



# **Growth of Agarwood (*Aquilaria malaccensis*) in Enriched Soils at Pulau Banding, Perak.**

by

**NURUL HADIRAH IZZATI BINTI KHIRROLNIZAM**

A report submitted in fulfillment of the requirements for the degree of  
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Honours

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2024

## DECLARATION

I declare that this thesis entitled “The Growth of Agarwood (*Aquilaria malaccensis*) In Enriched Soil at Pulau Banding Perak” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



**Signature :**

**Name :** Nurul Hadirah Izzati binti KhirrolNizam

**Date :** 21 August 2024

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## The Growth of Agarwood (*Aquilaria malaccensis*) In Enriched Soil at Pulau Banding ,Perak

### ABSTRACT

*Aquilaria malaccensis*, sometimes referred as "Gaharu," is well-known for its aromatic and extremely precious heartwood. Indicated by Red list, classified that these species as vulnerable base on the reduction about 20% over three generation cause by levels of exploitation and declined in population. However, knowledge on the potential of enriching the *A. malaccensis* using amendments is limited and less sources done. Therefore, this study aims to evaluate the growth response of Agarwood (*Aquilaria malaccensis*) before and after soil enrichments and to study interaction between growth and soil properties of Agarwood. Twenty-two samples of *Aquilaria malaccensis* tree were selected across three plots which were control (C), insect-frass amended soil (IF), and agarwood debris amended soil (D). The measurement of growth response in term of plant height, stem diameter, leaf number and soil properties (soil pH, temperature, and water content) were taken prior to enriched soil application and denoted day -11 and after the treatment application. Prior to treatment application, the stem diameter, plant height, and leaf number of *A. malaccensis* at the control plot (C) were already higher (1.2, 1.6, 116) as compared to plot IF and plot D. However, two months after the fertiliser application, *A. malaccensis* soil treated with agarwood debris showed positive response as compared to insect frass. The soil pH, moisture, and temperature data provide insights into the growing conditions and may have influenced the plant growth observed in the experiment.

# **Pertumbuhan Gaharu (*Aquilaria malaccensis*) Dalam Tanah yang Diperkaya di Pulau Banding, Perak**

## **ABSTRAK**

*Aquilaria malaccensis*, kadang-kadang dikenali sebagai "Gaharu," terkenal dengan kayu terasnya yang harum dan sangat berharga. Menurut Senarai Merah, spesies ini diklasifikasikan sebagai terancam berdasarkan pengurangan sekitar 20% dalam tiga generasi akibat tahap eksploitasi dan penurunan populasi. Walau bagaimanapun, pengetahuan mengenai potensi memperkaya *A. malaccensis* menggunakan pindaan adalah terhad dan kurang sumber yang dijalankan. Oleh itu, kajian ini bertujuan untuk menilai tindak balas pertumbuhan Gaharu (*Aquilaria malaccensis*) sebelum dan selepas pengayaan tanah serta mengkaji interaksi antara pertumbuhan dan sifat tanah Gaharu. Dua puluh dua sampel pokok *Aquilaria malaccensis* dipilih di tiga plot yang terdiri daripada plot kawalan (C), tanah yang dipinda dengan serangga (IF) dan tanah yang dipinda dengan serpihan gaharu (D). Pengukuran tindak balas pertumbuhan dalam bentuk ketinggian tumbuhan, diameter batang, bilangan daun dan sifat tanah (pH tanah, suhu, dan kandungan air) diambil sebelum pengayaan tanah dan ditandakan sebagai hari -11 dan selepas aplikasi rawatan. Sebelum aplikasi rawatan, diameter batang, ketinggian tumbuhan, dan bilangan daun *A. malaccensis* di plot kawalan (C) sudah lebih tinggi (1.2, 1.6, 116) berbanding dengan plot IF dan plot D. Walau bagaimanapun, dua bulan selepas aplikasi baja, tanah *A. malaccensis* yang dirawat dengan serpihan gaharu menunjukkan tindak balas positif berbanding dengan serangga. Data pH tanah, kelembapan, dan suhu memberikan pandangan mengenai keadaan pertumbuhan dan mungkin telah mempengaruhi pertumbuhan tumbuhan yang diperhatikan dalam eksperimen ini.

## TABLE OF CONTENT

	PAGE
<b>ACKNOWLEDGEMENT</b>	i-ii
<b>ABSTRACT</b>	iii
<b>ABSTRAK</b>	iv
<b>TABLE OF CONTENTS</b>	v-vii
<b>LIST OF TABLES</b>	viii
<b>LIST OF FIGURES</b>	ix-x
<b>LIST OF ABBREVIATIONS AND SYMBOLS</b>	xi
<b>CHAPTER 1 INTRODUCTION</b>	
1.1 Background of Study	1-3
1.2 Problem Statement	3
1.3 Objective	4
1.4 Scope of Study	4
1.5 Significance of Study	4-5
<b>CHAPTER 2 LITERATURE REVIEW</b>	
2.1 Tropical Rainforest	6-7
2.2 Royal Belum State Park	7-8
2.3 Characteristic of <i>Aquilaria malaccensis</i>	9
2.4 Morphology of <i>Aquilaria malaccensis</i>	9
2.4.1 Leaf Morphology	10
2.4.2 Fruits Morphology	10-11
2.4.3 Seed Morphology	11
2.4.4 Resin Production	11
2.5 <i>Aquilaria</i> Species	12-16
2.6 Enriched Soil	16-17
2.7 Insect Frass	17-18
2.8 Agarwood Debris	18
2.9 Soil Bulk Density	18-19
2.10 Grow Response	19
2.11 Significant of Agarwood	19-20

**CHAPTER 3 MATERIAL AND METHOD**

3.1	Study Area	21-23
3.2	Material	23 -24
3.3	Method	24
	3.3.1 Sample of <i>Aquilaria malaccensis</i>	24
	3.3.2 Experimental Design	25
	3.3.3 Data Collection	25-26
	3.3.4 Growth of <i>Aquilaria malaccensis</i>	26
	3.3.5 Soil Analysis	27
	3.3.6 Soil Bulk Density	27- 30
3.4	Water Content	31
3.5	Statistical Analysis	31

**CHAPTER 4 RESULT AND DISCUSSION**

4.1	Overall Growth of <i>A. malaccensis</i> and Soil Condition	32-33
4.2	Non- Parametric Data Results for Kruskal Wallis- Test (Response x plots)	33- 34
	4.2.1 Overall Median for Tree Growth Parameters across plots	35
	4.2.2 Overall Median Soil Parameters across plots	36
4.3	Growth of Tree and Change in Soil Parameters over the Days	37
4.4	Tree Graph Parameters and Soil Parameters within plots	38
	4.4.1 Tree Parameters Graph Within Plots	38
	4.4.2 Soil Parameters Graph Within Plots	39
4.5	Soil Organic Matter and Soil Gravvimetric Water Content	40-41
4.6	Overall Correlation of tree Growth Parameters and Soil Properties	41
4.7	Correlation between Plant Growth and Soil Properties within Each plot	42

4.7.1 Plot Control (C)	42
4.7.2 Plot Insect Frass (IF)	42
4.7.3 Plot Agarwood Debris (D)	43
<b>CHAPTER 5 CONCLUSION AND RECOMMENDATION</b>	
5.1 Conclusion	44-45
5.2 Recommendation	46
<b>REFERENCES</b>	47-50
<b>APPENDIX A</b>	51-58
<b>APPENDIX B</b>	59-63

## LIST OF TABLES

NO	TITLE	PAGE
Table 2.1	<i>The genus of Aquilaria spp in Malaysia</i>	14-16
Table 2.2	<i>Aquilaria spp</i> Morphology (leaf, flower, seed, and fruit)	15-16
Table 3.1	Organic amendments of insect frass and agarwood debris organic matter and water Content.	28
Table 4.1	Overall Growth of <i>Aquilaria malaccensis</i> and Soil Condition	32
Table 4.2	soil organic matter and soil gravimetric water content before the application (day 0) on organic armament within sampling plot at Pulau Banding, Perak.	40

## LIST OF FIGURES

NO	TITLE	PAGE
Figure 1.1	<i>Aquilaria malaccensis</i> species	2
Figure 3.1	Location of UMK TRaCe Tasik Banding, Perak	21
Figure 3.2	Distribution <i>A. malaccensis</i> at Agarwood plantation plot in a) Vertical and b) Horizontal View at Pulau Banding, Perak	22
Figure 3.3	<i>A. malaccensis</i> population and area calculation at study area Pulau Banding, Perak	23
Figure 3.4	Sampling plot design and distribution of <i>A. malaccensis</i> at each treatment plot	24
Figure 3.5	Measuring plant growth parameter and soil properties	26
Figure 3.7	Agarwood Debris Fertilizer and Insect Frass Fertilizer Structure	29
Figure 3.6	Soil sample of <i>A. malaccensis</i> species population being measured	27
Figure 4.1	Overall median of tree growth parameters a) stem diameter, b) height c) leaf number across plots	
Figure 4.2	Median of tree growth parameters (a) stem diameter, (b) height and (c) leaf number across plots.	35

Figure 4.2	overall median Soil parameters a) soil pH, b) soil moisture c) soil temperature between plot.	35
Figure 4.4	overall tree growth parameter (a) stem diameter, (b) height and (c) leave number within plots.	38
Figure 4.4	overall tree growth parameter a) stem diameter, b) height c) leave number within plots.	
Figure 4.4	Overall Soil Parameters (a) Soil pH, (b) Soil Moisture and (c) Soil Temperature within plots.	39

**LIST OF ABBREVIATIONS AND SYMBOLS**

<b>NO</b>	<b>SYMBOLS</b>
Percentage	%
Organic Matter	(OM)
ANOVA	Analysis of Variance
IUCN	International Union Conservation status
Spp	Species
<i>A.malaccensis</i>	<i>Aquilaria malaccensis</i>
IF	Insect Frass
D	Agarwood debris
C	Control

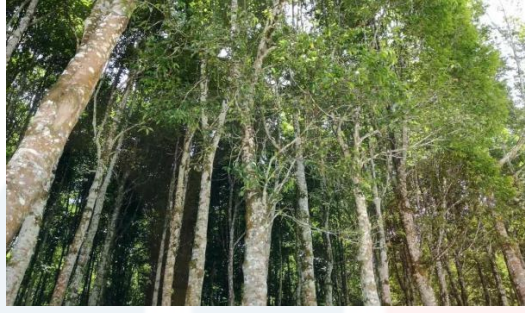
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## CHAPTER 1

### INTRODUCTION

#### 1.1 Background of Study

*Aquilaria malaccensis*, sometimes referred to as "Gaharu," is well-known for its aromatic and extremely precious heartwood (Hamzah et al, 2021). *A. malaccensis* is one of *Aquilaria* species that under Thymelawaceae family that have a very highly valuable and high demand which is very famous among other *Aquilaria* species. Based on the evidence presented, it can be inferred that, *A. malaccensis* stands out as the most prevalent among the five species belonging to the *Aquilaria* genus in Peninsular Malaysia, as highlighted by (Chua et al, 2011) and widely recognized tree species across southeast Asia, predominantly prevalent in Malaysian forest. Among various species, the 'Karas' variant holds substantial commercial value, as highlighted (Adam et al., 2012). However, Indicated by Red list, classified that these species as vulnerable based on the reduction about 20% over three generations caused by levels of exploitation and declined in population (Barden et al., 1000; Hilton-Taylor, 2002).



