



Institute of Biodiversity and Environmental Conservation

**Advance Reforestation Strategies: Predicting Potential Species from
Available Species in Jagoi Heritage Forest (JHF) and Mycorrhizal Fungi-
Trichoderma-Fertilizer Combined Effects on *Durio zibethinus* and
Artocarpus heterophyllus Growth**

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**Doctor of Philosophy
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Trichoderma-Fertilizer Combined Effects on *Durio zibethinus* and *Artocarpus*
heterophyllus Growth

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DECLARATION

I declare that the work in this thesis was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Except where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.


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ABSTRACT

Reforestation can occur by two main methods namely, natural regeneration and intervention during replanting. This study consists of two experiments. Experiment 1 predicted the potential native tree species for mixed-planting reforestation in degraded areas around Bau District using the ecological criteria using the ecological criteria i.e., natural regeneration status, importance value (IV), and standing biomass (SB). The study was carried out at Jagoi Heritage Forest (JHF), Bau, Sarawak. A total of 52 (20 m x 20 m) nested quadrats were placed systematically in primary forest (PF), old secondary forest (OSF), young secondary forest (YSF), and agroforest (AF). Shannon-Wiener diversity index results showed that YSF and AF have the highest species diversity ($H' = 4.10$). Kruskal-Wallis H test showed that there is a significant difference in IV ($X^2[3] = 12.20$, $p = 0.01$) and SB ($X^2 [3] = 27.29$, $p < 0.05$) between forest types. The cross-matched between Indicator species analysis (ISA) result and natural regeneration status found that *Dipterocarpus* sp. and *Archidendron jiringa* (Jack) Nielsen have the highest indicator values (based on IV and SB) and good regeneration. Thus, *Dipterocarpus* sp. and *A. jiringa* has a higher potential for mixed-planting reforestation in degraded areas around Bau District. Meanwhile, Experiment 2 investigated the effect of mycorrhizal fungi and *Trichoderma* (MF-T) application with different fertilizer types and amounts on *Durio zibethinus* Murray (durian) and *Artocarpus heterophyllus* Lam. (jackfruit) growth. A randomized complete block design was used with ten replicates per species of tree per treatment. Seven treatments were used. The profile diagram shows the highest marginal mean of *D. zibethinus* height was at 100 g organic fertilizer (OF) with MF-T (Mean = 65.52), and *A. heterophyllus* height was at 50 g OF with MF-T (Mean = 113.77). The marginal mean stem diameter also showed that the highest mean of *D. zibethinus* diameter was at 100 g chemical fertilizer (CF) with MF-T (Mean = 7.15). However, the

highest marginal mean diameter for *A. heterophyllus* was at 50 g OF with MF-T (Mean = 8.98). The factorial ANOVA result indicated that there was a significant difference between treatments versus species of tree on height ($F [6,154] = 12.44, p < 0.05$) and stem diameter ($F [6,154] = 5.57, p < 0.05$). The Tukey post-hoc analysis showed that treatment of 50 g OF with MF-T is the most suitable treatment for the successful establishment of *D. zibethinus* and *A. heterophyllus*. The study concluded that reforestation can be achieved through two methods namely, natural regeneration and manipulation during replanting. A predictive approach based on the tree's natural regeneration status, IV, and SB can predict successful establishment of the selected species in a new area. The replanting method with co-inoculation of MF-T with OF not only helps in promoting plant growth and recovers the soil's chemical and biological properties but also helps in reducing dependencies on chemical fertilizer.

Keywords: Biodiversity, biomass, mycorrhiza fungi, mixed-planting reforestation, natural regeneration

Strategi Pengembangan Semula Hutan: Meramal Spesis Berpotensi daripada Spesis yang Sedia Ada di Hutan Warisan Jagoi dan Kesan Penggunaan Gabungan Trichoderma-Baja Terhadap Pertumbuhan Durio zibethinus dan Artocarpus heterophyllus

ABSTRAK

*Penghutan semula boleh berlaku melalui dua kaedah utama iaitu, pertumbuhan semula jadi dan manipulasi semasa penanaman semula. Kajian ini mengandungi dua eksperimen. Eksperimen 1 meramalkan spesis yang berpotensi untuk penghutan semula melalui penanaman campur di kawasan terdegradasi di sekitar daerah Bau dengan menggunakan kriteria-kriteria ekologi i.e., status pertumbuhan semula jadi, nilai kepentingan dirian (KD), dan biomas dirian (BD). Kajian ini telah dijalankan di Hutan Warisan Jagoi (HWJ), Bau, Sarawak. Sejumlah 52 (20 m x 20 m) kuadrat bertindih telah diatur secara sistematik di hutan dara (HD), hutan sekunder tua (HST), hutan sekunder muda (HSM), dan hutan pertanian (HP). Keputusan indeks kepelbagaian Shannon-Wiener menunjukkan bahawa HSM dan HP mempunyai nilai kepelbagaian tertinggi ($H' = 4.10$). Analisis H Kruskal-Wallis menunjukkan terdapat perbezaan signifikan bagi nilai KD ($X^2[3] = 12.20, p = 0.01$) dan BD ($X^2 [3] = 27.29, p < 0.05$) di antara empat jenis hutan tersebut. Padanan silang antara keputusan analisis spesis indikator (ASI) dan status pertumbuhan semula jadi mendapati *Dipterocarpus* sp. dan *Archidendron jiringa* (Jack) Nielsen mempunyai nilai penunjuk tertinggi (berdasarkan nilai KD dan BD) dan pertumbuhan semula jadi yang baik. Oleh itu, *Dipterocarpus* sp. dan *A. jiringa* mempunyai potensi untuk penanaman hutan campuran yang tinggi di kawasan terdegradasi di sekitar daerah Bau. Eksperimen 2 pula menyiasat kesan penggunaan kulat mikoriza dan *Trichoderma* (KM-T) dengan jenis dan jumlah baja yang berbeza ke atas pertumbuhan *Durio zibethinus* Murray (durian) dan *Artocarpus heterophyllus* Lam. (nangka). Reka bentuk blok lengkap rawak telah digunakan*

dengan sepuluh replikasi bagi setiap spesis pokok dan rawatan. Tujuh jenis rawatan telah digunakan. Plot profil menunjukkan min marginal tertinggi bagi ketinggian *D. zibethinus* adalah 100 g baja organik (BO) dengan KM-T (Min = 65.5) manakala *A. heterophyllus* adalah 50 g BO dengan KM-T (Min = 113.8). Min marginal diameter batang juga menunjukkan bahawa min tertinggi untuk *D. zibethinus* adalah 100 g baja kimia (BK) dengan KM-T (Min = 7.15). Namun begitu, min marginal tertinggi untuk diameter batang *A. heterophyllus* adalah 50 g BO dengan KM-T (Min = 8.98). Keputusan faktorial ANOVA menunjukkan terdapat perbezaan signifikan di antara rawatan melawan spesis pokok terhadap ketinggian ($F [6,154] = 12.44, p < 0.05$) dan diameter batang ($F [6,154] = 5.57, p < 0.05$). Analisis post-hoc Tukey menunjukkan bahawa rawatan 50 g OF dengan KM-T adalah rawatan yang paling sesuai untuk pertumbuhan *D. zibethinus* dan *A. heterophyllus*. Kajian ini menyimpulkan bahawa penghutanan semula boleh dicapai melalui dua kaedah iaitu, pertumbuhan semula jadi dan manipulasi semasa penanaman semula. Kaedah ramalan berdasarkan status pertumbuhan semula jadi, nilai KD, dan BD dapat meramalkan kejayaan pertumbuhan spesis terpilih di kawasan baharu. Kaedah penanaman semula dengan inokulasi bersama KM-T dengan BO bukan sahaja membantu dalam menggalakkan pertumbuhan tumbuhan dan memulihkan kandungan kimia dan biologi tanah, tetapi juga membantu dalam mengurangkan pergantungan kepada baja kimia.

