantan. Desa Putra, Jakarta, Indonesia. p. 244.

Weeks, A. R., Stoklosa, J., & Hoffmann, A. A. (2016). Conservation of genetic uniqueness of populations may increase extinction likelihood of endangered species: the case of Australian mammals. *Frontiers in Zoology 13*(13), 1-9.

Weidelt, H. J. (1997). *Tropical silviculture.* Goettingen: Faculty of Forestry and Ecology, Gottingen University.

White, T. J., Bruns, T., Lee, S., & Taylor, J. (1990). Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In A. I. Michael, H. G. David, J. S. John, & J. W. Thomas (Eds.), *PCR protocols: A guide to methods and application*. San Diego, USA: Academic Press. p. 315-324.

Wong, A. H. H., & Singh, A. P. (1995). Soft rot decay of Belian (*Eusideroxylon zwageri*) wood. *The international research group on wood preservation* 1-8. Helsingor, Denmark.

Wright, S. (1931). Evolution in Mendelian populations. *Genetics 16*, 97-159.

Wright, S. (1978). Evolution and the genetics of populations, Vol. 4. Variability within and among natural populations. University of Chicago Press, Chicago, IL.

Yoon, C. M. (2006). *Thesis*. Genotyping of *Eusideroxylon zwageri* Teijsm & Binn. and *Potoxylon melagangai* Kosterm. (Borneo Ironwood) using

DAMD markers. Faculty of Resource Science and Technology, Universiti Malaysia Sarawak.

Zubek, S., Nobis, M., Blaszkowski, J., Mlecko, P., & Nowak, A. (2011). Fungal root endophyte associations of plants endemic to the Pamir Alay Mountains of Central Asia. *Symbiosis 54*(3), 139-149.