**Figure 1.1:** *Aquilaria malaccensis* species (source: Goole Image)

Highly prized for its resinous wood which is called Resin. Resin product that sought after primarily for its unique fragrance and for a variety of uses including religious, cultural, and medicinal purpose (Zuhaidi et al., 2018). Species that native to Malaysia, predominantly habitat found across East Asia, spanning from northeast India through Myanmar, Malaysia, Indonesia and the Philippines. Widely recognized tree species across southeast Asia, predominantly prevalent in Malaysian forest. Declared by (Swee &Chua, 2008) *A. malaccensis* is found in the phytogeographical regions of Borneo, Peninsular Malaysia, Sumatra, India, Myanmar, and the Philippines. The species is widespread, although its density is modest. While other species in this genus are said to be generally scarce, *A. malaccensis* is not found in Sarawak (Tawan 2004). The plant *Aetoxylonsympetalum*, which is the source of Gaharu, was reported to be reasonably abundant across the State (Tawan 2004) and locally frequent in the heath forests of west Sarawak (Anderson 1980). In Sabah, *Aetoxylonsympetalum* does not exist.

Furthermore, there were two major market regions for Agarwood consumption which are north-east Asia comprising the market of Taiwan, Japan and the Republic of Korea and the region of the west Asia or the “Middle East” which centers on the countries of the Arabic Peninsula (Antonopoulsu et sl., 2010). Therefore, Due to its social importance and economic value, the over-harvesting of Agarwood has resulted

in *A. malaccensis* being listed as vulnerable in the International Union for Conservation of Natural (IUCN) Red List of threatened Species (IUCN, 2017) and the genus included in Appendix II of the Conventions on international Trade in Endangered Species of Wild Fauna and Flora (CITES, 2017).

## 1.2 Problem Statement

*Aquilaria malaccensis* species have slow growth rate which can make cultivation a lengthy process and its take many years for tree to mature. Usually, the average time that take by the tree to mature and ready to harvest is nine years. A study by Sumardi (2009) stated that if replanting and transplant is being done in Gaharu tree, the success rate is about 80% of planted *A. malaccensis*. Since 2018, *A. malaccensis* being listed as vulnerable in the IUCN Red List of threatened OF Threatened Species (IUCN, 2017) and the genus included in Appendix II of the conservation on International Trade in Endangered Species of Wild Fauna and Flora. (CITES, 2017). Moreover, A study by (Adam et al. 2012) reported that the population of *A. malaccensis* is decreasing due to uncontrollable logging activities that are difficult to curb while replanting initiatives are less done, which make the species this is threatened with extinction. Additionally, there were not many studies have been down on accelerating *A. malaccensis* tree growth, the sources are scarce and limited in term of knowledge. There are few reports on effective *Aquilaria* cultivation methods and management, and extensive research is desperately needed, *paticularly* related to *A. malaccensis*. Due to lack of information and research finding on this *Aquilaria malaccensis* this study aims to study growth of *A. malaccensis* in enriched soil and the correlation between soil properties to plant growth rate.

### 1.3 Objectives of Study

The objective of this study are as follows

1. To evaluate the growth response of *Aquilaria malaccensis* before and after soil enrichments at Pulau banding, Gerik Perak.
2. To examine the interaction between growth and soil properties of *Aquilaria malaccensis* at Pulau Banding, Gerik, Perak.

### 1.4 Scope of Study

This study will be focusing on the growth response of *Aquilaria malaccensis* in terms of diameter of stem, height and the tree fertility following the application of soil enrichment and its interaction with the soil properties. Hence, this research wants to investigate the result of the soil properties after administering enriched soil in the *A. malaccensis* tree like soil pH, temperature and water content.

### 1.5 Significance of Study

Previous study has demonstrated that growth response of *Aquilaria malaccensis* correlated with soil amendments. However, little is known regarding its growth interaction with the environment, especially soil condition. Therefore, the significance of this *A. malaccensis* research is to evaluate how enriched soil properties affect the development of Agarwood tree. This research is to estimate and analysis the change that happens on the 'Gaharu' tree after applying the treatment. The change in height, stem diameter, tree health weather the tree is grow healthier after being apply the treatment. This this research is being done to observe and analyze a way to

promote faster growth and development of Agarwood tree. To observe how to grow a high quality and healthy tree by applying cultivation techniques like soil enrichment and tree management. Furthermore, due to the lack of research conducted on this Agarwood tree species, this research can be beneficial by provided the information and knowledge about Agarwood tree to researcher, scientist or also to student that interesting on Agarwood tree study.

## CHAPTER 2

### LITERATUL REVIEW

#### 2.1 Tropical Rainforest

Rainforest comprises towering, predominantly evergreen trees and receives abundant rainfall. Rainforests represent the planet's most ancient ecosystems, some persisting in their current state for over 70 million years. They exhibit remarkable diversity and intricacy, hosting over half of the world's plant and animal species, despite covering merely six percent of Earth's surface. Consequently, rainforests are exceptionally rich in both plant life and wildlife (Rainforest, n.d.) While some research has stated that tropical rainforest was lush forests thrive in moist tropical regions both in highlands and lowlands near the Equator. These tropical rainforests constitute one of the planet's vastest biomes, characterized by an abundance of broad-leaved trees forming a dense canopy and supporting a wide variety of plant life and ecosystems (Smith, 2024b). From (MyGov - *the Government of Malaysia's Official Portal*, n.d.-b) Malaysia Peninsular Malaysia's forested areas are primarily comprised of tropical rainforests, characterized by a layered structure. This includes a lower layer with slender trees, a middle layer forming the main canopy, and vegetation covering the forest floor. The slender trees in the lower layer can reach heights of 60m to 70m and are from the Dipterocarpus and Leguminosae families, known for commercially valuable timber species. The rainforests in

Malaysia can be categorized into mixed forests, like the dipterocarp forest, which feature diverse plant species, and single dominant forests, such as the lime single dominant forest, which are dominated by specific species like *Dryobalanops aromatic*. Based on elevation, these forests are further classified into various types, including flat dipterocarp forests, hill dipterocarps forests, top dipterocarps forests, oak forests, and mountain ericaceous forests. These forests cover a vast land area, comprising 44% of Peninsular Malaysia's total land area, with a significant portion designated as forest reserves. Malaysia's rainforests support a rich biodiversity, including over 17,000 plant species and numerous animal species. This includes iconic species like orangutans, tigers, and elephants. Malaysia is recognized as one of the world's mega-biodiversity countries and has implemented policies like the National Biodiversity Policy to conserve its biodiversity.

## **2.2 Royal Belum State Park**

The data presented by United Nations Educational, Scientific and Cultural Organization World Heritage Convention (UNESCO) stated that Royal Belum State Park in Perak, Malaysia, originally designated as the Belum Forest Reserve in 1971, attained the prestigious status of a State Park in 2007 under the Perak State Park Corporation Enactment 2001. This transformation was reinforced by its gazettelement under the Perak State Forestry Enactment and its recognition as a National Heritage Site in 2012, marking the pinnacle of governmental acknowledgment. In the 1970s, the ecological significance of the Belum Forest Reserve garnered recognition for biodiversity conservation, spurred by recommendations from authoritative reports like the Colombo Plan Report and initiatives outlined in the Third Malaysia Plan (1976-1980) and by the Department of Wildlife and National Parks, Peninsular

Malaysia (PERHILITAN) in 1988. Bordering Thailand's Halabala National Park to the north and the Malaysian state of Kelantan to the east, the Royal Belum State Park spans approximately 300,000 hectares, offering the potential for a transfrontier park (UNESCO, 2017). Gazetted in May 2007, the State Park is dedicated to biodiversity conservation, facilitating biodiversity education, research, and ecotourism. Accessible only by boat from the public jetty at Pulau Banding, it encompasses a total area of 117,500 hectares, encompassing pristine lowland dipterocarp, hill dipterocarp, and lower montane forests. As a relic of geological antiquity, the State Park, over 130 million years old, stands as a testament to the geological convergence of Gondwanaland and Laurasian supercontinents. Geographically, its terrain ranges from 80 to 1,533 meters above sea level, predominantly featuring metamorphosed marine sedimentary rocks from the Baling Group and Triassic granites, shaped by tectonic activities and igneous intrusions. This unique geological substratum fosters the diverse biodiversity found within the State Park. Meanwhile Pulau Banding is one of the islands located within Temengor lake in Royal Belum State Park. With the presence of suitable characteristics such warm daily temperature between twenty-two until 32 C, High humidity, and 300-1,533 m above sea level making its suitable habitat for plant species *Aquilaria malaccensis* to be development. Being one of the most high demand source will lead to threatened to extinction due to uncontrollable logging, overused sourced while replanting was less done. Listed under International Union Conservation Nature (IUCN) the endeavour to conduct research on this issue is undertaken by researchers to proactively mitigate its occurrence.

### 2.3 Characteristic of *Aquilaria*

*A. malaccensis* is a tropical tree which has a warm climate year-round, grows over high rainfall tract throughout humid regions. This region low in temperature variation 20- 28 and humidity between 80%, grow over sandy loam and the soil preference slightly acidic soil (Vikaspedia Domains, n.d.) furthermore, in some study, *A. malaccensis* typically found in the plains of both primary and secondary forest habitats. Additionally, it thrives on hillsides and ridges, reaching altitudes up to 750 meters. The tree's distribution ranges from the Indian subcontinent to Myanmar, the Malay Peninsula, Borneo Island, and the Philippines (Sarmah et al., 2022). According to Hamzah et al. (2021), *A. malaccensis* have the capacity to grow to a height of 49 meters but it typically has a smaller stature, reaching approximately 20 meters. They are thriving within the temperatures of 20 - 22°C (Barden, 2000), and usually can grow up to 850 m (Keller, 1994). The stem diameter can be grown up to 60 cm. Whereas, a research by (M.Norwati, 2018) stated that *A. malaccensis tree* can reach up to 36 m in height and 180 cm of girth barks , (Ali et al., 2016) stated *A. malaccensis tree* thrives on hillside and ridges, with a height reach up to 20 - 40 meters at altitude of up to 750 meters and the steam diameter can go up to 150 cm. The bark color was grey, smooth and on the old tree becoming finely and irregularly. It can be easily stripped from the stem. The inner bark is soft and creamy white

## 2.4 Morphology of *Aquilaria malaccensis*

### 2.4.1 Leaf Morphology

The leaves of *Aquilaria malaccensis* exhibit an oblong, lanceolate, or vent elliptic shape, characterized by a caudate and acuminate tip. They are glabrous with slender nerves. The color of the leaves is vibrant green, and their size ranges from two to five centimeters in length.