Kata kunci: *Kepelbagaian biologi, biomas, kulat mikoriza, penghutanan semula melalui penanaman campur, pertumbuhan semula jadi*

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LIST OF ABBREVIATIONS

AF	Agroforest
AMF	Arbuscular mycorrhizal fungi
ANOSIM	Analysis of Similarities
ANOVA	Analysis of Variance
ANR	Assisted natural regeneration
BA	Basal area
CBC	Community-based-conservation
CBH	Circumference at Breast Height
CF	Chemical fertilizer
DBH	Diameter at Breast Height
DSH	Diameter at Stump Height
E	Pielou's evenness index
FAO	Food and Agriculture Organization
FRIM	Forest Research Institute Malaysia
GFGP	Grain-for-Green Program
H'	Shannon-Wiener diversity index
ISA	Indicator species analysis
ITTO	International Tropical Timber Organization
IUCN	International Union for Conservation of Nature
IV	Importance Value
IVI	Importance Value Index
JADC	Jagoi Area Development Committee
JHF	Jagoi Heritage Forest

Kg.	<i>Kampung</i> (village)
MF-T	Mycorrhizal fungi and <i>Trichoderma</i>
N	Nitrogen
OF	Organic fertilizer
OSF	Old secondary forest
P	Phosphorus
PASW	Predictive Analytical Software
PC	Personal computer
PCoA	Principal coordinates analysis
PF	Primary forest
RCBD	Randomized complete block design
S	Menhinick richness index
SFM	Sustainable Forest Management
Sg.	Sungai
SP	South Pole
SSB	Seedling/sapling standing biomass
TSB	Tree's standing biomass
UNDP	United Nation Development Programme
UNEP-WCMC	United Nation Environment Programme World Conservation Monitoring Centre
UPM	Universiti Putra Malaysia
YSF	Young secondary forest

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Forest and humans have an interchangeable relationship in which, both play crucial roles to ensure the continuity of one another. Forest has multiple functions, including as a gene pool, carbon sink, source of timber and non-wood forest products, provides multiple ecosystem services, and a home for wildlife and indigenous people (Chazdon et al., 2016). However, this relationship has constantly been abused by humans, and this has put the forest in a critical condition. Hence, an effort to rehabilitate the forest has been widely discussed and practised. One of the possible solutions is reforestation. The reforestation initiative has proven to conserve and rehabilitate the natural forests from further degradation while providing environmental services (Hashim et al., 2015).

The Malaysian reforestation strategy can be divided into two main methods namely, natural regeneration and replanting with native or exotic species (Wan Mohd et al., 2015). In the United States of America, ‘reforestation’ is defined as transforming non-forested areas into forests through active restoration using the planting method or passive restoration using natural regeneration (Hanson et al., 2015). Reforestation can also be conducted through nucleation, vegetation clustering, and agroforestry methods (Shimamoto et al., 2018). The increasing rate of deforestation in the Southeast Asia region due to agriculture, urbanization, increased demand for timber, and forest fires has led to the adoption of reforestation and forest conservation policies (Ahmadzai et al., 2023). It is expected that through continuous

effort of reforestation, the Southeast Asia region will gain 19.6 million ha of forests by 2050 (Estoque et al., 2019).

Malaysia is among the tropical countries, which had recently started reforestation initiatives through forest plantation due to high demand for timber and the depletion of natural forests (Hashim et al., 2015). According to a study by Estoque et al. (2019), Malaysia has lost 16.6% from the total of 80 million ha of forest loss in the Southeast Asia, between 2005 and 2015. Although there have been several forest plantations established to cope with the demand for timber and to reforest the degraded forests, the success rate of reforestation is yet to be determined, and more research is needed to improve the results (Abd Latif et al., 2018). Despite the uncertainty, forest plantations may have the potential to offer social and environmental benefits and would slowly replace the dependency on natural forests (Hashim et al., 2015).

Hence, there is a need for a comprehensive evaluation of the targeted species for reforestation and a new alternative to overcome these concerns. This study covers both methods of reforestation namely, the natural regeneration method and replanting method. It was divided into two experiments in which, the first experiment predicted the potential tree species for mixed-planting reforestation in degraded areas around Bau District using the ecological criteria i.e., natural regeneration status, importance value (IV), and standing biomass (SB). The study has been carried out at Jagoi Heritage Forest (JHF), Bau, Sarawak, in two primary forest (PF), five old secondary forest (OSF), four young secondary forest (YSF), and three agroforest (AF) sites.

The second experiment investigated the potential of mycorrhizal fungi and *Trichoderma* (MF-T) as biofertilizers to accelerate the growth of planted trees in

reforestation works. It was carried out in the greenhouse's environment for one year. *Durio zibethinus* and *Artocarpus heterophyllus* were selected, planted, and treated with seven types of treatments, including the control treatment. The treatments involve the fertilization procedure using two types of fertilizer namely, organic (OF) and chemical fertilizer (CF), with inoculation of MF-T.

The results from the first experiment are important to determine the dominant native tree species from JHF that is suitable for planting in reforestation areas around Bau District. The results from the second experiment then provide insight into methods to accelerate reforestation.

Each main topic is divided into two sections namely, (a) Experiment 1: Predicting the Potential Species for Reforestation Based on Natural Regeneration Status, Importance Value and Standing Biomass, and (b) Experiment 2: The Effect of Mycorrhizal Fungi and *Trichoderma* Application with Different Fertilizer Types and Amounts on *Durio zibethinus* and *Artocarpus heterophyllus* Growth.

1.2 Predicting the Potential Species for Reforestation Based on Natural Regeneration Status, Importance Value and Standing Biomass

1.2.1 Background of Study for Experiment 1

Reforestation has been a complicated yet essential effort to combat the challenges of deforestation, climate change, and biodiversity loss (Food and Agriculture Organization [FAO], 2015b). It can contribute to the world's economic growth, poverty alleviation, food security, climate resilience, biodiversity conservation, and the rule of law (Stanturf et al., 2015). Reforestation is made up of multiple elements, among all monitoring and evaluating

processes. Monitoring and evaluating is one of the important elements in reforestation as they provide a lot of useful information on the activities conducted, predict the results, and assist the forest management (FAO, 2015b). However, monitoring and evaluating reforestation is a complicated process with heated debates on what qualifies successful reforestation and how best to measure it. The monitoring and evaluation process can be categorized into three aspects, namely, ecological, economic, and social. The ecological aspects are divided into three attributes namely, vegetation structure, diversity and abundance, and ecological processes (Le et al., 2015).

Past reforestation efforts, such as in the degraded area of former copper mining in Sabah often prefer exotic species due to its fast growth rate and environmental-stress tolerance. However, the growth performance of the exotic species planted varied between different species and sites in the same area (Lintangah et al., 2016). Introducing exotic species may also disrupt the natural environmental and ecological process, indirectly leading to high maintenance costs to preserve the natural environment (FAO, 2015b).

Numerous past studies have also been conducted to investigate the ecological attributes of vegetation structure, diversity, and abundance in different forest areas, such as Aliyi et al. (2015) in tropical montane forests, Kuma and Shibru (2015) in dry woodland forests, and Maua et al. (2020) in tropical rainforests. In tropical montane forests, Aliyi et al. (2015) investigate the flora's structure, diversity, and abundance. Their findings showed a wide variety of plant species with significant degrees of endemism and distinctive adaptations to the alpine habitat. The study emphasised how crucial it is to preserve the forests due to their ecological value and capacity to preserve biodiversity. Then, Kuma and Shibru's (2015) discovered that dry woodland forests had less species diversity compared to

other forest types. However, they identified several indigenous tree species that demonstrated tolerance to arid conditions, indicating their potential for regeneration and reforestation initiatives in dry areas. The study by Maua et al. (2020) then emphasised the remarkable richness of tropical rainforests, which contain a wide variety of plant species and intricate ecological relationships. Additionally, Maua et al. (2020) discovered possible local species that could be employed in reforestation efforts to restore degraded rainforests. However, these studies indicate the need to systematically identify the potential native species that could be used in reforestation efforts based on their ecological adaptability.

Among the most recent conservation-based research conducted in JHF involving the diversity of vegetation, such as medicinal plants and non-timber forest products are by Ripen and Noweg (2016), Baling et al. (2017), and Toaiang and Sayok (2019). The present research has mainly concentrated on the diversity and utilisation of plants. However, there has been a lack of identification of native species that have the potential for replanting in other degraded areas. Researching local species with quick growth, high environmental adaptation, and ecological significance could help reforestation succeed.

Studies conducted to determine the potential species for reforestation, such as Saha et al. (2016) in Dhanaulti of Garhwal Himalaya, Mallegowda et al. (2018) in South India, and Thang et al. (2018) in northwestern Vietnam also mainly focus on the economic value of the species and single-ecological criterion, rarely combining several ecological criteria. These research findings may have shed important light on the suitability and distinctive traits of different tree species for reforestation in diverse localities. A thorough understanding of the optimal reforestation techniques may be hampered by research gaps caused by the absence of studies combining the traits of several species. The two primary research issues

raised by these studies including (1) lack of possible environmental benefits that could result from integrating multiple tree species in reforestation operations and (2) lack of determination on how a mixture of different species can increase the resilience of reforested areas to environmental stressors, such as climate change, pests, and diseases. More effective and long-lasting reforestation techniques can result from evaluating the adaptability of various replanting techniques.

The study by Charles et al. (2018) then aimed to identify suitable tree species for reforestation in Australia's wet tropics by considering their common occurrence in local undisturbed rainforests, availability in local nurseries, and a range of functional characteristics aligning with different successional phases. The species in each focal family were chosen to represent a wide range of characteristic values, including maximum tree height, wood density, dispersal vector, seed size, and successional phase. The research problem stemming from this study could be to explore the importance of the species in the current reforestation areas, their current biomass, and their natural regeneration status. These parameters could serve as another crucial factor in species selection.

