DIVERSITY OF FOLIICOLOUS LICHENS AND HERBIVORY ON FIVE SPECIES OF COMMONLY PLANTED DIPTEROCARPS IN INIKEA REHABILITATION FOREST PROJECT AREA

MOHAMMAD SHAHRUL BIN SHAHPUAN

INSTITUTE FOR
TROPICAL BIOLOGY AND CONSERVATION
UNIVERSITI MALAYSIA SABAH
2020

DIVERSITY OF FOLIICOLOUS LICHENS AND HERBIVORY ON FIVE SPECIES OF COMMONLY PLANTED DIPTEROCARPS IN INIKEA REHABILITATION FOREST PROJECT AREA

MOHAMMAD SHAHRUL BIN SHAHPUAN

THESIS SUBMITTED IN FULFILLMENT FOR THE DEGREE OF MASTER OF SCIENCE

INSTITUTE FOR TROPICAL BIOLOGY AND CONSERVATION
UNIVERSITI MALAYSIA SABAH
2020

UNIVERSITI MALAYSIA SABAH

BORANG PENGESAHAN STATUS TESIS

JUDUL: DIVERSITY OF FOLIICOLOUS LICHENS AND HERBIVORY ON FIVE SPECIES OF COMMONLY PLANTED DIPTEROCARPS IN INIKEA REHABILITATION FOREST PROJECT AREA

IJAZAH: SARJANA SAINS (PROSES EKOLOGI)

Saya Mohammad Shahrul Shahpuan sesi 2016-2020 mengaku membenarkan tesis sarjana ini disimpan di perpustakaan Universiti Malaysia Sabah dengan syarat-syarat kegunaan seperti berikut:-

1. Tesis ini adalah hak milik Universiti Malaysia Sabah.
2. Perpustakaan Universiti Malaysia Sabah dibenarkan membuat Salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat Salinan tesis ini sebagai bahan pertukaraan antara institusi pengajian tinggi.
4. Sila tandakan (/):

☐	SULIT	(mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA 1972)
☐	TERHAD	(mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/ badan di mana penyelidikan dijalankan)
☐	TIDAK TERHAD	

Disahkan oleh,

_____ _____

MOHAMMAD SHAHRUL SHAHPUAN (Tandatangan Pustakawan)

ANITA BINTI ARSAD
PUSTAKAWAN KANAN
UNIVERSITI MALAYSIA SABAH

Tarikh: 10 JUN 2020

_____

(Prof. Dr. Charles S. Vairappan)
Penyelia

DECLARATION

I declare that this dissertation is based on my original work, except for quotations and summaries, each of which has been fully acknowledged.

10 JUN 2020

MOHAMMAD SHAHRUL BIN SHAHPUAN

MX1611015T

CERTIFICATION

NAME : **MOHAMMAD SHAHRUL BIN SHAHPUAN**

MATRIC NO : **MX1611015T**

TITLE : **DIVERSITY OF FOLIICOLOUS LICHENS AND HERBIVORY ON FIVE SPECIES OF COMMONLY PLANTED DIPTEROCARPS IN INIKEA REHABILITATION FOREST PROJECT AREA**

DEGREE : **MASTER OF SCIENCE (ECOLOGICAL PROCESSES)**

VIVA DATE : **27 FEBRUARY 2020**

CERTIFIED BY;

SIGNATURE

SUPERVISOR

Prof. Dr. Charles S. Vairappan _____

ACKNOWLEDGEMENT

Alhamdulillah, thank you Allah S.W.T for His will to give me the opportunity to complete my Masters research entitled "Diversity of Foliicolous Lichens and Herbivory on Five Species of Commonly Planted Dipterocarps in Inikea Rehabilitation Forest Project Area". The completion of this research dissertation is to fulfil the requirement for Master of Degree in Advancement of Biodiversity. Several parties have involved in giving support, advice and guidance throughout the research's period.

First of all, I would like to express my gratitude to my supervisor, Prof. Dr. Charles S. Vairappan for endless guidance and valuable advice throughout the research investigation, keeping my research progress on schedule and preparation of this dissertation

Next, I would like to thank to my family member for their endless support in moral and financial while I am conducting my study in University Malaysia Sabah, thanks are also given to University Malaysia Sabah for the SBP (Skim Bantuan Pengajar) Scholarship and UMSGreat grant.

I wish to express my deepest appreciation towards all the staffs of Institute for Tropical and Biology Conservation (ITBC) especially Mr. Rolinus Paulus and Ms. Julianah Joseph who involved and helped me for completion of this research.