### 2.4.2. Fruits Morphology

Stated by (Hou 1960) *Aquilaria malaccensis* flower is relatively small (5 to 6 mm long) and white in color. It is bell shaped with calyx lobes usually as long as the calyx tube, filamentous stamens, and a densely pubescent ovary with a sessile stigma. The flowers are arranged in terminal inflorescences, which usually branched with 2 to 3 umbels (Zuhairi et., al 2018). The flower has five calyx lobes that are densely ouberulous within. There was an interesting fact about *Aquilaria malaccensis* flower, the flower will commence early in the morning when the stigma becomes receptive then the stigma receptive until late afternoon round 1800 h. the dehiscence of the anthers begins around 1200h, which means self-pollination can only occur after this hour.

Ideally, to be know that *Aquilaria malaccensis* fruit whether it is mature, or immature is a mature fruit, it is green to yellowish in colour while immature fruit are green in colour. *Aquilaria* fruits can be described as having a bivalve loculicidal capsule, obovoid, compresses

laterally, base enclosed by persistent calyx, pericarp leather and warty, brownish pale green with simple colourless hairs (Mandakranta & Datta 2014).

### **2.4.3 Seed Morphology**


The seeds are usually one or two in one fruit and the seed shape is ovoid, having dark brownish to blackish color and tail covered with dense brownish-colored (Nashatul Zaimah et al.,2005).

### **2.4.4 Resin Production**



In the Agarwood stick, there is a liquid called resin. This resin is a point of departure that makes the Agarwood tree a very useful resource. (Adam et al., 2012) Resin is Phyto-alexin, which is produced as a response to an injury by the plant tissue that is formed in the core and root part of the Agarwood tree. Normally, the natural formation of resin takes a long time, i.e. The resin is produced over a period of 20 years or more. The resin was fragrant heartwood, basically This resin is saturated with aromatic compounds, which gives it a distinctive and pleasant fragrance. The scent of agarwood resin is often described as woody, sweet, balsamic, and complex. It is highly valued in the perfume industry for its unique and alluring fragrance. Due to its social importance and economic value, the over-harvesting of agarwood has resulted *in A. malaccensis* being listed as vulnerable in the IUCN Red List of threatened Species (IUCN 2017) and the genus included in Appendix II of CITES (CITES 2017).


**2.5 Aquilaria Species**

The family of *Aquilaria* is Thymelaeaceae., There are several common species from the genus of *Aquilaria* in Malaysia such as *A malaccensis*, *A. hirta*, *A. rostrata*, *A. beccariana* and *A. macrocarpa*.

<i>Scientific Name</i>	Habitat	Characteristic
 <p data-bbox="464 1384 628 1487"><i>Aquilaria malaccensis</i></p>	<p data-bbox="794 801 1102 1055">Found throughout Peninsular Malaysia, Sabah and Sarawak except Kedah and Perlis</p>	<p data-bbox="1203 801 1342 1200">Height around 49 meters tall and 60 cm diameter stem</p>




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 <p><i>Aquilaria hirta</i></p>	<p>The entire east coast, Terengganu, Pahang and Johor</p>	<p>Small tree in the range of 15m high</p>
 <p><i>Aquilaria rostrata</i></p>	<p>Noted in Pahang (Mount Tahan), mountainous areas.</p>	<p>Height about 2 to 5 meters, between 3 and 4 centimeter in circumference</p>
 <p><i>Aquilaria beccariana</i></p>	<p>Mostly grow in the southern part of the peninsula (Johor)</p>	<p>A medium-sized tree with a diameter of around 20 cm</p>

	<p>Johor and mangrove area</p>	<p>a large tree with a diameter of 36 cm, with heart-shaped fruit</p>
<p><i>Aquilaria microcarpa</i></p>		

**Table 2.1** The genus of *Aquilaria* in Malaysia

Source: (<http://Gaharu-pertanian.blogdrive.com/>)

Species	Character	Leaf	Flower	Seed	Fruits
 <p><i>Aqularia malaccensis</i></p>	<ul style="list-style-type: none"> <li>● 49 metre tall</li> <li>● 60 cm diameter</li> <li>● Bark grey colour and smooth</li> </ul>	<ul style="list-style-type: none"> <li>● Oblong, lanceolate or elliptic, caudate, acuminate and glabrous with slender nerves</li> <li>● 2-5 cm</li> </ul>	<ul style="list-style-type: none"> <li>● White Light-yellow</li> <li>● Bell shaped with calyx lobes (5mm long)</li> </ul>	<ul style="list-style-type: none"> <li>● Browish to blackish colour</li> <li>● Ovoid shaped</li> </ul>	<ul style="list-style-type: none"> <li>● Green to yellowish colour</li> </ul>
 <p><i>Aqularia hirta</i></p>	<ul style="list-style-type: none"> <li>● 40 metre tall</li> <li>● Bole - 80 cm</li> <li>● Bark grey colour</li> </ul>	<ul style="list-style-type: none"> <li>● Hairy leaves at the base and slightly rusty</li> </ul>	<ul style="list-style-type: none"> <li>● Yellow white</li> </ul>	<ul style="list-style-type: none"> <li>● Black and ovoid shaped (5mm)</li> </ul>	<ul style="list-style-type: none"> <li>● Greenish outside</li> </ul>
 <p><i>Aqularia rostrata</i></p>	<ul style="list-style-type: none"> <li>● Long beaked caosule</li> <li>● 2-5 m tall</li> <li>● 15 cm diameter</li> </ul>	<ul style="list-style-type: none"> <li>● Shining on both surface</li> <li>● Elliptic or lanceolate, rarely ovate-oblong</li> <li>● 6.5-14 cm</li> </ul>	<ul style="list-style-type: none"> <li>● Greenish outside and obovoid shaped</li> </ul>	<ul style="list-style-type: none"> <li>● Brownish colour and ellipsoid shaped (4-7mm)</li> </ul>	<ul style="list-style-type: none"> <li>● Green outside</li> <li>● Obovate, obovate shaped</li> <li>● 0.75-1.5 cm</li> </ul>

 <p><b><i>Aquilaria beccariana</i></b></p>	<ul style="list-style-type: none"> <li>● 28 m</li> <li>● 91 cm diameter</li> <li>● Grey and smooth bark</li> </ul>	<ul style="list-style-type: none"> <li>● leaves hairy below the base and slightly rusty</li> </ul>	<ul style="list-style-type: none"> <li>● Greenish-yellowish</li> </ul>	<ul style="list-style-type: none"> <li>● Black colour</li> <li>● Ovoid shaped</li> <li>● 5mm</li> </ul>	<ul style="list-style-type: none"> <li>● Ellipsoid /obovoid shaped</li> <li>● 1.75 cm</li> </ul>
 <p><b><i>Aquilaria microcarpa</i></b></p>	<ul style="list-style-type: none"> <li>◆ Bark grey</li> <li>◆ 40 metre tall</li> </ul>	<ul style="list-style-type: none"> <li>◆ Shining and glabrous</li> </ul>	<ul style="list-style-type: none"> <li>◆ White light-yellow</li> <li>◆ 5mm long</li> </ul>	<ul style="list-style-type: none"> <li>◆ Densely brownish pubescent</li> <li>◆ Seed ovoid</li> <li>◆ 6 by 4 mm</li> </ul>	<ul style="list-style-type: none"> <li>◆ Densely brownish pubescent</li> <li>◆ Caruncle-like</li> <li>◆ 2mm</li> </ul>

**Table 2.2:** *Aquilaria spp* Morphology: Leaf, Flowers, Seed, and Fruits

Source: Google

## 2.6 Enriched Soil

Plant development largely depends on the combination and concentration of mineral nutrients available in the soil. Plants often encounter considerable obstacles in securing a satisfactory provision of essential nutrients to satisfy the needs of fundamental cellular processes, primarily because of their inherent lack of mobility (Morgan et., al 2013). Due to that, enriched soil was required to improve the plant development and fertility to increase the nutrient uptake. Enriched soil is processed to Increasing soil quality. A vital element in the growth of lush, healthy lawns and

landscapes is fertile soil. Regular watering is more successful when the soil is enriched because it increases root penetration and soil water retention. It lessens harmful soil salts from the root zone, enhances soil aeration, and lessens thatch buildup (Bbomi, 2023). Moreover, nutrient aspects must be present in sufficient and balanced amounts for optimal plant growth. Related to that, fertilizers are formulated to complement the nutrient already in soil and the enriched soil has advantages to promote faster growth as nutrient supply. Previous research on enhancing the growth of *A. malaccensis* has predominantly concentrated on the application of basic fertilizer regimes for conservation and restoration purposes (Lok E H & Ahmad Z, 2016). Based on (Hamzah, et al., 2021) Fertilizers are formulated to supplement the existing nutrients within the soil. Inorganic fertilizer, organic fertilizer, and biofertilizer each have their respective merits and drawbacks concerning nutrient provision, crop development, and ecological impact. Nevertheless, the potential benefits of using organic amendments to stimulate *A. malaccensis* growth and enhance soil properties are often underestimated due to their slower effects on plant growth and production rates.

## 2.7 Insect Frass

Insect Frass or called as insect larvae faeces or dejecta (IPIFF, 2024) is an organic fertilizer used to promote the plant growth and health. Frass, the residual material from insect breeding comprising spent feedstock, insect frass, and cuticles, has emerged as a promising fertilizer candidate within a circular economy framework, especially the type derived from *Hermetia illucens* breeding, boasting inherent chemical and agronomic traits that render it an exceptional biofertilizer without the need for pre- or post-treatments (Salomone et al., 2017). Insect frass harbors beneficial

bacteria that serve as microorganisms promoting plant growth, enhancing plant vitality, and aiding in nutrient absorption. With a noteworthy NPK profile (nitrogen, phosphorus, and potassium), it holds significant potential for repurposing as a fertilizing agent, such as an organic fertilizer, compost material, or soil enhancer. Additionally, frass could be harnessed for biogas production. Analogous to compost or conventional animal manure, frass contains essential nutrients, micronutrients, and chitin, which may stimulate the proliferation of beneficial soil bacteria. These attributes position frass as a valuable solution for farmers engaged in crop cultivation, including vineyard producers, as well as for gardeners throughout the EU, who can integrate insect frass into their fertilization methodologies (referencing the IPIFF contribution paper from September 2019).

## **2.8 Agarwood Debris**

Agarwood debris / waste is an organic fertilizer that came from the plant *Aquilaria malaccensis*. That was used as fertilizer to promote plant health and growth. Come from tree itself certainly occur the benefic and more suitable, which the best for the tree growth. There were no recorded data that used Agarwood waste as fertilizer to promote plant growth.