Another study by Asigbaase et al. (2019) in the Eastern Region of Ghana utilized the importance value index (IVI) to quantify the significance of various plant species in both agroforestry systems. The study suggested the potential of IVI in selecting the species for reforestation. IVI identifies species that are important to the ecosystem's total diversity and helps to preserve that diversity. High IVI scores can be used as a criterion when choosing tree species for reforestation since they are more likely to support a wide range of different organisms and boost ecosystem resilience (Asigbaase et al., 2019). The IVI scores are interconnected to the size of trees, which directly translate to the trees' dominance (Mewded

et al., 2021). The trees' dominance influences the ecological and economic importance of the trees.

A review by Pietrzykowski (2019) focused on experiences from Central and Eastern European regions, specifically on tree species selection and their responses to soil reclamation in a newly reforested post-mining area. The review emphasised how crucial it is to coordinate reforestation techniques with the desired level of soil substrate quality and the species composition from various functional groups. The review examined a number of species response factors, such as tree growth, morphology, biomass accumulation, root system behaviour, and the availability of macronutrients. However, the review mainly focused on post-reclamation species responses. Assessing possible tree species' suitability for replanting before reclamation begins could be an interesting research topic. In order to help optimise reforestation techniques, this could entail prediction based on species traits and conditions of the area to be reclaimed. Hence, this experiment is conducted to evaluate the potential of native tree species in JHF for reforestation in degraded areas around Bau District based on their ecological criteria, which include natural regeneration status, IV, and SB.

1.2.2 Objectives of Experiment 1

Generally, this study is aimed to predict the potential native tree species for reforestation in degraded areas around Bau District using the ecological criteria i.e., natural regeneration status, IV, and SB. The specific objectives of this study are:

1. To compare the diversity of trees between four different forest types, namely PF, OSF, YSF, and AF in JHF,

2. To determine the differences between the natural regeneration status, IV, and SB, and
3. To determine the potential tree species for mixed-planting reforestation in degraded areas around Bau District using the ecological criteria i.e., natural regeneration status, IV, and SB.

1.2.3 Research Questions of Experiment 1

1. How big is the difference in species diversity between PF, OSF, YSF, and AF in JHF?
2. How big is the difference, between the natural regeneration status, IV, and SB?
3. What are the potential native species from JHF to be used for mixed-planting reforestation in degraded areas around Bau District?

1.2.4 Hypothesis Statements of Experiment 1

H1 : PF has the highest species diversity than the OSF, YSF, and AF in JHF.

H₀ : The species diversity does not differ between PF, OSF, YSF, and AF in JHF.

H_A : The species diversity differs between PF, OSF, YSF, and AF in JHF.

H2 : There are differences in natural regeneration status, IV, and SB between the PF, OSF, YSF, and AF in JHF.

H₀ : The natural regeneration status, IV, and SB does not differ between PF, OSF, YSF, and AF in JHF.

H_A : The natural regeneration status, IV, and SB differs between PF, OSF, YSF, and AF in JHF.

H3 : Species found in JHF have the potential for mixed-planting reforestation in degraded areas.

H₀ : All species found in JHF have the potential for mixed-planting reforestation in degraded areas.

H_A : Not all species found in JHF have the potential for mixed-planting reforestation in degraded areas.

1.2.5 Significance of the Study of Experiment 1

This study is important to measure ecosystem indicators. The ecosystem indicators include vegetation structure, habitat quality, soil fertility, and genetic variability (Trumbore et al., 2015). Measuring the vegetation structure and other indicators is important as these indicators are interrelated to the environmental changes (Wong & Neo, 2019). This study uses the term ‘vegetation structure’ interchangeably with the term ‘natural regeneration status.’ The measure of natural regeneration is important to produce information for tree diversity restoration (Chazdon & Uriarte, 2016). Regeneration study is also important to provide information on the potential and readily available native tree species for reforestation (Martínez-Ramos et al., 2016).

1.3 The Effect of Mycorrhizal Fungi and *Trichoderma* Application with Different Fertilizer Types and Amounts on *Durio zibethinus* and *Artocarpus heterophyllus* Growth

1.3.1 Background of Study for Experiment 2

The environment plays an important role in every living being's life. All living organisms depend on the environment for their existence and compete with others for the necessities in life. The term 'environment' can be defined as the physical and biological habitats around us, which can be felt by our physical senses. It is classified into two categories, namely (a) physical environment or abiotic environment and (b) living environment or biotic environment (Saravanan et al., 2004). The abiotic and biotic environments have an interchangeable relationship in which, both play crucial roles toward the continuity of one another. Hence, this study investigated the relationship between the abiotic component (MF-T) and biotic component (plants) of the environment.

Numerous studies have been conducted in the past to investigate the potential of MF-T as a biofertilizer. For example, Tsvetkov et al. (2014) stated that mycorrhizal fungi are important for a good rate of nutrient uptake of young host plants. Scientific evidence also proved that arbuscular mycorrhizal fungi (AMF) have the potential to be a good biofertilizer such as improving soil attributes, increasing above and belowground biodiversity, improving tree/shrub seedlings survival, and preventing invasive species (Asmelash et al., 2016). A study conducted by Guissou (2009) also found that the inoculation of mycorrhizal fungi positively affected tamarind and jujube growth in phosphorus-deficient soil as compared to the non-inoculated trees. *Trichoderma* also has been proven to be a good growth promoter

(Zhang et al., 2018). Besides that, it was also found to be beneficial in helping plants adapt and cope with stressful conditions (Mishra et al., 2016).

However, past research conducted to determine the effect of mycorrhizal fungi on the growth of plants, such as in Guissou (2009), Kumar et al. (2009), and Asmelash et al. (2016), mostly only involved the manipulation of different fungi species toward the plant's growth rate and degraded land restoration. Research conducted by Thamsurakul and Charoensook (2006) to establish the technology for utilizing mycorrhizal fungi to increase fruit trees also did not specify the most effective amount of fertilizer and mycorrhizal fungi for tree cultivation. A study by Fediala et al. (2014) then suggested a need for further field trials to establish the suitable amount and frequency of applications of any biofertilizers to obtain a better yield. Besides that, mycorrhizal fungi's success as biofertilizers is unpredictable since different plant species showed different responses toward the same AMF species mix (Berruti et al., 2016). In this case, it may result in no net benefits to the host plant. The co-inoculation of MF-T is also understudied. The study by Khoshmanzar et al. (2020) for example, only mentioned the increase of chemical contents in tomatoes after the co-inoculation of *Trichoderma harzianum* and *Glomus mosseae*. However, it failed to mention the effect of these increases.

Besides the research gaps found in past studies, it is also important to highlight some fundamental issues concerning the applications of MF-T as biofertilizers. The first issue is that both the MF-T are strongly influenced by the biotic and abiotic environments (Ranelli et al., 2015). This issue affects the determination of suitable fungi species and *Trichoderma* strains for a different environment. The second issue is that the MF-T abilities used in field conditions are yet to be widely experimented (Igiehon & Babalola, 2017). These issues

indicate the need for a more detailed study to investigate the suitability and adaptability of the selected fungi species and *Trichoderma* strains in different environments. Finally, the third issue is that the success rate of reforestation is still low despite the number of forest plantations established and more modernized techniques used in the field. This issue suggests a need for an alternative technique to ensure the success of reforestation.

Last but not least, the justification for selecting *D. zibethinus* and *A. heterophyllus* in this study was to imitate forest tree species. The diversity and structure of fruit trees found by Davivongs and Arifwidodo (2023) in Thailand are also similar to that of forested areas. They found differences in species diversity and canopy layers between the older and younger orchards. There is a difference in species succession between older and younger forests, contributing to differences in forest structure (Mackey et al., 2020). Older forest usually consists of trees belonging to the climax species, whereas the younger forest consists of pioneer species.

The difference in growth rate between *D. zibethinus* and *A. heterophyllus* is also similar to that of forest tree species. There are significant differences among forest ages in the dynamics of tree growth, death, and recruitment (Davies et al., 2021). Both selected species also show different growth. Depending on the varieties, *D. zibethinus* is a long-lived, slow-growing species (Ketsa et al., 2020). On the other hand, *A. heterophyllus* is a long-lived and fast-growing species (Ranasinghe et al., 2019). In its initial years, *A. heterophyllus* experiences rapid growth, gradually decelerating upon reaching maturity (Prakash et al., 2009).

Both tree species also show high economic and ecological potential, making them suitable to be planted for reforestation (Danarto & Budiharta, 2019). Agroforestry can

promote forest health while benefiting local communities (Murniati et al., 2022). A study by Muhamad Yusup et al. (2021) in Indonesia, suggested that fruit trees are comparable to timber tree species in terms of their high economic and ecological worth. Thus, they need to be prioritized for forest and land rehabilitation.

1.3.2 Objectives of Experiment 2

This study investigated the potential of MF-T in accelerating the growth of plants and, at the same time, accelerating reforestation. This study also aimed to establish suitable organic and chemical fertilizers with MF-T application for *D. zibethinus* and *A. heterophyllus* cultivation.

The specific objectives for this study are,

1. To analyse the effect of organic and chemical fertilizer with MF-T application on the growth (height and stem diameter) of *D. zibethinus* and *A. heterophyllus*.
2. To determine the suitable amount of organic and chemical fertilizer with MF-T for *D. zibethinus* and *A. heterophyllus* cultivation.