MOHAMMAD SHAHRUL BIN SHAHPUAN

21 August 2019

ABSTRACT

Growth and survival of Dipterocarps are often known to be dependent on sunlight intensity, nutrients, biofoulers, and herbivory. Investigation was carried out in INIKEA "Species Plot", Luasong on five species of Dipterocarps; *Dipterocarpus conformis* (KBK)*, Dryobalanops keithii* (KPG)*, Dryobalanops lanceolata* (KPJ)*, Shorea fallax* (SDK) and *Shorea ovalis* (SKE) to better understand presence biofoulers and extent of herbivory on their leaves. Main objective of this investigation was to obtain information on the diversity of foliicolous lichen on Dipterocarp leaves.. In addition, leaf-loss due to herbivory was also investigated and correlated with leaf age and chemistry From 185 specimens, a total of 32 species of foliicolous lichens were identified from 9 families and 19 genera with 9 new records to Sabah, *Badimia polillensis*, *Chroodiscus verrucosus*, *Calenia pseudographidea, Loflammia gabrielis*, *Phyllocratera papuana*, *Sporopodium leprieurii*, *Sporopodium antonianum*, *Trichothelium brasiliense* and *Tricharia santessonii*. Species richness between all dipterocarps was higher in KBK with 18, while KPG recorded as the lowest with only 7 species. The PCoA shows that KBK and SKE have a more similar diversity as compared to the other 3 species. Total area loss due to herbivory was evaluated and quantified. Highest percentage of leaf loss can be seen on the young leaf and gradually decreased over the age of the leaf. In an effort to establish correlation between the inherently available chemicals and herbivory, total phenolic/total tannin contents was analysed to establish its pattern between the leaves studied. Data showed that the value of the tannins and phenolics were much higher in young leaves and lower in mature leaves. However, some insects were still able to graze on leaves with high phenolics/tannin content. Tannins can be the stimulants for feeding while the role of phenolics as defence mechanisms could have been over emphasized. The Volatile Organic Compounds in lichenized sample shows more detected chemical than in unlichenized sample. Most of the changes can be detected at the "fingerprint" region of the spectra implying the differences in the presence of minor compounds. Foliicolous lichen that lichenized the leaves can indirectly change the chemical fingerprint of the leaves by adding more functional groups due to the compounds produced by the lichens.

ABSTRAK

KEPELBAGAIAN LIKEN FOLIICOLOUS DAN HERBIVORI PADA DAUN LIMA SPESIES DIPTEROKARP YANG DITANAM DI KAWASAN PROJEK HUTAN REHABILITSI INIKEA

Pertumbuhan dan kelangsungan hidup Dipterokap sering dianggap bergantung kepada keamatan cahaya matahari, nutrien, biofoulers dan herbivori. Siasatan telah dijalankan di plot spesies INIKEA, Luasong pada lima spesies Dipterokap, Dipterocarpus conformis (KBK), Dryobalanops keithii (KPG), Dryobalanops lanceolata (KPJ), Shorea fallax (SDK) and Shorea ovalis (SKE) bagi lebih memahami pemanfaatan biofouler dan herbivori di daun spesies tersebut. Objektif utama penyelidikan ini adalah untuk mendapatkan maklumat tentang kepelbagaian liken foliicolous pada daun Dipterokap. Kekayaan dan kepadatan spesies liken dianalisis secara statistic untuk menunjukkan keutamaan kepada kematangan daun. Di samping itu, daun yang menghadapi herbivori juga diselidik dan dikaitkan dengan usia daun dan kimia. Daripada 185 spesimen, kepelbagaian liken foliicolous telah dikenalpasti dari 9 keluarga dan 19 genera dengan 9 adalah rekod baru untuk Sabah iaitu Badimia polillensis, Chroodiscus verrucosus, Calenia pseudographidea, Loflammia gabrielis, Phyllocratera papuana, Sporopodium leprieurii, Sporopodium antonianum, Trichothelium brasiliense dan Tricharia santessonii.. Kekayaan spesies antara semua Dipterokap lebih tingi di KBK dengan 18 spesies manakala KPG merekodkan sebagai terendah dengan hanya 7 spesies. Keputusan Analisa PCoA menunjukkan kesamaan dari segi kepelbagaian spesies liken di antara Dipterocarpus conformis dan Shorea ovalis berbanding 3 spesies yang lain. Peratusan yang paling tinggi boleh dilihat pada daun yang muda dan secara beransur-ansur nilainya menurun sepanjang umur daun. Data menunjukkan bahawa nilai tannin dan fenolik lebih tinggi pada daun muda dan lebih rendah pada daun yang matang. Walau bagaimanapun, sesetengah serangga masih memilih daun dengan kandungan fenolik/tannin yang tinggi. Hal ini kerana, tannin boleh menjadi penarik bagi serangga sementara peranan fenolik sebagai mekanisme pertahanan mungkin telah disalahanggap. Sebatian Organik Meruap pada daun yang mempunyai liken menunjukkan lebih banyak sebatian kimia yang dikesan berbanding daun yang tidak mempunyai liken. Kebanyakkan perubahan boleh dikesan di Kawasan cap jari sepktrum yang menunjukkan perbezaan dalam kehadiran sebatian kimia. Liken foliicolous yang berada di atas daun secara tidak langsung mampu mengubah cap jari sebatian kimia pada daun dengan menambah lebih banyak kumpulan kimia kerana sebatian yang dihasilkan oleh liken.