## **2.9 Soil Bulk Density**

Umara et al. (2022), Soil bulk density (SBD) is a basic physico-chemical characteristic of the soil, and this includes soil texture and structure, presence of organic matter etc. Normal ranges for soil bulk density were reported by Chaudhari et al. (2013) to be 1.0 to 1.6 mg/m<sup>3</sup> and 1.2 to 1.8 mg/m<sup>3</sup> for soil particles made of clay and sand, respectively, and > 1.4 mg/m<sup>3</sup> and ≥ 1.6 mg/m<sup>3</sup> as possible levels that might

limit root development in the corresponding media. According to Chaudhari et al. (2013), there is a substantial positive correlation between bulk density of soil and sand, and a negative correlation with clay. High levels of compaction cause plants to develop unevenly, produce poor quality and quantity of yield, late seed emergence, thin stands, poor seedling establishment, and uneven growth (Grzesiak et al. 2013).

### **2.10 Grow Responses**

Research made from 1928 to 1995; a comprehensive 67-year study was conducted by the Forest Research Institute Malaysia (FRIM) to observe the growth performance of *A. malaccensis* in Peninsular Malaysia. The research focused on this species, commonly found in lowland forests across Malaysia, Myanmar, Borneo, and other regions. A mature plant of this species can attain a height of up to 30 meters, featuring a trunk with flutes at the base. The findings of the experiment, conducted by (Hai and Yahya in 1996, revealed that ‘Karas’ trees exhibited an impressive overall diameter of 38.2 centimeters and an average height. of 26.7 meters. Additionally, according to (Ahmad Zuhaidi, 2016) stated that *A. malaccensis* tree species demonstrates rapid growing during its initial development particularly at age of five years old stand with mean annual increment diameter and height of 2.8 cm and 2.0 m respectively.

### **2.11 Significant of Agarwood**

There were a lot of benefits of *Aquilaria malaccensis*. Among its specialties is its use in terms of fragrance and medicine. Agarwood is frequently used in perfumery and for religious purposes, and it has been generally acknowledged for its many medical benefits (Naef 2011). In the perfume and cosmetics industry, Agarwood is

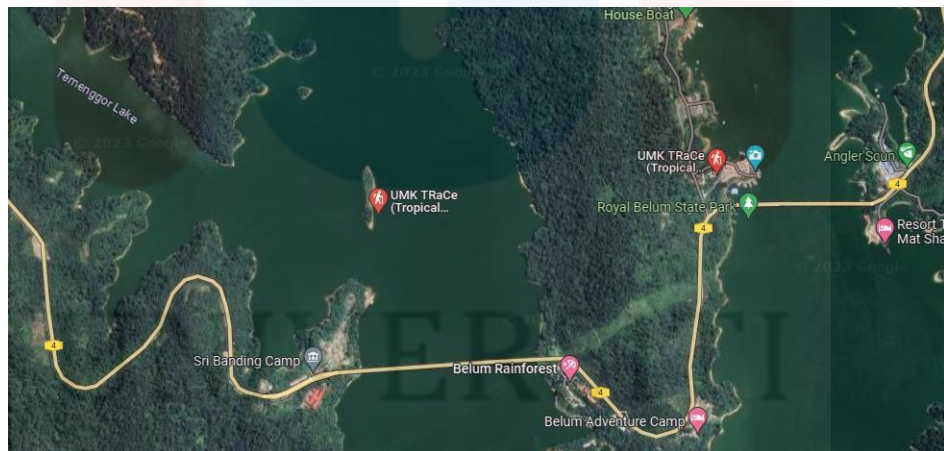
needed as a fixative, while in the health field, Agarwood is used as an herbal medicine that is safe too. Another that that, apart from “Gaharu” tree like roots, leaves and fruit are believed to be able to treat malaria, high blood pressure and diabetes. In the Agarwood stick, there is a liquid called resin. This resin is a point of departure that makes the Agarwood tree a very useful resource. This resin is saturated with aromatic compounds, which gives it a distinctive and pleasant fragrance. The scent of agarwood resin is often described as woody, sweet, balsamic, and complex. It is highly valued in the perfume industry for its unique and alluring fragrance. In other studies, there also show and state that, (Adam et al., 20120) Gaharu mint essence compound has many unusual compounds. Usually the compounds are sesquiterpenes, sesquiterpene alcohols, chromone derivatives, esters and resins, while agarospirol compounds, jinkolhol-eremol, jinkohol and kesenol are the most important compounds in agarwood oil. In addition, other compounds such as 2-(2-4'- methixpyphenylethyl) chromone are compounds that influence the fragrance of Agarwood to last longer during combustion (Adam et al., 2012).

## CHAPTER 3

### MATERIAL AND METHOD

#### 3.1 Study Area

This study was conducted at Agarwood Tree Plantation plot, Pulau Banding, (5°33'05.1"N 101°20'47.2"E), Gerik, Perak. The total area is 13152.56.ft. of the Pulau Banding (12,728.58 hectares). Forest areas cover 8,957.210 hectares or 66.26 percent of the total area. Other land uses include road/drainage (21.64 percent), rubber agriculture (10.9 percent), abandoned/vacant land (1.17 percent), and trade (0.03 percent)



**Figure 3.1** The location of UMK-TRaCe Tasik Banding Perak

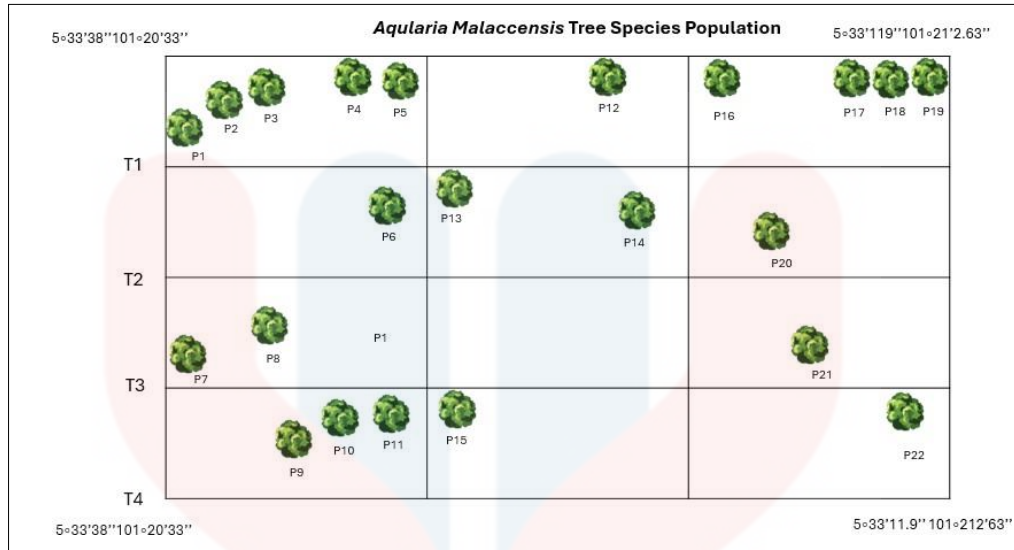
Source: Google Map



**Figure 3.2:** Distribution of *A. malaccensis* at Agarwood Plantation Plot in (a) Vertical and (b) Horizontal View at Pulau Banding, Perak. (Source: Google Earth Pro)



**Figure 3.3** *A. malaccensis* Population and Area Calculation (13152.56) at Study Area Pulau Banding, Perak



**Figure 3.4** Sampling Plot Design and Distribution of *A. malaccensis* at Each Treatment Plot

### 3.2 Materials

Materials used in this study are:

- DBH Tape: Measured tree trunk and tree height
- Takemura Electric Works: Measured soil pH and soil moisture parameters.
- Temperature Meter: Assess soil temperature
- GPS: Marking *A. malaccensis* tree species population coordinate and area calculation
- Caliper: Measures stem diameter
- Tagging: Label tree base on treatment applied
- Marker pen: Marking tree
- A4 paper: Data collection
- Clip Board: Paper backing

- Glove: Fertilizer application
- Wet Tissue: Cleaning pH meter tool
- Machete: Clean out the study area
- Water: watering the tree
- Watering Pot: To put water
- Sampling Bag: To Collect tree soil
- Soil Ring: Collect soil sample for analyses
- Trowel: Digging soil
- Organic fertilizer: Improved soil condition and promote tree development

### 3.3 Methods

#### 3.3.1 Sample of *Aquilaria malaccensis*

*Aquilaria malaccensis* is tree species that were used in this Research to study the impact of enriched soil effect on tree growth. Twenty-two samples of *Aquilaria malaccensis* tree were chosen to conduct this research. The *Aquilaria* species tree sampled were already being planted at back of Umk TRaCe, Pulau Banding, Perak at the same range time (2018) and location. Furthermore, the tree species were the same age range (1 years old), same species choose growth at the same environment and the tree also growth at the same time. The species' habitat is planted in hillside areas with very humid environments and warm temperatures. The habitat area was near water sources (Temenggor lake) and the habitat area is the world's oldest rainforest that surrounded with a variety of flora and fauna species.

### 3.3.2 Experimental Design

This study compared the effect of soil enrichment on the growth of Agarwood in agarwood plantation plot, Pulau Banding, Perak. This plot that has about 1000 Agarwood tree that being planted in the area 0.301184 hectare located at Pulau Banding (5°33'28''101°20'38''). Organic amendments were used in this research as main properties to observe the growth response on Agarwood tree. The Identification was made to determine the tree morphology, and habitat species. Twenty-two of *A. malaccensis tree* species (n =22) will be utilized at Pulau Banding, Perak. Three distinct plots of *A. malaccensis* were applied and each of the plot subjected to a different treatment. Each of the plot and *A. malaccensis* tagged based on the plots and treatment applied. The measurement of grow response in term of plant height, stem diameter, leaf number and soil properties (soil pH, temperature, and water content) intensity were taken prior to enriched soil application and denoted day -11 and a after treatment application. Continues to day -11, 1,7 and 70 after treatment application. As for soil bulk density, the soils sample will be collected three time as 11 days before, and the last day of sampling done.

### 3.3.3 Data Collection

Measures for plant growth (plant height, diameter of stem and leave number) and soil properties (soil pH, moisture and temperature were taken before and after application of soil treatment. The measurement change will be measured and recoded on day -11, 13 ,1 (only in soil parameter) and days seventy. The data will be collected throughout the month after to analysis and observe the responses, weather positive and negative response on plant growth following the application of soil amendments.



**Figure 3.5** Measuring Plant Growth Parameter and Soil Properties

### 3.3.4 Growth of *Aquilaria malaccensis*

The growth changes in the height, stem diameter, and leaf were count of *A. malaccensis* following the addition of organic amendments were indicative of their growth response. During the sample time, the plants' height was measured using a DBH tape and Calliper, starting from the base of the highest leaf on the plant and working our way up to the ground. Using a DBH tape to measure of diameter. On days -11, day 13 and 70 days after the plant height and stem diameter were measured.

### 3.3.5 Soil Analysis

To see the growth response and soil properties correlation, this soil analysis is being applied to see the factor that can affect the Agarwood tree growth. In this research, soil pH and temperature are being measured using handheld water-resistant pH meter for soil pH and pH electrode and temperature for Soil temperature. The process will be taken before the soil enrichment and will be taken two times every month for three months.