1.3.3 Research Questions of Experiment 2

1. How does the application of organic and chemical fertilizer with MF-T affect the growth (height and stem diameter) of *D. zibethinus* and *A. heterophyllus*?
2. What is the suitable amount of organic and chemical fertilizer with MF-T for a successful establishment of *D. zibethinus* and *A. heterophyllus*?

1.3.4 Hypothesis Statements of Experiment 2

H1 : The application of organic and chemical fertilizer with MF-T helps the growth (height and stem diameter) of *D. zibethinus* and *A. heterophyllus*.

- H₀ : There are no significant differences in the height and stem diameter of *D. zibethinus* and *A. heterophyllus* when treated with organic and chemical fertilizers with MF-T.
- H_A : There are significant differences in the height and stem diameter of *D. zibethinus* and *A. heterophyllus* when treated with OF and CF with MF-T.
- H₂ : All of the treatments are suitable for the successful establishment of *D. zibethinus* and *A. heterophyllus*.
- H₀ : All treatments help to accelerate the height and stem diameter of *D. zibethinus* and *A. heterophyllus*.
- H_A : Not all treatments help to accelerate the height and stem diameter of *D. zibethinus* and *A. heterophyllus*.

1.3.5 Significance of the Study of Experiment 2

This study is important for several reasons. The results will contribute to the forestry sector in increasing the effectiveness and success rate of reforestation projects in Sarawak. Effective reforestation initiative has proven to conserve and restore natural forests from further degradation while providing environmental services (Hashim et al., 2015). Besides that, using MF-T as biofertilizers will help to reduce dependencies on CF and promote sustainable agriculture practices (Revillini et al., 2016). The application of MF-T as biofertilizers will also help in maintaining and improving biodiversity (Sabogal et al., 2015). The method of MF inoculation in reforestation also will lower the cost of operation (Cordell et al., 2002).

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of Literature Review Chapter

The literature review chapter describes and forms the theoretical framework of this study. It is divided into ten sections. The first section reviewed the definitions of reforestation and the models used internationally. The second section narrated the history of reforestation, starting from the largest reforestation in China to the recent reforestation in Sarawak, dating back from the mid-1800s till the 2000s. Next, the third section describes the issues and challenges faced by forest managers in executing reforestation. The fourth, fifth, and sixth sections reviewed the three methods of reforestation i.e., natural forest regeneration, planting, and assisted reforestation. These methods are the key methods applied in this study. Last but not least, sections seven and eight reviewed the significance of species IV and SB to reforestation.

2.2 Reforestation Models

Generally, the term ‘reforestation’ is defined as an act of replanting trees in the forest. The term ‘forest restoration’ is also often used interchangeably to refer to the reforestation of a disturbed forest (Hanson et al., 2015). There are various definitions of ‘reforestation’ from all over the world. The earlier definition defined ‘reforestation’ as replanting the former tree that has been deforested during the past 50 years, either with a different or the same species as before (Bredemeier & Dohrenbusch, 2000). ‘Reforestation’ is also generally defined as an outlined action to attain the ecological and social aspects of deforested areas (Mansourian et al., 2005). The definition of ‘reforestation’ by FAO (2015a) states that

reforestation can be achieved through deliberate planting on forest land, and the definition excludes natural regeneration. However, the former definition was contradicted by Hanson et al. (2015) and Wan Mohd et al. (2015) when they mentioned that the method of reforestation can be divided into two namely, natural regeneration and assisted reforestation.

International Tropical Timber Organization (ITTO) [2016] later stated that ‘reforestation’ is rehabilitating trees and undergrowth plants after forest clearing. Reforestation models are divided into four namely, revegetation, ecological restoration, forest landscape restoration and functional restoration, and each model has different goals and measures of success, as listed in Table 2.1. Nonetheless, these models share one main goal, which is to restore the forests to their natural state (Stanturf et al., 2015).

Table 2.1: Four Types of Reforestation Models with Goals and Measure of Success

Types of Models	Goal/Measure of Success
Revegetation	- Restore degraded land to make it fit for agriculture/forestry - Social - Soil protection - Forest cover
Ecological restoration	- Restore forest structure and diversity
Forest landscape restoration	- Restore the ecological processes - Socioeconomic
Functional restoration	- Restore biological processes

Source: Adapted from Stanturf et al. (2015)

Despite all the contradicting definitions of reforestation, Chazdon (2008) has previously suggested that the reforestation management system can be applied depending on the state of degradation, visually shown in the forest restoration staircase (Figure 2.1). The outcomes of the specific restoration efforts are (1) Restoration of soil health for

agricultural/forestry utilization, (2) Production of timber and non-timber forest products and, (3) Rehabilitation of the biodiversity and ecosystem services. The state of land degradation is interconnected with deforestation (Qin et al., 2021). The land degradation occurs through the creation of forest edges and increased of forest perimeter exposed to source of fire ignition through deforestation. This has resulted to a loss of aboveground biomass.

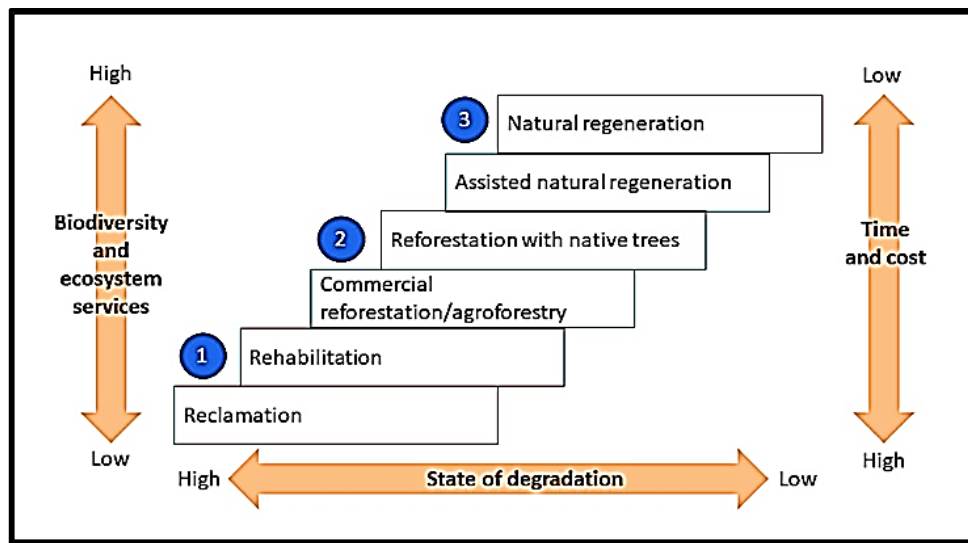


Figure 2.1: The Forest Restoration Staircase

Source: Chazdon (2008)

Reforestation is a very slow process, often taking more than 50 years to recover fully and the recovery time differs between different forest types and manipulation of forest structure (Shoo et al., 2016). The recovery process should not only focus on the forest structure but also include the diversity of understory plants, inland and water animals, soil health and structure (Cunningham et al., 2015). This study holds the definition of ‘reforestation’ as a method of restoring forests to their natural state (Stanturf et al., 2015) through two methods of reforestation i.e., natural regeneration and assisted reforestation (Hanson et al., 2015; Wan Mohd et al., 2015).

2.3 History of Reforestation

Reforestation dates back to the mid-1800s and has a long implementation history. Among the earliest countries to start reforestation is Brazil, which was in the mid-1800s. Reforestation has been implemented in many other countries. Countries such as Costa Rica, Denmark, Ethiopia, India, and Nepal started their restoration program as early as the 1950s. The restoration programs not only restore the forest landscapes but also help improve the soil quality, protect the watershed, conserve biodiversity, and provide economic support for the locals (Hanson et al., 2015).

The world's largest reforestation scheme, the Grain-for-Green Program (GFGP), was carried out in China in 1999. However, the monoculture system practised through this scheme falls short of restoring the diversity of vegetation and animals in the reforested areas (Hua et al., 2016). Previously, huge amounts of money have been invested in the Reforestation Policies in arid and semi-arid areas in China, yet the policies have also shown negative impacts on the environment, such as damaging the groundwater balances, lack of vegetation diversity due to monoculture practices, and increasing of desertification (Cao et al., 2010).

Malaysia, on the other hand, started the forest plantations with the *Palaquium gutta* (Nyatoh taban), *Ficus elastica* (Rambung), *Tectona grandis* (teak) and *Swietenia macrophylla* (mahogany) plantations in late 1880s to early 1990s, and further plantation trials have been established in subsequent years (FAO, 2002). The Forest Research Institute (FRIM) was set up in Kepong in 1927, and this marked the start of extensive experimental reforestation projects in Peninsular Malaysia. Multiple species have been planted over the years, such as teak, *Eucalyptus* spp., *Pinus* spp., *Gmelina arborea*, *Dryobalanops aromatica*,

Eusideroxylon zwageri, *Fragraea fragrans*, *Khaya* spp., *Rubroshorea macrophylla*, and *Azadirachta excelsa*. However, it has only involved planting high-quality timbers with a long rotation period, and the results were considered unprofitable. Hence, learning from this experience, initiating the reforestation works in Sabah and Sarawak is easier and faster (Krishnapillay et al., 2007).