TABLE OF CONTENTS

CHAPTER 3 DIVERSITY OF FOLIICOLOUS LICHENS ON DIPTEROCARP LEAVES

CHAPTER 4 VOLATILE ORGANIC CHEMICALS AND PRINCIPLE CHEMICAL FINGERPRINT ANALYSIS BETWEEN LICHEN COLONIZED AND UNCOLONIZED LEAVES

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

%	Percentage
^{o}C	Degree Celcius
g	Gram
m	Multiplet
s	Singlet
d	Double
t	Triplet
mg	milligram
mg/ml	Milligram per mililiter
µl	Microliter
µl/ml	Microliter per mililiter
FTIR	Fourier Transform InfraRed
LCMS	Liquid Chromatography Mass Spectrometer

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

In the new geological Anthropocene, humans are the drivers of global environmental change. The most obvious impact is human induced pressures that causes major changes in tropical rainforest ecosystem. Tropical rainforest is facing drastic changes that possess to degrade and erode its ecosystem function via uncontrolled activities such logging, fires, land conversion into agriculture and infrastructure development. Restoration initiatives are often hampered due to the limitation of knowledge on the ecology of rainforest tree species as these informations are necessary for appropriate and successful forest management and interventions effort to save the degradation of tropical rainforest.

Main environmental drivers for Dipterocarp growth and survival in tropical forest are light and nutrient availability. Light is often the primary limiting factor in regenerating seedling, and in rehabilitated forest human intervention can ensure improved survival and growth. In Borneo, particularly in Sabah there are approximately 3000 known tree species, the dipterocarps are dominant in terms of numbers as well as biomass. However, these are also the most sorted out timber species and are being removed *via* logging (Ashton & Kettle, 2012). Therefore, Dipterocarps are most in need of support during restoration because these are usually late successional, shade tolerant hard-woods and referred to as climax species (Whitmore & Burnham, 1975).

In early 1980s, logged and partially degraded Kalabakan Forest Reserve was destroyed by forest fire during the drought season affecting Borneo (Walsh, 1996). The once a complex structure of forest, now become a simpler structure. Hence, in June 1998, Innoprise Corporation of Sabah and Sow-A-Seed Foundation of Sweden signed a Memorandum of Agreement to collaborate in a forest rehabilitation project (INIKEA project) in Kalabakan Forest Reserve within the Yayasan Sabah Concession area. The project area was severely damaged during the drought in early 80's and because of the log extraction a few years later. The aim of the project is to improve the biodiversity in the forest. Sow-A-Seed Foundation provides financial assistance and Innoprise Corporation implements the project. Sow A Seed Foundation with the assistance of Yayasan Sabah started an initiative to regenerate the destroyed forest area. An approximately 14,000 ha was replanted with varieties of Dipterocarp seedlings, in addition two different planting techniques were utilized. Seedlings for this initiative was generated from wild seeds collected from the primary forest in this vicinity.

1.2 Dipterocarps

Tropical rainforest has been recognized as one of the ecosystems that contains highest biodiversity, making it also as one of the fragile ecosystem in the world. Rainforest in Malaysia can be divided into montane and lowland, depending on the influences of geography, climate and ecology. Rainforests in Malaysia are dominated by trees from the family *Dipterocarpaceae*, thus, rainforests in Malaysia is also often called as Dipterocarp forest (Lee *et al.,* 2001). Dipterocarps are also the preferred hard wood in the global timber market, and the main producers are in the South East Asian countries such as Malaysia and Indonesia (Poore, 1989). Timbers derived from Dipterocarps are the preferred material for home furnitures, building construction and compressed wood industries. Due to the demand and price, Dipterocarps have been over harvested that has led to forest degradation and decline in forest ecosystem services.