### 3.3.6 Soil Bulk density



**Figure 3.6** shows the soil sample of *A. malaccensis* Species Population

The presence of organic matter significantly influences almost all soil type properties, although it was usually found in relatively small quantities. Organic contains three distinctly different components as living organism, fresh residues and molecules derived from well-decomposed residues. Organic matter is heart of the soil properties as is positively impacts or alters Nearly all soil properties making the soil fertile and this is why it is crucial for understanding soil health and improving soil management (USDA Sustainable Agriculture Research and Extension, 2023). The

soil sample was collected on day (0) at the sampling site Pulau Banding, Perak with each of sampling plot Insect Frass (IF), Agarwood Debris (D) and Control (C) being collected randomly three soil sample with Soil bulk density technique. By using soil corer and hammer, the soil was collected and placed in sampling bag. Next, the soil sample will be further analyzed in lab by weight the soil 5g, placed into aluminum foil and placed in oven to dry the soil for 24 hours. After the soil is completely dry, the soil then being transferred into crucible cup and burn into furnace to turn the soil texture into an ash and finally get the final weight of the soil to calculate the organic matter represent and soil water contain. The same technique was used in this experiment on organic amendment Insect Frass (IF) and Agarwood debris (D) to measure the containment of Organic amendment (OM) in fertilizer.

### 3.3.7 Organic Amendments

Item	Insect Frass (IF)	Agarwood Debris (D)
Organic matter (%)	39384	12043
Water Content (%)	10.179	40.755

**Table 3.1** Show Organic amendments of insect frass and agarwood debris organic matter and water Content.



**Figure 3.7** Shows (a) Agarwood Debris Fertilizer and (b) Insect Frass Fertilizer Structure

From table 4.4 The organic amendments that the richest in organic matter was Insect frass (IF) 39384 but more less in water content compared to less Agarwood Debris 12043 percentage. (Bhadha et, al, 2021) stated, the more highest OM Subsequent the more it can absorb the water quantity or can be said as the moistest can it be. Nevertheless, despite the Insect Frass (IF) plot having the highest OM content, it has less WC compared to Agarwood debris (D) plot, which has lowers in OM but highest moisture content. What can be concluded from this discussion is that the probable reason for this occurrence is included various of aspect that may influence the change of the results. The physical or chemical properties contain in Agarwood Debris (D) structure may have the most suitable structure to water retention compared to Insect Frass (IF). (D) fertilizer could have the capacity to absorb water due to its fertilizer structure, even though the OM percentage was lower. This can be further supported by Statement From (Li et al., 2018) have stated that from the study made by explored the use of woody amendments, such as wood chips from tree branches, to enhance soil health and agricultural productivity. The findings indicated

that woody amendments significantly improved soil moisture availability, fertility, microbial activity, and plant growth compared to amendments like wheat straw, rice husks, and cow manure. When incorporated into the soil, woody materials increased soil water storage and boosted microbial activity, leading to better soil health and nutrient cycling. This improvement is attributed to the high carbon content and slow decomposition rate of woody materials, which provide a steady source of nutrients for soil microbes.

### 3.4 Water Content

Gravimetric water content will be being used to measure the water content of the Agarwood soil. The primary technique for assessing soil water content involves directly measuring the mass, as the quantity of soil water is determined through this method. The soil of Agarwood tree will be taken as a sample and the soil will be drying into oven. When the soil is ready, the soil will be weighed.

$$w = \frac{M_{moist} - M_{dry}}{M_{dry}}$$

### 3.5 Statistical Analysis

In this research, the Statistical Analysis System (SAS, 1988) used the influence of applying enriched soil on both plant growth and soil parameters and was investigated through a one-way analysis of variance (ANOVA). The growth response in terms of height and stem diameter, along with soil pH and temperature, will be examined using a general linear model.

## CHAPTER 4

### RESULT AND DISSUSION

#### 4.1 Overall Growth of *Aquilaria malaccensis* and Soil Condition

Parameters	Insect Frass (IF)	Agarwood debris (D)	No amendment-Control (C)
<b>Plant Growth</b>			
Stem diameter	1.1 (0.2)	1.2 (0.2)	1.9 (0.5)
Height	1.2 (0.1)	1.3 (0.1)	1.6 (0.1)
Leave Number	62 (18.9)	58 (8.5)	116 (69.8)
<b>Soil</b>			
pH	6 (0.5)	6 (0.7)	5.4 (0.5)
Moisture	4.4 (1.1)	6.1 (1.0)	4.2 (1.2)
Temperature	28 (2.1)	30.9 (6.4)	28 (3.5)

Table 4.1 Total Median of plant and soil measurements within 70 days

Overall, the diameter, height, and leaf numbers of *A. malaccensis* at agarwood plot, Pulau Banding, Perak is 1.37, 1.43 and 88.67 (**Table 4.1**). From the experiment conducted there were positive change in plant development. Observation have stated that in plot Insect frass both growth parameter (stem diameter, height and leave number) have positive change throughout the experimental days.

Based on **table 4.1** the growth parameter (stem diameter, height and leave number) of *A. malaccensis* at Control (C) plot has the highest number in growth parameter compared to Inset Frass (IF) and D Agarwood Debris). The Stem diameter is 1.9 SD (0.5), height 1.6 (0,1) and leaver number 116 (69.8). while Agarwood has

second higher in growth parameter, stem diameter 6 (0.7, height 6.1 (1.0) and leave number 58 (8.5). Furthermore, Insect Frass (IF) has the lowest which were 1.1 SD (0.2), height 1.2 (0.1) and leave number 62 (18.9).

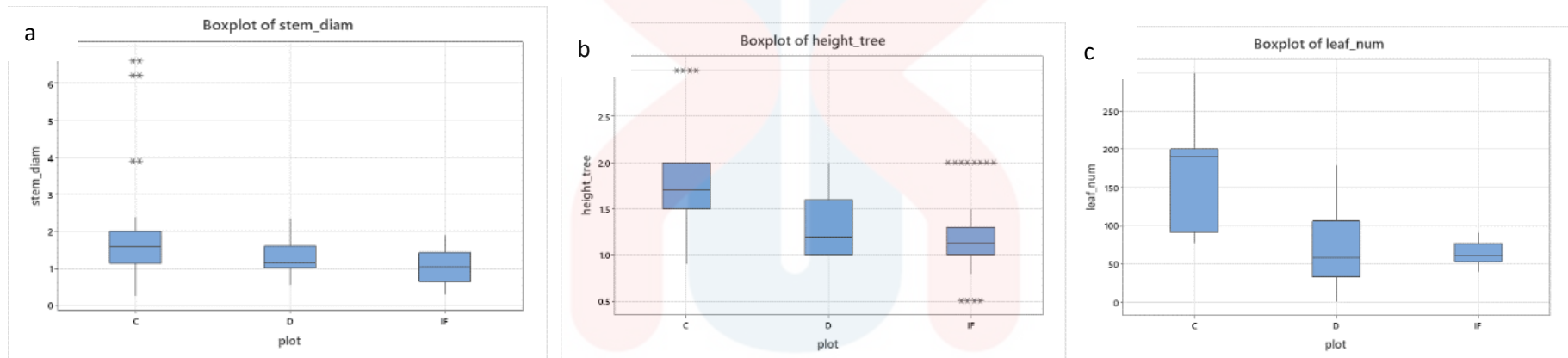
Next, For soil parameter, Insect Frass (IF) and Agarwood Debris (D) result in a neutral pH of six. However, the Control (C) has a slightly more acidic pH of 5.4. For soil moisture, D plots is the moistest soil condition compared to both If and C plot. Across the treatments plot, D plot have the highest temperature compared to If and C. From observations made, both tree populations on Plot IF and D have the similarity tree figures characterise as *A. malaccensis* tree on plot IF and D seems to have smallest stem diameter, low in height and along with less leave number compared to C plot have the highest in stem diameter, height and leave number. Although the tree was the same age range (1 years old) and being planted at the same time on the contrary the development on tree were different. Can be conclude *A. malaccensis* tree species population in plot C exhibit greater vitality and robust growth compared in D and If plot.

#### **4.2 Non-Parametric Data Results for Kruskal Wallis- Test (response x plots)**

From table 4.1 shows there were statistically significant differences in growth parameters (stem diameter, height and leaf number) with p-value 0.000 This indicated that there were significant differences effect on growth parameters (stem diameter, height and leaf number) across the Insect frass (IF), agarwood Debris (D) and Control (C) plot. Additionally, from the results demonstrating, the application of enrichment soil certainly had an influence and positive impact on tree growth development. Nevertheless, analysis of soil parameters (soil moisture and soil temperature) shows

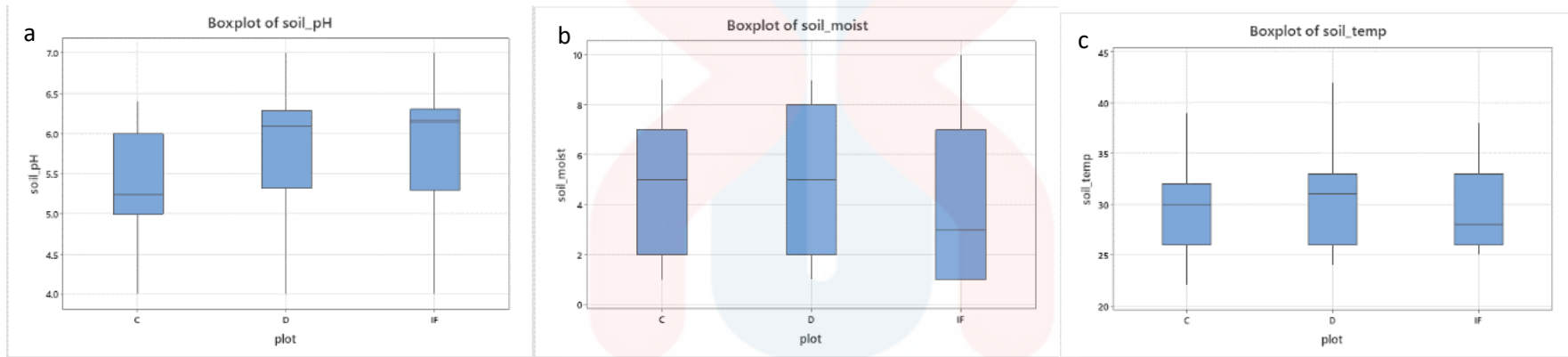
there were no statistically significant differences in measured parameters as indicated by the  $p$ -value  $>0.05$ . The  $p$ -value for soil moisture  $p=0.511$  and soil temperature  $p=0.830$  shows there were no effects on parameter measures across the study period. However, there were statistically significant differences on Soil pH parameter as the  $p$ -value measured  $=0.00 < 0.05$ .