A rainforest reforestation project was initiated in Sabah in the mid-90s through a collaboration between the South Pole Carbon Asset Management Ltd. and Sabah Foundation. The works involved include the silviculture management and enrichment planting of dipterocarp species and indigenous fruit tree species. The project has shown satisfying results, not only in protecting and conserving the endangered tree species and wildlife but also in the socio-economic development of local communities (South Pole [SP], 2013). Another reforestation project was carried out using *Paraserianthes falcataria*, *Eucalyptus deglupta*, and *Pinus caribaea* at a former copper mining area in Mamut, Ranau in the late 90s. The result shows that *P. caribaea* was adjusting well than the other tree species, and this suggests the potential of *P. caribaea* for the reclamation of degraded areas within the adjacent zones of the upper Mount Kinabalu (Lintangah et al., 2016).

Besides that, another ongoing reforestation project was conducted in 2007 at the Sungai Pinangah Forest Reserve within the concession of Rakyat Berjaya and Sabah Foundation Concession, Sandakan, Sabah with the cooperation between the Maxland Sdn. Bhd. of Rakyat Berjaya Sabah and Forest Research Institute Malaysia (FRIM). They adopted the Mosaic Planting Approach in which, the fast-growing trees such as *Khaya ivorensis*, *P. falcataria*, and *Neolamarckia cadamba* were planted between the silvicultural treated indigenous plants in the area. This project is predicted to produce a medium-sized diameter

logs of indigenous and fast-growing species in the next 15 to 20 years (Yahya & Albert Ikau, 2016).

Previously, Sarawak had less urgency to implement reforestation programs as it is still covered by vast areas of natural forest (Krishnapillay et al., 2007). The reforestation effort in Sarawak is mainly still at the experimental stage (Hattori et al., 2013). However, in the early 1920s, the Forest Department Sarawak took the initiative to develop the first forest plantation, which was started in Semengoh Forest Reserve. There was approximately a 19 ha area planted with indigenous tree species from the Engkabang group. The first Reforestation Research Programme was started in 1965 to study the potential of fast-growing exotic tree species. The forest plantations in Sarawak continued to grow after the amendment of the Forest Ordinance, which then includes section 65B in the Forests Ordinance, 1958 (Cap 126) on the regulation of the establishment of planted forests and the adoption of the Forests (Planted Forests) Rules 1997 under section 95(1)(w) and (x), which adds the regulations and procedures in the establishment of planted forests (Forest Department Sarawak, 2020a). A total of 23, 096 ha area of forest plantations has been established up to the end of the year 2000. This includes 16, 751 ha of areas planted with indigenous species, 4, 123 ha of exotic species, and 2, 222 ha of *Calamus* species (Forest Department Sarawak, 2020b).

Among the earliest reforestation programmes in Sarawak are the Sabal reforestation and agroforestry programmes, which were conducted in Sabal Forest Reserve in 1981 (Nor Rasidah, 2011). The planted forests in the Sabal Forest Reserve cover an area of 2, 063.20 ha (Forest Department Sarawak, 2020b). The exotic tree species, *Acacia mangium* was first planted and later, interplanted by the native species, *R. macrophylla* in the areas that were

abandoned after logging and shifting cultivation. The reforestation programme has shown positive results in increasing forest cover and providing employment opportunities for the locals (Nor Rasidah, 2011).

The reforestation programme in Sampadi Forest Reserve was first started in 1996 (Perumal et al., 2012). The forest reserve covers an area of 5, 163.70 ha (Forest Department Sarawak, 2020b). Dipterocarp species, *R. macrophylla* was planted in logged-over areas in the forest reserve (Aina et al., 2018). The success of this reforestation programme in increasing the forest cover and restoring biodiversity shows that *R. macrophylla* is one of the potential dipterocarp species to be planted in future reforestation projects due to its high survivability and good growth performance despite the poor site conditions (Perumal et al., 2012). Experimental plots in degraded tropical secondary forests in Niah Forest Reserve were set up from 2000-2007. Seedlings of *R. macrophylla* were planted on slopes and valleys with a variation of the forest structure and soil conditions. However, there were major differences in the trees' stand density and total aboveground biomass between the valley and slopes plots. It was then concluded that the soil structure and conditions factors should be considered to determine the success of enrichment planting with specific species (Hattori et al., 2013). Following the experimental plots, the forest plantations then were set up in the Niah Forest Reserve and up to the end of the year 2000, approximately 8, 442 ha areas have been planted. Niah Forest Reserve is the biggest forest plantation in Sarawak (Forest Department Sarawak, 2020b).

A reforestation project at secondary forests with a previous history of selective logging and agricultural activities in Gunung Apeng Forest Reserve, Sarawak, was also conducted in 2005. Various tree species have been planted, including *Dryobalanops*

beccarii, *R. macrophylla*, *Shorea falcifera*, *Rubroshorea parvifolia* and *Calophyllum alboramulum*. Among the tree species planted, *D. beccarii* has shown positive progress in terms of its survival rate and growth performance (Wasli et al., 2014). This indicates its potential to be planted in the reforestation efforts.

2.4 Issues and Challenges to Successful Reforestation

The measure of reforestation success can be categorized into two categories namely, the ecological attributes (diversity and abundance, forest structure and ecological process) and socioeconomic attributes. A review of past studies showed that 94% of studies measured the ecological attributes to define the success of reforestation, 1% measured the socioeconomic attributes, and the other 5% is a combination of both attributes (Wortley et al., 2013).

A similar review by Stanturf et al. (2014) in building a forest restoration paradigm stated that the measure of forest restoration success depends on ecological and human factors. The ecological factors consist of two paradigms namely, the vegetation structure and ecological process. The measure of forest restoration success is to restore these ecological paradigms to their original conditions.

On the other hand, the human factors include the landscape and functional restoration, with the goal of ensuring mutual benefits for communities depending on the target area. However, the sole involvement of local communities does not guarantee the success of reforestation. All relevant stakeholders should compromise with one another to further ensure the success of reforestation (Lazos-Chavero et al., 2016). Case studies of the success of reforestation efforts in South Korea, Vietnam, and China found that reforestation

success is often rooted in the government itself. The governments initiated the earlier reforestation works, including building a partnership involving all forest stakeholders and creating awareness of the importance of reforestation (Choi et al., 2019).

Despite all the efforts taken to measure and ensure the success of reforestation, there are a number of issues and challenges, which must be taken into consideration. A study by Lamb (2012) highlighted some issues of reforestation, such as the importance of native species, the number of species needed to rehabilitate the degraded areas fully, manipulation of the forest age stands, monetary issues, areas prioritization, and landowners' interest. The implementation of reforestation in the tropics also faces two main challenges namely, government policies and climate change. Government policies determine the success or failure of reforestation on the national level. The pressure to meet the carbon sequestration goal influences the enacted policies (Locatelli et al., 2015). Besides that, challenges such as funding, reforestation partnerships, technical support, and infrastructure also often occur at the administrative level, which further complicates and prolongs the implementation (Le et al., 2014). Modern biological and synthetic technologies are among other new challenges tropical reforestation faces (Stanturf et al., 2014).

On the contrary, climate change poses the biggest threat to species establishments, natural regeneration, and ecological processes on the local level (Locatelli et al., 2015). Natural regeneration in degraded areas may be slowed down due to several factors such as seed mortality due to harsh environments, repeat forest fires, forest hydrological disturbance, and loss of soil biological and ecological processes. It is also suggested that, in order to maximize the reforestation success, the forest manager should incorporate the key ecological principles such as the environmental conditions, native species selection and target

restoration site (Graham et al., 2017). Figure 2.2 shows the natural regeneration issues caused by forest degradation and reforestation methods that can be carried out to counter the issues. The natural regeneration issues that often result from forest degradation are seed mortality, forest fires, hydrological disturbance, and loss of soil biological and ecological processes. Four methods can be carried out to restore the forest namely, transplanting, fire management system, constructing canals or preserving the water source, and inoculating seedlings with mycorrhizae.