Dipterocarps are very resilient forest trees and can live in a wide variety of habitats due to their ability to adapt to certain environment variance such as coastal, swamp, dry land, even in poorly drained and poor in nutrients habitats. Some cases as can be seen in Peninsular Malaysia the main habitats can be divided into several altitudinal zonation ranges form 0-300 m, 300- 750 m and 750- 1200 m. Type of Dipterocarp forest also varies by altitudinal zonation from low-undulating Dipterocarp forest, hill Dipterocarp forest and upper Dipterocarp forest. However, in Borneo the zonation is differ when part of freshwater swamps that is drier are rich in species compared with true peat-swamp that is poor in species. The level of species richness can also be seen to be low on limestone and riverine fringes. In INIKEA project area, numerous dipterocarps species have been planted and naturally regenerated from wild seedlings during mass fruiting. According to Backlund (2013), at least a total of 119 Dipterocarps are known to exist in the INIKEA replantation

1.3 Lichen

Lichen are very resilient as they are formed through symbiosis between a fungal and algae or cyanobacteria that acted as a photosynthetic partner. Fungus needs carbohydrates to stay alive and that needs are met by the photobiont through photosynthesis, and in return fungus helps to extend the ecological and geographical range of the photobiont. (Pinokiyo *et al.,* 2006). Although lichens are frequently associated with cool temperate, humid-climate, they are also found in abundantly in the tropics due to the humid nature of our ecosystem and abundance of sunlight. Lack of information on the lichen diversity and their impact in the tropical rainforest is due to the lack of interest to study their function in our forest. Not much is known and this investigation could be considered as one of the few that attempts to better associate certain functional roles of lichen in the Dipterocarp forest on Sabah.

1.4 Herbivory

Plants and herbivores make up to about 50% of the organisms on earth, their interactions have profound implication on both ecological function and evolutionary process. These interactions are particularly important in the tropics, where strong reciprocal selection by both plants and herbivores has led to the higher rates of herbivory and greater investment in defences in the tropics as compared to the temperate region (Levin & York, 1978, Basset, 1994, Kursar & Coley, 2003). Plants and insects have been co-existed for millions of years and has been undergoing co-evolutionary to avoid each other's system of defence mechanisms. Plants have in the course of evolution developed an elegant defence system where they can detect any foreign molecules or signals from damaged cells and automatically activates the plant immune response against herbivores. Plants that colonized by herbivores may suffer from physiological stress (Cornelissen and Stiling, 2010). Herbivory also affects the fitness of the plants, development of leaves by influencing the pattern of growth and the expansion of leaf blades. Plants react to the herbivory through various morphological, biochemicals and molecular mechanism to inhibit the herbivore attack or the effects. By producing secondary metabolites that can repellent or antinutritional effects on the herbivores are the way for the plant to counterattack the herbivore (War et al., 2012). Host plant either will goes in direct defence or indirect defence to confront the herbivore. Direct defence are done by changing the plant characteristics such as thorns that can affect the way of herbivore's biology. Indirect defence mediated by releasing volatiles that can attract the natural enemies of the herbivores.

1.5 Justification

Present research was carried out to accumulate basic data on two important aspect that is seen as interaction of biofoulers and herbivores with the planted Dipterocarp plants; 1) diversity of lichen on different substrates of Dipterocarp leaves, and 2) Extent of leave herbivory on Dipterocarp leaves. It also takes into account the age of the leaf and the extent of biofouling and herbivory. Research such as this is still lacking in the Tropical Rainforest of South East Asia, there is a lack of understanding

on the diversity of foliicolous lichen in Sabah, Malaysia and to add more information of herbivory on the Dipterocarp leaves. Information pertaining to these two aspects being investigated in this study will provide important knowledge to foresters as to the type of Dipterocarp that is more resilient to lichen biofoulers and herbivory. Data from this study will assist foresters in general and foresters in INIKEA to better plan and manage their nursery and reforestation project for better outcome and regeneration of the degraded forest.

1.6 Research Objectives

The objectives of this study are;

1) To identify and document the diversity of foliicolous lichens (biofoulers) on five main species of commonly planted dipterocarps in INIKEA plots
2) To analyse the changes in chemical profile between uncolonized (lichen) and colonized (lichen) leaves
3) To document the extent of leave-loss due to herbivory in the five main species of planted in INIKEA

CHAPTER 2

LITERATURE REVIEW

2.1 INIKEA

After the forest fire hit Sabah during the late 1982 and early 1983 due to the prolonged drought, the effects are devastating (Walsh, 1996). The rain forest that was a complex structured became a simpler forest structure with fewer plant species. Some bigger trees suffered partial damage in the trunk and survived. Pioneer tree and vines started to infest the area that is badly burnt. Most of the surviving larger trees interspersed the continuous canopy of mostly *Macaranga.* The regeneration of the primary species varies depending on the surviving mother trees to disperse the seed and create more offspring in order to replace the damaged trees.

In the year 1983 after the devastating tragedy happened in the rainforest of Sabah, one Memorandum of Agreement (MoA) had been signed by Innoprise Corporation of Sabah and Sow-A-Seed Foundation of Sweden to collaborate in a forest rehabilitation project (INIKEA project) in Kalabakan Forest Reserve within the Yayasan Sabah Concession Area. The aim of the project was to improve the biodiversity in this forest that had been severely damaged during the drought followed by log extraction a few years later.