#### 4.2.1 Overall Median for tree growth parameters across plots



**Figure 4.1** Median of tree growth parameters (a) stem diameter, (b) height and (c) leaf number across plots

#### 4.2.2 Median Soil Parameter across plots



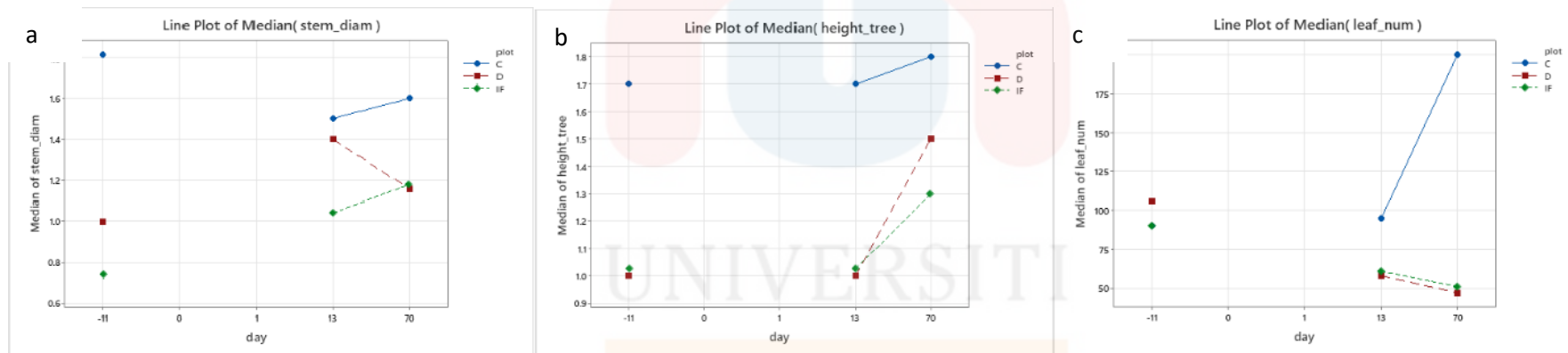
**Figure 4.2** Median of Soil parameters a) soil pH, b) soil moisture c) soil temperature between plots

### 4.3 Growth of trees and changes in soil parameters over the days

The soil parameter data, (soil pH and soil temperature) had shown a statistically significant difference with overall p-value (0.000) while only one significant difference had effect on Soil moisture in Control (C) plot  $p=0.046$ . Regarding the conclusion made, the analysis indicated Soil parameters (Soil pH and soil temperature) had significant effects across different treatments over the days. However, soil moisture showed significant data only in control plots. Furthermore, plant growth parameters, shows only one data analysis had a significant difference on stem diameter which were insect frass plot with p- value 0.031 while Control (C)  $=0.444$  and agarwood debris 0.119 that( $p>0.05$ ) which the data were not statistically significant. For overall growth parameters (Height) had shown there were no statistically significant events across the different treatments (C), (IF), (D) over the days as all the p-value ( $P>0.05$ ). Leaf number data showed significant difference in control and insect frass plots as the p-value ( $P=0.003$ ) and ( $P= 0.000$ ) while not significant in agarwood debris.

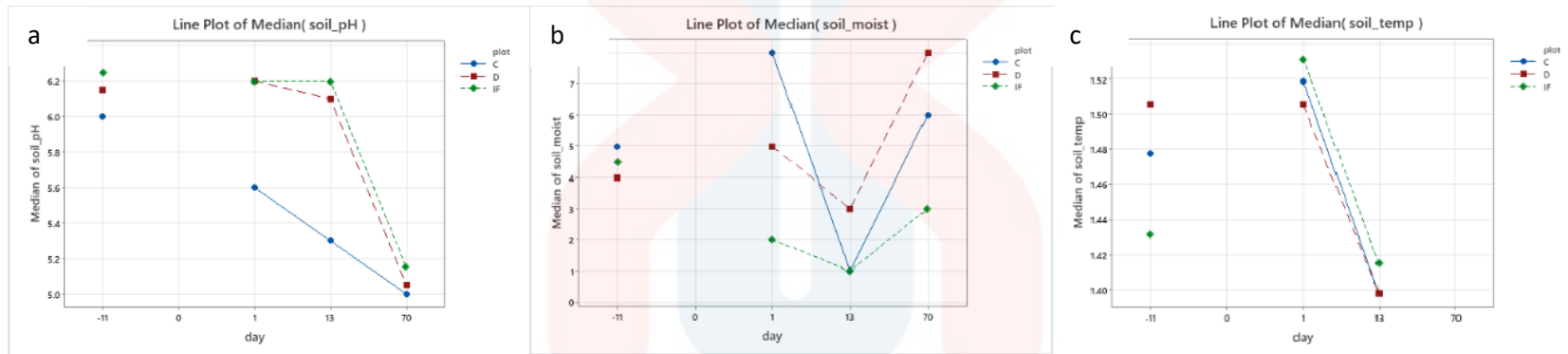
#### 4.4 Tree Graph parameters and Soil parameters within plots

##### 4.4.1 Tree Parameters Graph within plots



**Figure 4.3.** overall tree growth parameter (a) stem diameter, (b) height and (c) leaf number within plots.

### 4.4.2 Soil Parameters Graph within plots



**Figure 4.4** Overall Soil Parameters (a) Soil pH, (b) Soil Moisture and (c) Soil Temperature within plots.

#### 4.5 Soil Organic Matter and Soil Gravimetric Water Content

Item	Insect Frass (IF)	Agarwood Debris (D)	Control (C)
Soil Organic Matter (%)	66	738	107
Soil Gravimetric Water Content (%)	15	20	34

**Table 4.2** shows soil organic matter and soil gravimetric water content before the application (day 0) on organic armament within sampling plot at Pulau Banding, Perak.

From **table 4.2** shows the overall means of organic matter subsequence between three different plots which were Insect Frass (IF), Agarwood Debris (D) and Control (C) plot. Organic matter content in soil within the Agarwood Debris plot have the higher percentage of organic matter 738 % with 20 % of water content compared with Insect Frass (IF) plot and Control (C) plot. From the results show (D) plot contain have exceptionally high in organic matter which it is have ability to helps plants to have health and fertility. The rich on organic matter will helps the soil to improve retention capacity this indicate the truth where (D) plots have the highest moisture in soil content 5.6 compared to me (IF) 4.4 and (C) four as show in table 4.1. State by (Bhadha et, al, 2021) from 'IFAS' Extension University of Florida, The United States Department of Agriculture's Natural Resources Conservation Service states that "each 1% increase in soil organic matter allows U.S. cropland to store an amount of water

equivalent to the flow over Niagara Falls in 150 days" (Nichols, 2015). Enhancing soil organic matter is crucial for improving soil health (Doran and Zeiss, 2000). Furthermore, control (C) plots have the second higher in percentage of OM 107% and as the WC was 34 %. Insect frass soil sample have the lowest OM Subsequence as 66% of OM and WC 15%.

#### **4.6 Overall correlation of tree growth parameter and soil properties**

Based on the data, shows that Soil properties, soil pH has a significant influence on plant growth, with negative correlation of -0.323 with stem diameter and -0.243 with height, both of which are statistically significant with p-values of 0.000 and 0.0005, respectively. This indicates reliable relationship where higher soil pH is associated with smaller stem diameters and shorter plant heights. In contrast, soil moisture and temperature show no significant correlations with plant growth. Although soil moisture and temperature both have positive and negative correlations, their p-values were above 0.05, indicating that these relationships are not statistically significant. Therefore, despite some observed correlations, the lack of significant p-values for soil moisture and temperature suggests that these variables do not have a meaningful or reliable impact on plant growth based on the data.

## 4.7 Correlation between Plant Growth and Soil Properties within Each Plot

(Spearman Rho)  $P < 0.05$  (CI = 95%)

### 4.7.1 Plot Control (C)

The data analysis shows that there was only one correlation happening with statistically significant value in the difference effect in control plot. Furthermore, there were significant differences between leaf number and soil pH P-value (0.002) and ( $r = -0.710$ ). This indicated a strong correlation between leaf number and soil pH. This will show that as the soil pH increases, the leaf number decreases.

### 4.7.2 Plot Insect Frass (IF)

Table 4.7 shows that there was a positive correlation between leaf number and soil pH with correlation coefficient ( $r = 0.519$ ) which led to an increase on both parameters when one of the parameters increase. The p-value also  $< 0.05$  which shows a strong statistically significant between the parameters. Next there is correlation happen between stem diameter and Soil pH ( $- r = 0.293$ ) with P-value (0.025) Moreover, there is also positive correlation happen between leaf number and soil pH ( $r = 0.519$ ) p value  $< 0.05$ . this indicates as one variable increase; another variable will be also increasing the soil organic matter (Om), and Soil Bulk density shows a strong correlation between them with positive ( $r = 0.900$ ) which means when that higher level of soil organic matter is associated with higher soil bulk density. the p value also strong statistical difference (0.037) ( $P < 0.05$ ).

#### 4.7.3 Plot Agarwood Debris (D)

The data analysis shows that there were several statistically significant correlations between soil and plant growth parameters in the studied plots Agarwood debris (D). Additionally, there is a significant negative correlation between plant height and soil pH ( $p = 0.000$ ,  $r = -0.604$ ), indicating that taller plants tend to be found in soils with lower pH. On the other hand, significant positive correlation between stem diameter and soil moisture ( $p = 0.008$ ,  $r = 0.549$ ), had shown that higher soil moisture levels are associated with increased stem diameter. There is a strong positive correlation between soil organic matter and soil bulk density ( $p = 0.037$ ,  $r = 0.900$ ), suggesting that higher levels of soil organic matter are strongly associated with higher soil bulk density. Soil parameter as soil pH had shown the correction between two growth parameters (stem diameter and height) as the correlation value was negative ( $r = -0.549$ ,  $-0.604$ ) with both p-value  $<0.05$ . Othe than that, the soil properties (soil moisture) also had same influence in growth parameter (Stem diameter and height) with positive correlation ( $0.549$ ,  $0.476$ ) with P-value both  $<0.05$  In summary, the analysis highlights key relationships between soil properties and plant growth parameters. Soil moisture, soil pH, and soil organic matter significantly influence the growth of plant stems and height. Negative correlations with soil pH suggest that more acidic soils may limit stem diameter and height, while positive correlations with soil moisture and organic matter highlight the importance of these factors for plant grow

## CHAPTER 5

### CONCLUSION AND RECOMMENDATION

#### 5.1 Conclusion

Based on this study, it can be concluded that enriched soil significantly aids and plays a crucial role in promoting plant growth. The findings indicate a notable change once fertilizer is applied to the trees. The data recorded shows that fertilizer applied (Insect Frass and Agarwood Debris) has a positive impact on plant growth, particularly in terms of stem measurement and height. Data recorded that Agarwood debris have second highest average means of stem diameter 1.3 and height 1.4 compared to the lowest mean from Insect Frass 1.0 and 1.2. Control (C) Recorded the highest data in diameter (1.8) and height (1.7). Control plot dominant in all growth parameter (stem diameter, height and leave number) compared with IF and D despite none of treatment applied in control plot. And considering that early observations indicated the control plot already had higher stem diameter and height compared this both plots. This indicates that plants in the control plot were initially healthier or more Robus and showed that the initial conditions in the control plot were more favourable for plant growth. Other than that, the used and right selection of fertilizer were importance to promoted plant. Thus, Agarwood debris show a significant increase rate on plant development compared to Insect frass. From this observation on data collection from this research study have shown that the used of fertilizer surely one of the main aspects that influence the plant development and health nevertheless aspect like the humidity, soil type, canopy of the tree, temperature and the environment

surrounding the plant need to be considered in order to have an good and healthy plant grow.