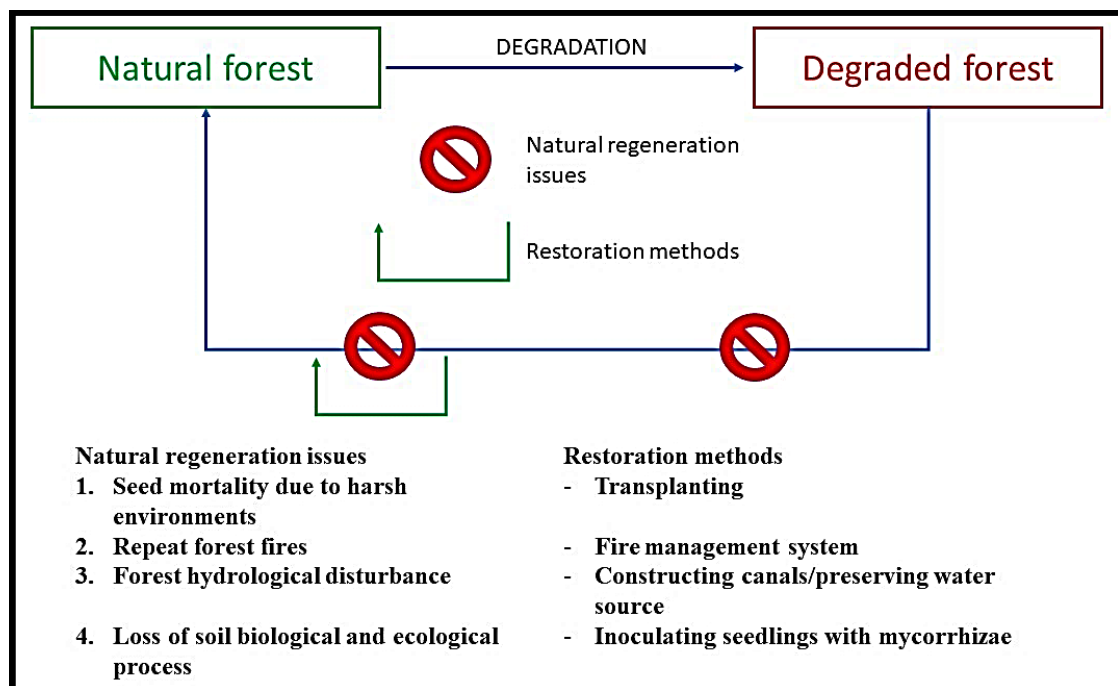


Figure 2.2: Natural Regenerations Issues and Forest Restoration Methods

Source: Adapted from Graham et al. (2017)

The world experiences have shown that reforestation is complicated and involves a long process (Stanturf et al., 2014). Yet, it holds the key to biodiversity security, biomass production, and climate change mitigation and adaptation. It also offers several social and economic benefits to the forest stakeholders (Chazdon & Uriarte, 2016).

2.5 Natural Forest Regeneration as a Mean to Reforest

The earlier definition of ‘natural regeneration’ defined it as the young plants derived from a natural seeding process or through coppice formed after the plants were cut, burnt, or blown out (Hubbard et al., 2006). It can also be defined as an increase in forest cover through a natural expansion of forests, for example, the abandonment of agricultural land and re-establishment of planted forests to other naturally regenerated forests in some European countries (FAO, 2010). It can also be defined as the forested areas constituted of more than 50% of the growing stock at maturity, including the sprouting, germination of surviving seeds after deforestation, and naturally regenerated trees of introduced species (Putz & Redford, 2010).

The recent definition of ‘natural regeneration’ defined it as the establishment of trees from the seeds produced and germinated on-site (Hanson et al., 2015). It is can also be defined as a process of forest renewal through the recruitment of young plants deriving from seedlings and then continuing to the sapling phase (Neuschulz et al., 2016). This process is known as the forest succession.

A study in the Amazon rainforest has shown uncertainties in rainforest succession (Mesquita et al., 2015). A succession of forests is mainly influenced by canopy cover and natural regeneration status at the time of forest disturbance (Bischoff et al., 2005). Notably, an abundant canopy cover possesses the potential to constrain the proliferation of light-dependent vegetation. In contrast, species with a disposition for shade tolerance exhibit robust successional trajectories, even within environments characterized by a dense canopy cover. The extent of forest degradation further influences the quantity and viability of extant natural regeneration processes. The effectiveness of land-use strategies also plays a crucial

part in defining the trajectory of forest succession's success (Mesquita et al., 2015). The complex interaction between anthropogenic factors and ecological dynamics highlights the need for a thorough understanding of how various land-use strategies interact with natural processes to influence the results of forest succession eventually.

Natural regeneration is affected by several biotic and abiotic factors. A study by Neuschulz et al. (2016) in 34 countries shows a positive relationship between natural regeneration and seed dispersers. More than 87.5% of tropical angiosperms depend on animal pollinators such as birds, bees, and mammals during the early recruitment process. Hence, forest disturbance, including land-use changes, forest exploitation, and animal poaching, will play a negative influence on this relationship. Site characteristics such as altitude also play a significant role in the species composition, diversity, and regeneration potential of trees, as shown in a study in India (Saha et al., 2016). The abiotic factors such as disturbance history and the time passed since restoration started also determine the rate and quality of the restoration in the tropical forests (Crouzeilles et al., 2017).

Previously, Simonsen (2013) also found that the natural regeneration of *Pinus sylvestris* L. (Scots pine) in Sweden was the most optimal method compared to the planting method by considering the location, site index, and discount rate. He also stated that planting was considered optimal only for stands with the most productive sites and a low seedling mortality rate.

However, implementing a large-scale natural regeneration programme is not easy as it also faces major challenges such as reforestation policies, lack of government support, and conflict between the government and the community (Chazdon & Guariguata, 2016). Besides that, the programme also being constrained by the community's bad perception, lack

of research and information, inadequate capacity, and inadequacy of supportive governance (Chokkalingam et al., 2018). The natural regeneration and forest colonization process is also a slow process, especially in highly degraded areas (Brancalion et al., 2016).

The challenges can be overcome through moderate disturbance. Moderate disturbance plays a crucial part in improving species richness and accelerating the natural regeneration process (Brancalion et al., 2016). This method is called assisted natural regeneration (ANR) (Nunes et al., 2017). It does not only assist the natural regeneration but also the enrichment planting, fire management, protection against over-grazing, and weeding.

The effectiveness of ANR in conserving soil and water, protecting biodiversity, accumulating biomass, and enhancing ecosystem services has been proven through experimental forest stands in China. The ANR works involved include maintaining the seedlings of dominant species, weeding of non-planted species, and thinning of crowded shoots (Yang et al., 2018). ANR in the forest arboretum in Sri Lanka also shows positive results in increasing the soil's total organic carbon density and it was found that the organic matter content in the area is higher than in other areas in the country (Nalaka et al., 2011). ANR costs less than tree planting, as shown by an example from Brazil.

Ecologically, natural regeneration has a higher success rate in restoring vegetation structure and biodiversity than assisted reforestation or replanting (Crouzeilles et al., 2017). Natural regeneration is also a simple, cheaper, and more efficient method as compared to assisted reforestation, although the success is also highly dependent on the forest ecological health (FAO, 2015b). Nunes et al. (2017) calculated the estimated operational costs for different forest restoration methods in Brazil. They found that the natural regeneration

method costs less than assisted natural regeneration and replanting methods. The highest difference was in the private costs between natural regeneration (175 ± 47 million USD) and replanting (508 ± 126 million USD). The average minimum carbon price to practice ANR was $\$65.8 \text{ t CO}_2^{-1}$ as compared to trees planting, $\$108.8 \text{ t CO}_2^{-1}$, which is 60% lower and can sequester 1.6-2.2 times more carbon (Evans et al., 2015).

A management strategy to demonstrate a low-cost method with the assistance of the local community was prepared and tested in Himachal Pradesh, India, in 2012. The management strategy involves nine critical steps namely, identification of stakeholders, outlining the stakeholders, community commitment, planning the negotiation, training, designing the negotiation plan, demonstration, documenting the process, and concluding action. The demonstration step conducted then has enabled the local authority to foresee a low-cost ANR strategy for a larger area (Tetra Tech, 2017).

2.5.1 Methods of Natural Forest Regeneration Survey

The forest natural regeneration survey can be divided into two types namely, the survey of either mature trees or seedlings/saplings only and the multi-aged regeneration survey. In a study by Alamgir and Al-Amin (2007) in Bangladesh, they calculated the Importance Value Index (IVI) of only the seedlings and saplings found in the study areas. Subsequently, they calculated the abundance and frequency ratio for different tree species to determine the distribution patterns. The distribution patterns were divided into three types of natural regeneration status namely, regular (< 0.03), random ($0.03 - 0.05$), and contagious (> 0.05). On the contrary, Gonçalves et al. (2017) only measured the trees with > 5 cm diameter at breast height (DBH) to determine the forest regeneration in three former agricultural abandoned areas and a mature forest area in Africa. The analysis carried out

were Shannon diversity index, Buzas and Gibsons' Evenness index, a non-parametric test to assess the differences of stand density between the areas, the IVI, the Principal coordinate analysis (PCoA), analysis of similarity (One-way ANOSIM), and Indicator species analysis (ISA).

The multi-aged regeneration survey is more widely used as compared to the survey of seedlings or mature trees at one time. Saha et al. (2016) measured the natural regeneration status of tree species in three different altitudinal ranges of the temperate forest in Garhwal Himalaya using the method of measuring the circumference at breast height (CBH) of the trees (> 30 cm CBH), saplings (10 - 30 cm CBH) and seedlings (< 10 cm CBH). The study then calculated the species richness, diversity index, and IVI to determine the natural regeneration status in the study areas.