Study showed that the relationship between soil properties and plant growth is surely associated with one another. The soil properties (soil pH, moisture, and temperature) and plant growth (Stem diameter, height and leave number) influenced by the present of soil properties. The positive correlation shows that there was strong correlation happen between two variables while negative correlation showed when one variable decreases another variable tend to decrease. Nevertheless, when a correlation happens between the same parameter, in this case soil moisture and soil pH this also show a correlation happen between plant growth and soil properties, because the change in two soil properties may influence the nutrient availability which can affect the growth of tree.

## 5.2 Recommendation

From this study, *Aquilaria malaccensis* surely one of the main and importance sources to the country that have high demand on value. This plant species decreases dramatically through years due to uncontrollable logging, overused sourced and less replanting were done that lead this species as critically endangered by the International Union of Conservation of Nature (IUCN). From this case, an action should be done for restore and conserve on this species habitat. From study, the used of enriched soil should be used to increase plant development and health considering it have positive / significant response in plant development. Furthermore, aspect like soil type, water sources, sunlight source and habitat should be considered in order encourage the plant development. Conservation in this species should be done to make sure they continue to this species he sustainability of this species is always maintained. Apart from that, there were lack of information or research done on this plant species especially on agriculture or cultivation aspect. This scop was importance to have a good method of cultivation.

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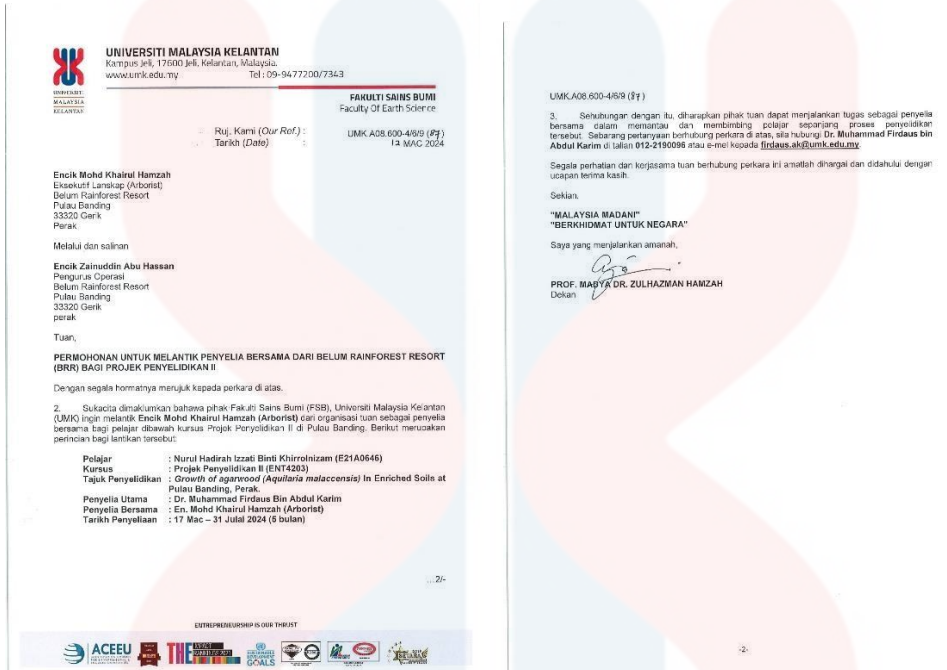
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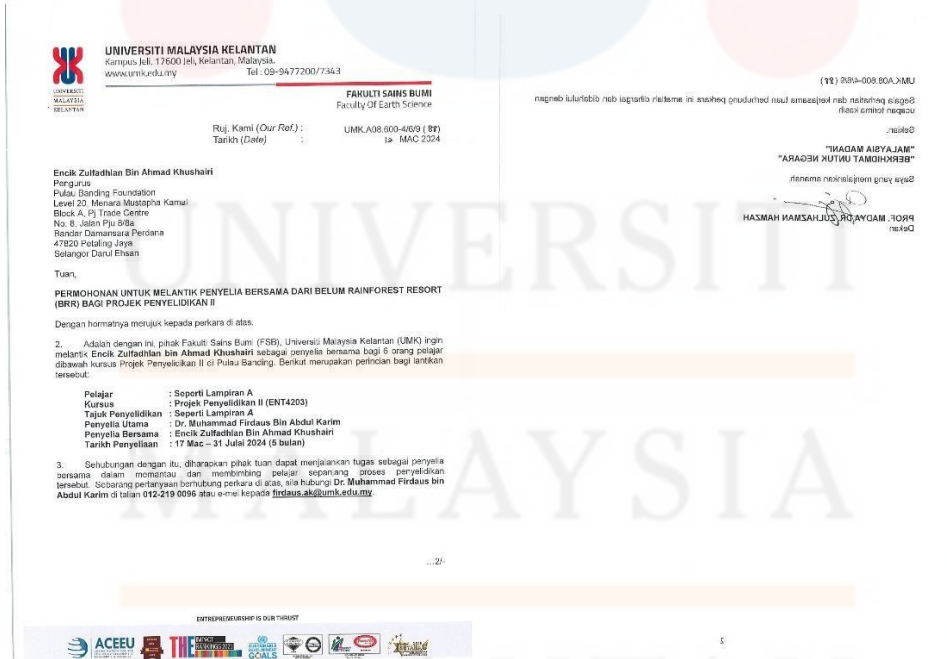
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# APPENDIX A



Collaboration letter request invitation to Royal Belum Rainforest Resort staff Mr. Mohd Khairul Hamzah (Landscape Executive) Arborist as Co-Supervisor

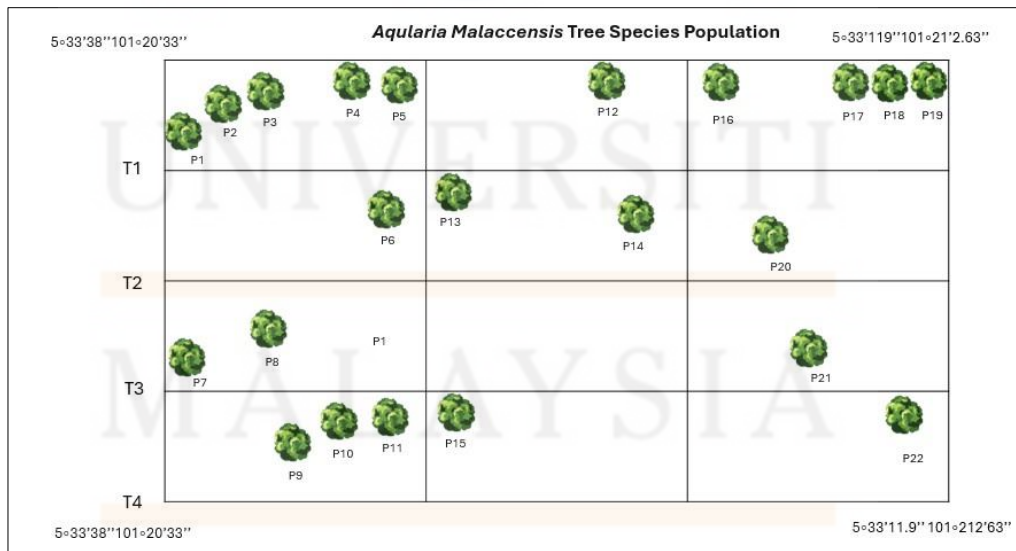


Collaboration letter request invitation to Pulau Banding Foundation (PF) Mr. Zulfadhlan bin Khushairi (Pulau Banding manager) as Co-Supervisor





**Figure 3.3 *A. malaccensis* population and Area Calculation (13152.56) at study area Pulau Banding, Perak**



**Figure 3.4 Sampling plot design and distribution of *A. malaccensis* at each treatment plot**

**4.2 Non-Parametric Data Results for Kruskal Wallis- Test (response x plots)**

Response	Compare Plot C x IF x D
Stem Diameter	P=0.000 (Significant difference in Median)
Height	P=0.000 (Significant difference in Median)
Leaf Number	P=0.000 (Significant difference in Median)
Soil pH	P=0.000 (Significant difference in Median)
Soil Moist	P= 0.511 > (No significant difference in Median)
Soil Temperature	P = 0.830 (No significant difference in Median)

**4.3 Growth of tree and change in soil parameters over the days**

Response	Plot C	Plot IF	Plot D
Soil pH	P=0.000 (Significant)	P=0.000 (Significant)	P=0.000 (Significant)
Soil Moist	P=0.046 (significant)	P=0.069 (not Significant)	P=0.511 (not significant)
Soil Temperature	P=0.000 (significant)	P=0.000 (Significant)	P=0.000 (Significant)
Stem Diameter	P=0.444 (not significant)	P=0.031 (significant)	P=0.119 (not significant)

Height	P=0.381 (no Significant)	P= 0.078(not significant)	P=0.154(not significant)
Leaf Number	P=0.003 (Significant)	P=0.000 (Significant)	P= 0.413 (not significant)

#### 4.6 Overall correlation of tree growth parameter and soil properties

Sample one	Sample two	N	Correlation	Ninety-five percent CI for $\rho$	P-Value
soil_moist	soil_pH	141	-0.461	(-0.587, -0.312)	0.000
soil_temp	soil_pH	132	-0.058	(-0.227, 0.114)	0.509
stem_diam	soil_pH L	131	-0.323	(-0.472, -0.156)	0.000
height_tree	soil_pH L	132	-0.243	(-0.399, -0.072)	0.005
leaf_num	soil_pH L	65	-0.084	(-0.322, 0.163)	0.504
soil_bulkd	soil_pH	0	*	(*, *)	*
soil_OM	soil_pH	0	*	(*, *)	*
soil_temp	soil_moist	108	-0.000	(-0.189, 0.189)	0.998
stem_diam	soil_moist L	105	0.161	(-0.032, 0.344)	0.100
height_tree	soil_moist L	106	0.094	(-0.099, 0.280)	0.337
leaf_num	soil_moist L	55	-0.060	(-0.321, 0.208)	0.661
soil_bulkd	soil_moist	0	*	(*, *)	*
soil_OM	soil_moist	0	*	(*, *)	*
stem_diam	soil_temp L	87	-0.084	(-0.290, 0.129)	0.439
soiheight_tree	soil_temp L	88	-0.013	(-0.222, 0.197)	0.903
leaf_num	soil_temp	42	0.205	(-0.109, 0.482)	0.193
soil_bulkd	soil_temp	0	*	(*, *)	*
soil_OM	soil_temp	0	*	(*, *)	*
height_tree	stem_diam	131	0.482	(0.330, 0.610)	0.000
leaf_num	stem_diam	64	0.154	(-0.097, 0.387)	0.223
soil_bulkd	stem_diam	0	*	(*, *)	*
soil_OM	stem_diam	0	*	(*, *)	*
leaf_num	height_tree	65	0.167	(-0.082, 0.396)	0.184
soil_bulkd	height_tree	0	*	(*, *)	*
soil_OM	height_tree	0	*	(*, *)	*
soil_bulkd	leaf_num	0	*	(*, *)	*
soil_OM	leaf_num	0	*	(*, *)	*
soil_OM	soil_bulkd	15	0.621	(0.109, 0.873)	0.013