In a different study by Ebert et al. (2014) in southern Amazon, Brazil, they measured both the tree height and DBH to determine the floral composition, species diversity, plant size category, and phytosociological structure in a tropical secondary forest. The multi-aged trees were divided into five categories of natural regeneration status i.e., seedling (0.3 - 1.5 m tall), seedlings (1.5 - 3.0 m tall), change established (> 3.0 m tall and < 5.0 cm DBH), rod 1 (5 - 10 cm DBH) and dipstick 2 (10 - 20 cm DBH). The natural regeneration estimation, expressed in percentage, was then calculated using the values of frequency and absolute abundance of each species in each size class.

Another study by Kuma and Shibru (2015) in Ethiopia measured the ratio of a tree (≥ 2.5 cm DBH): seedling (< 2.5 cm DBH and ≤ 0.6 m tall): sapling (2.5 - 15 cm DBH and 0.61 - 3 m tall) to determine the floristic composition, vegetation structure, and regeneration of woody species of a dry woodland forest. The natural regeneration status was divided into

four categories namely, good regeneration: seedlings > saplings > adults, fair regeneration: seedlings > or $\leq$ saplings $\leq$ adults, poor regeneration: if the species survives only in the sapling stage (saplings may be $\leq$ or $\geq$ adults) and not regenerating: if a species is present only in an adult form.

The study by Do et al. (2016) was conducted in areas of high-impact logging, low-impact logging, and an undisturbed forest in Vietnam to determine the tree, sapling, and seedling's density and basal area (BA). The permanent plots were used to sample trees (DBH ≥ 10 cm), saplings (DBH < 10 cm and height ≥ 2 m), and seedlings (height < 2 m). The density and BA of trees, saplings, and seedlings were calculated and compared between the three forest types.

On the contrary, Bogale et al. (2017) measured the natural regeneration status of trees and shrubs in a single type of forest in Berbere Forest, southeast of Ethiopia. The distinction of natural regeneration status used was a tree (DBH ≥ 10 cm and 2 m height), sapling (DBH < 10 cm and 0.5 m > height < 2 m) and seedling (≤ 0.5 m height). Structural data analysis of DBH, height, BA, density, frequency, IVI, and comparison of seedling: sapling: mature tree's density was then conducted to analyse the structure and natural regeneration status. The regeneration rate was categorized into five categories namely, good': if the density of seedling > sapling > tree, fair: if the density of seedling > sapling < tree, poor: if only sapling present, none: if only tree present, and new: if only sapling and seedling present.

Another similar study conducted by Abunie and Dalle (2018) in the Yemrehane Kirstos Church Forest, Ethiopia also divided the tree's status based on the DBH and height. All the trees and shrubs with DBH > 2.5 cm and height > 2 m were categorized as mature trees and the undergrowth with height < 1 m was categorized as seedlings and height 1 to 2

m as saplings. The vegetation data then was analysed to determine the floristic composition, vegetation structure, frequency, species diversity and evenness, IVI, diameter, height class distribution, and natural regeneration status. The natural regeneration status was determined through the ratio of seedling: sapling: mature tree per hectare.

The regeneration study by Khaine et al. (2018) also used a similar method of classifying the tree status in which, mature trees: > 5 cm DBH, saplings: < 5 cm DBH and > 130 cm height and seedlings: > 30 cm to 130 cm. The natural regeneration status of the tropical forests in Myanmar was divided into two categories namely, the natural regeneration status of the forest as a whole and the natural regeneration status of different species. The natural regeneration status was categorized into four categories namely, good regeneration: seedling $>$ mature; sapling $>$ mature; fair regeneration: seedling $>$ sapling; sapling $\leq$ mature; poor regeneration: sapling absent, but seedling $>$ mature or seedling absent, but sapling more than mature; and no regeneration: only mature present.

One of the recent studies conducted by Atsbha et al. (2019) in Ethiopia then divided the tree' status based on both DBH/diameter at stump height (DSH) and height i.e. (i) seedling: DSH < 2.5 cm and height 1 to 50 cm, (ii) sapling: DBH/DSH < 2.5 cm and height 50 to 150 cm and (iii) mature tree: DBH/DSH ≥ 2.5 cm and height ≥ 1.5 m. The natural regeneration status of the study areas was then analysed by comparing the total number of seedlings and saplings with the number of mature trees. Besides that, mathematical analyses including species richness (S), evenness (E), Shannon-Weiner Diversity Index (H'), IVI, and BA were also used to analyse further the diversity and population structure in the study areas.

Despite the differences in forest regeneration methods, the importance of these efforts outweighs all the hard work taken. Ecologically, measuring the natural forest

regeneration rate is important to picture the ecological factors and human or natural activities affecting the vegetation of the area (Kuma & Shibru, 2015). Economically, it is also important to safeguard the continuity of timber production from the natural forest while managing it sustainably (Do et al., 2016).

2.6 Method of Assisted Reforestation by Replanting Trees

Assisted reforestation is the process of forest restoration by replanting trees (FAO, 2015a). However, it can also be categorized into two categories namely, replanting trees and experimental or natural intervention in the reforested areas (Hanson et al., 2015). However, replanting trees is always the popular method of reforestation for example, in Malaysia (Krishnapillay et al., 2007; Kammesheidt, 2017), Indonesia (Hesti et al., 2014), China (Xu & Jiang, 2009; Frayer et al., 2014) and Vietnam (Thang et al., 2018; Choi et al., 2019).

The success of tree replanting in Serbia is heavily affected by tree species selection and species characteristics (Ivetic, 2015). The study by Grossnickle and Ivetić (2017) also reviewed that species richness and competition in the planted area, site qualities, seed predation, and growth performance of seeds as compared to the seedlings also contribute to the success of replanting techniques. Tree replanting can be carried out either by direct seeding or planting seedlings (Palma & Laurance, 2015). However, planting seedlings is more favoured due to higher survivorship and the possibility of accelerating the structural recovery. The species selection for trees replanting in the tropics is always the fast-growing and early successional species (Cunningham et al., 2015). Species with a fast growth rate are also important to accelerate the recovery process of degraded areas in Malaysia (Lintangah et al., 2016). The early successional species was preferred most as this species has a high tolerance to environmental stress, such as high light intensity, and dry and low soil nutrients

(Chechina & Hamann, 2015). Besides that, Lu et al. (2017) in their study in China, also found that, besides the survivability and growth rates factors, the seeds' suitability for technology propagation at the local level should also be taken care of.

In the past, exotic species with fast growth rates have always been preferred to be planted monoculturally in Malaysia (Krishnapillay et al., 2007). Although this practice was able to promote rapid forest recovery, it has been extensively criticized due to its underlying risks of susceptibility to mass mortality due to pests and pathogens epidemic, lack of ecosystem services provided, and threatening faunal forest-dependent species as shown in the subtropical forest restoration in China (Lu et al., 2017). However, the trends have changed from planting exotic species to native species such as in Sabah, Malaysia, in which a native species of *Peronema canescens* (sungkai) was planted in the forest plantations due to its fast-growing characteristics (Kammesheidt, 2017). Recently, an attempt to plant the slow-growing climax species alternately with the fast-growing pioneer species, such as in Australia, showed promising potential to accelerate reforestation (Charles, 2018).

Besides that, there are also efforts to introduce fruit trees in reforestation areas such as in the Philippines. However, the success of this effort is highly influenced by funding and organizational factors (Cagalan, 2016). A study by Xu et al. (2019) in China also found that, although fruit trees proved to be efficient in improving forest coverage, the fruit trees have a negative effect on the surface water run-off of the forest. The high intensity of fruit tree maintenance, such as weeding, and pruning, will increase the degree of surface water run-off, and there is a high chance of flooding in the areas.

The success of tree replanting is also influenced by the conditions of the reforestation area. The forest canopy opening due to high-intensity selective logging promotes the seed's

germination and growth of the shade-intolerant species (Do et al., 2016). Shade-intolerant species or light-demanding species, are often the pioneer species that can grow in an open area with abundant sunlight and are often found in newly established secondary forests (Wang & Meng, 2018). This species also has a high relative growth rate as compared to shade-tolerant species (Feng et al., 2018). Ecological factors such as total soil nitrogen (N), phosphorus (P), and topography also show significant effects on the establishment of newly planted seedlings (Cheesman et al., 2017).

2.7 Method of Assisted Reforestation through Experimental or Natural Intervention

Human interventions to reforest the degraded area, such as direct seeding and artificial bird perches, have shown mixed success in Ecuador (Palomeque et al., 2017). A review of 120 studies showed that direct seeding is able to contribute to species diversity (Palma & Laurance, 2015). However, the on-field survivorship is lower than planting seedlings. A study by Elgar et al. (2014) also found a promising result of human intervention toward the success of reforestation through weeding using herbicides and facilitating seed dispersal using perches in Australia. Experimental manipulation such as the utilization of genetically modified seeds of Scots pine in Sweden may also contribute favour towards planting methods (Simonsen, 2013).