## 4.7 Correlation between Plant Growth and Soil Properties within Each Plot

(Spearman Rho)  $P < 0.05$  (CI = 95%)

### 4.7.1 Plot Control (C)

Pairwise Spearman Correlations

Sample 1	Sample 2	N	Correlation	95% CI for $\rho$	P-Value
soil_moist	soil_pH	43	-0.331	(-0.580, -0.026)	0.030
soil_temp	soil_pH	42	0.027	(-0.279, 0.328)	0.866
stem_diam	soil_pH	42	0.186	(-0.127, 0.466)	0.237
height_tree	soil_pH	42	-0.054	(-0.352, 0.255)	0.736
leaf_num	soil_pH	16	-0.710	(-0.904, -0.272)	0.002
soil_bulkd	soil_pH	0	*	(*, *)	*
soil_OM	soil_pH	0	*	(*, *)	*
soil_temp	soil_moist	36	0.306	(-0.033, 0.582)	0.070
stem_diam	soil_moist	30	0.225	(-0.152, 0.545)	0.231
height_tree	soil_moist	30	0.352	(-0.021, 0.639)	0.056
leaf_num	soil_moist	11	0.550	(-0.124, 0.877)	0.079
soil_bulkd	soil_moist	0	*	(*, *)	*
soil_OM	soil_moist	0	*	(*, *)	*
stem_diam	soil_temp	28	-0.026	(-0.395, 0.350)	0.895
height_tree	soil_temp	28	-0.238	(-0.565, 0.154)	0.223
leaf_num	soil_temp	8	0.000	(-0.705, 0.705)	1.000
soil_bulkd	soil_temp	0	*	(*, *)	*
soil_OM	soil_temp	0	*	(*, *)	*
height_tree	stem_diam	42	0.593	(0.329, 0.771)	0.000
leaf_num	stem_diam	16	-0.024	(-0.514, 0.477)	0.929
soil_bulkd	stem_diam	0	*	(*, *)	*
soil_OM	stem_diam	0	*	(*, *)	*
leaf_num	height_tree	16	0.638	(0.157, 0.874)	0.008
soil_bulkd	height_tree	0	*	(*, *)	*
soil_OM	height_tree	0	*	(*, *)	*
soil_bulkd	leaf_num	0	*	(*, *)	*
soil_OM	leaf_num	0	*	(*, *)	*
soil_OM	soil_bulkd	5	0.700	(-0.591, 0.984)	0.188

#### 4.7.2 Plot Insect Frass (IF)

##### Pairwise Spearman Correlations

Sample 1	Sample 2	N	Correlation	95% CI for $\rho$	P-Value
soil_moist	soil_pH	67	-0.491	(-0.662, -0.271)	0.000
soil_temp	soil_pH	60	-0.186	(-0.422, 0.074)	0.156
stem_diam	soil_pH	59	-0.292	(-0.514, -0.034)	0.025
height_tree	soil_pH	60	0.056	(-0.201, 0.305)	0.674
leaf_num	soil_pH	36	0.519	(0.209, 0.735)	0.001
soil_bulkd	soil_pH	0	*	(*, *)	*
soil_OM	soil_pH	0	*	(*, *)	*
soil_temp	soil_moist	48	-0.103	(-0.377, 0.187)	0.485
stem_diam	soil_moist	53	0.103	(-0.173, 0.364)	0.462
height_tree	soil_moist	54	-0.006	(-0.273, 0.263)	0.968
leaf_num	soil_moist	31	-0.206	(-0.525, 0.164)	0.266
soil_bulkd	soil_moist	0	*	(*, *)	*
soil_OM	soil_moist	0	*	(*, *)	*
stem_diam	soil_temp	39	-0.179	(-0.470, 0.147)	0.276
height_tree	soil_temp	40	0.165	(-0.156, 0.455)	0.309
leaf_num	soil_temp	26	0.170	(-0.235, 0.525)	0.405
soil_bulkd	soil_temp	0	*	(*, *)	*
soil_OM	soil_temp	0	*	(*, *)	*
height_tree	stem_diam	59	0.036	(-0.222, 0.290)	0.786
leaf_num	stem_diam	35	-0.134	(-0.449, 0.210)	0.442
soil_bulkd	stem_diam	0	*	(*, *)	*
soil_OM	stem_diam	0	*	(*, *)	*
leaf_num	height_tree	36	-0.151	(-0.459, 0.188)	0.379
soil_bulkd	height_tree	0	*	(*, *)	*
soil_OM	height_tree	0	*	(*, *)	*
soil_bulkd	leaf_num	0	*	(*, *)	*
soil_OM	leaf_num	0	*	(*, *)	*
soil_OM	soil_bulkd	5	0.900	(-0.169, 0.996)	0.037

### 4.7.3 Plot Agarwood Debris (D)

#### Pairwise Spearman Correlations

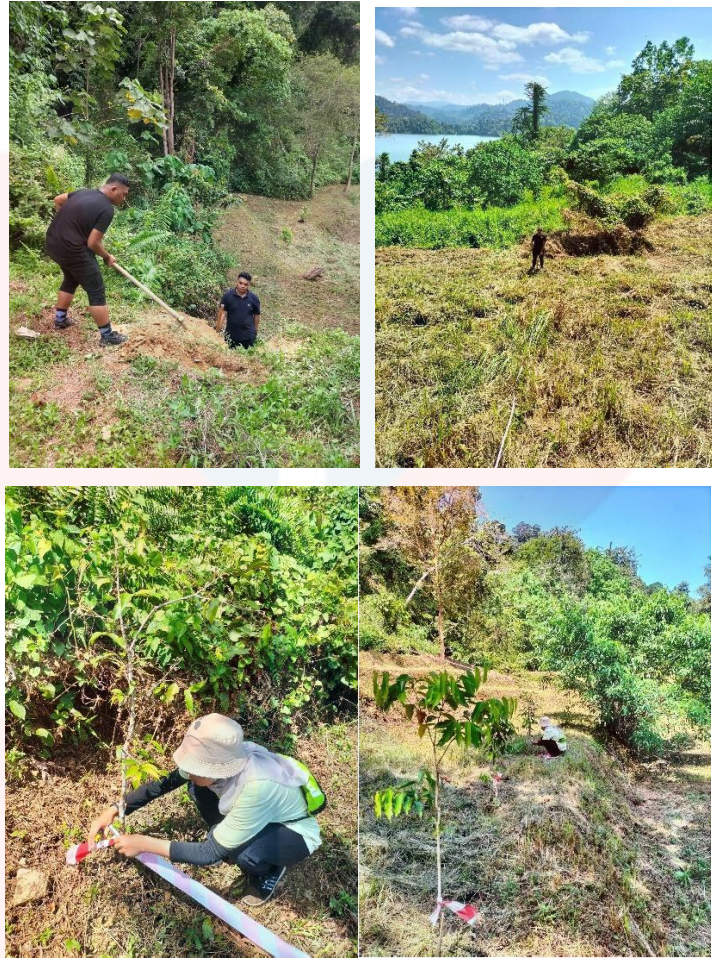
Sample 1	Sample 2	N	Correlation	95% CI for $\rho$	P-Value
soil_moist	soil_pH	31	-0.540	(-0.762, -0.205)	0.002
soil_temp	soil_pH	30	0.134	(-0.239, 0.473)	0.479
stem_diam	soil_pH	30	-0.594	(-0.798, -0.269)	0.001
height_tree	soil_pH	30	-0.604	(-0.804, -0.281)	0.000
leaf_num	soil_pH	13	0.011	(-0.543, 0.559)	0.971
soil_bulkd	soil_pH	0	*	(*, *)	*
soil_OM	soil_pH	0	*	(*, *)	*
soil_temp	soil_moist	24	-0.306	(-0.637, 0.121)	0.147
stem_diam	soil_moist	22	0.549	(0.134, 0.800)	0.008
height_tree	soil_moist	22	0.194	(-0.252, 0.572)	0.387
leaf_num	soil_moist	13	0.289	(-0.324, 0.730)	0.339
soil_bulkd	soil_moist	0	*	(*, *)	*
soil_OM	soil_moist	0	*	(*, *)	*
stem_diam	soil_temp	20	-0.295	(-0.658, 0.179)	0.207
height_tree	soil_temp	20	-0.117	(-0.533, 0.344)	0.622
leaf_num	soil_temp	8	-0.400	(-0.870, 0.452)	0.326
soil_bulkd	soil_temp	0	*	(*, *)	*
soil_OM	soil_temp	0	*	(*, *)	*
height_tree	stem_diam	30	0.476	(0.119, 0.724)	0.008
leaf_num	stem_diam	13	-0.062	(-0.593, 0.507)	0.840
soil_bulkd	stem_diam	0	*	(*, *)	*
soil_OM	stem_diam	0	*	(*, *)	*
leaf_num	height_tree	13	-0.450	(-0.813, 0.164)	0.123
soil_bulkd	height_tree	0	*	(*, *)	*
soil_OM	height_tree	0	*	(*, *)	*
soil_bulkd	leaf_num	0	*	(*, *)	*
soil_OM	leaf_num	0	*	(*, *)	*
soil_OM	soil_bulkd	5	0.900	(-0.169, 0.996)	0.037

APPENIX B



*Aquilaria malaccensis* tree species sampling plot at Pulau Banding, Perak

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MALAYSIA  
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Site visit, marking and zoning area, identification of *Aquilaria malaccensis* tree species, tree tagging tree and data collection on growth parameter and soil properties (-11) (17/2/2024) before treatment application



Plots area calculation and *Aquilaria malaccensis* tree distribution using GPS



Application of treatments, Insect Frass Fertilizer (IF) and Agarwood Debris Fertilizer on *Aquilaria malaccensis* tree and soil sample collection day (0) (29/2/2024)



Data collection on Soil properties after a day (28/2/2024) of application of fertilizer



Soil sample being weight, placed din crucible cup, baked in oven to dry the soil and put in furnace to turn the soil into ash and measure OM



Data collection on Plant growth parameter, soil properties and second application of fertilizer after 13 days (13/3/2024)



Data collection on plant growth parameter and soil properties after 70 days (9/5/2024)

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My fellows friends that gave in hand in this research projet, my supervisor , my Co-supervisor and encik mizi at sampling site

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