Previously, Shoo and Catterall (2013) reviewed that alleviating soil conditions such as cutting, pulling, and burning produces little effect on forest recovery. However, recent research advancement has promoted mycorrhizae application to improve soil conditions. The mycorrhizae application has also been mentioned by Graham et al. (2017) as one of the methods to restore degraded areas.

Planting trees and promoting natural regeneration at the same time has also shown successful results in accumulating biomass and tree diversity in Brazil (Bertacchi et al., 2016). The main factors contributing to this success are the availability of surviving native seeds, dispersal agents, and native-introduced species co-relationships in creating a suitable condition for growth.

2.7.1 Mycorrhiza and *Trichoderma*'s Influence on Plants' Growth

The term 'mycorrhiza' is derived from the Greek words for 'fungus' (myco) and 'root' (rrhiza). The recent definition of 'mycorrhiza' is the mutualistic relationship between plant roots and fungi (Yasnolob et al., 2017). Mycorrhizal fungi can be found in areas such as alpine and boreal forests, tropical forests, grasslands, and croplands (Bonfante & Genre, 2010). They are part of the important soil organisms (Saravanan et al., 2004).

Over the years, studies on mycorrhiza have found seven known types of mycorrhiza, including endomycorrhiza, ectomycorrhiza, ectendomycorrhiza, ericoid mycorrhiza, arbutoid mycorrhiza, monotropid mycorrhiza, and orchid mycorrhiza (Barman et al., 2016). There are seven major types of mycorrhizas and their plant-specific association in all types of forests (Table 2.2). Among these, endomycorrhiza also known as arbuscular mycorrhizal fungi (AMF), have started to gain attention as biological control organisms.

Table 2.2: Major Types of Mycorrhizae and Their Plants-Specific Association

Mycorrhizal Type	Fungal Taxa	Plants Association
Endomycorrhiza (also known as arbuscular mycorrhiza)	Glomeromycota	Mostly herbs, grasses, trees, hornworts, and liverworts
Ectomycorrhiza	Basidiomycota, Ascomycota and Zygomycota	Pinacaceae and angiosperms (shrubs and trees in temperate forests), some liverworts
Ectendomycorrhiza	Wilcoxina (<i>W. mikolae</i> , <i>W. rehmi</i>), <i>Sphaerospora brunnea</i> and, to a lesser extent, <i>Phialophora finlandia</i> and <i>Chloridium paucisporum</i>	Pinus and Larix
Ericoid mycorrhiza	Mostly Ascomycota and some Basidiomycota	Ericaceae and some liverworts
Arbutoid mycorrhiza	Basidiomycota	Ericales
Monotropid mycorrhiza	Basidiomycota	Monotropoideae
Orchid Mycorrhiza	Basidiomycota (Ascomycete) and Ascomycota (Basidiomycota)	Orchids

Source: Adapted from Yu et al. (2001); Barman et al. (2016); Prasad et al. (2017); Yasnolob et al. (2017)

AMFs are acknowledged as natural biofertilizers. They have a mutualistic relationship with the host plants in which, they interchange the nutrients and water with photosynthetic products produced by the plants. The propagation of AMF starts with the infection of contagious hyphae, hyphal particles, or asexual spores into the plant roots, and followed by colonization of the infected roots and nearby ones through the development of the branching structures or arbuscules from the branch hyphae. The arbuscules help in increasing the contact area between the plant roots and the fungus, and it is the primary point of the plant's carbon and fungus's phosphorus transaction (Prasad et al., 2017). The AMF

mycelium is also thinner than the plant roots and this allows the root system to acquire the nutrients unattainable to plant roots (Berruti et al., 2016).

Reviews of past studies found that AMF helps in increasing the plants' nutrient uptake, such as carbon, nitrogen, phosphorous, and potassium and allows nutrient transfer among plants. A study by Berruti et al. (2016) stated that several metal transporters namely, zinc, copper, and iron, were identified in *Glomus intraradices*. The presence of metal transporters shows the possibility of *G. intraradices* playing a major role in heavy metal homeostasis.

Glomus sp. has good potential as a plant growth promoter (Zhang et al., 2018). The relative abundance of *Glomus* spp. was found to have a positive correlation with *Leymus chinensis* biomass, indicating its' benefit towards *L. chinensis* growth. Some species in the *Glomus* genera, such as *G. fasciculatum* were found beneficial in improving Casuarina seedling quality (Chaturvedi et al., 2017). A study by Mishra et al. (2016) also found that *G. intraradices* have a beneficial effect on plants by increasing their antioxidant status and promoting development under stress. The study emphasises the potential of AMF to support plant health and resilience, particularly when plants are exposed to environmental stressors that may obstruct their growth and development. The results show that exploiting the advantageous interactions between plants and AMF can have practical applications in forestry, agriculture, and ecological restoration. AMF may help to reduce the detrimental effects of stressors on plants by encouraging the synthesis of antioxidants, nutrient uptake, and general plant health, eventually fostering sustainable plant development in stressful environments.

Previously, Mrabet et al. (2014) demonstrated that the application of AMF significantly boosted the growth of *Argania spinosa* trees in both nursery and field conditions in the Admine forest of Agadir, Southwestern Morocco. The symbiotic interaction between the plant roots and the AMF certainly contributed to this improvement in development by facilitating improved nutrient uptake, notably of phosphorus and other crucial minerals. AMF-inoculated seedlings developed more favourably in the nursery than non-inoculated seedlings did. Such achievement in the nursery is essential to produce strong, healthy plants that can be later transferred into field situations. AMF has beneficial impacts outside of the nursery as well. The treated seedlings continued to grow and develop more favourably than their untreated counterparts after they were moved to the forest's field.

A study by Setyaningsih et al. (2020) also demonstrated that the inoculation of *Samanea saman* seedlings with AMF and rhizobial bacteria (RB) on gold-mine tailings in Indonesia had positive effects on plant growth. The synergistic effects of these microbes on improving nitrogen uptake and general plant health were what caused the increase in plant growth. The uptake of nutrients by plants is aided by both AMF and RB. While RB aids nitrogen fixation, AMF improve nutrient absorption, particularly phosphorus. A more complete nutritional supply for the seedlings was achieved by inoculating with both microorganisms.

The study conducted by Husna et al. (2021) in Indonesia focused on the inoculation of AMF in nurseries and post-gold mining fields, with a particular emphasis on its effects on the growth of *Pterocarpus indicus* and *Pericopsis mooniana*. The result showed that both *P. indicus* and *P. mooniana* grew more rapidly after being treated with AMF. This strategy can potentially increase the survival and development rates of valuable tree species in

challenging environments, aiding in attempts to reforest and restore the ecological system. The findings of this study also show how reforestation initiatives can be made more successful by utilising beneficial soil microbes like AMF, especially in locations with damaged soils or difficult conditions. The results of the study have implications for conservation efforts and sustainable land use practices, highlighting the significance of encouraging advantageous symbiotic connections between plants and soil organisms.

AMF also helps in stabilizing the soil structure by providing the skeletal structure in the soil even after the host's death (Asmelash et al., 2016). AMF has shown good potential in reducing soil erosion, environmental clean-up from hazardous contaminants, and eliminating harmful organisms in soil (Igiehon & Babalola, 2017). An example of AMF's potential to eliminate harmful organisms in soil was shown in a study by Sundram et al. (2015) in Malaysia. They evaluated the combined effect of AMF and endophytic bacteria in lowering the development of basal stem rot disease in oil palms (*Elaeis guineensis*). The combination of AMF and *Pseudomonas aeruginosa* UPMP3 has demonstrated a considerable improvement in basal stem rot disease control during the trial planting. This offered a potentially successful alternative to basal stem rot disease control in the oil palm plantation.

On the other hand, *Trichoderma* is the most studied and used AMF in the agricultural and forestry sectors (Contreras-Cornejo et al., 2016). Applications of several *Trichoderma* strains, such as *T. viride* and *T. harzianum*, with biofertilizers, also help in promoting plant growth (Hyder et al., 2017). The *Trichoderma* ability to promote growth is due to their production of secondary metabolites such as 6-pentyl-alpha-pyrone produced by *T. harzianum* and konigin A, produced by *T. koningii* (Kumar & Ashraf, 2017).

T. harzianum has been tested for its ability to promote the growth of some soybean varieties (Izuogu & Abiri, 2015). It was found that the plants treated with *T. harzianum* showed significant growth differences from the untreated plants. It also showed positive impacts in inhibiting the growth and development effects of the root-knot nematode in the savannah areas in Nigeria.

Trichoderma acts as biocontrol agent against the target pathogens through hyperparasitism mechanism, which allows the fungus to inhibit the growth and development of soil-borne pathogens (Kumar & Ashraf, 2017). *Trichoderma* has proven effective as a biocontrol agent against *Rhizoctonia solani*, a soil-borne pathogen that causes severe damage to crop, including trees. *Trichoderma* also has been used in disease control of damping-off of beans and cucumber, sheath blight of rice, black scurf of potato, and root and crown rot at a bigger agricultural level in China (Abbas et al., 2017).

A study by Cavero et al. (2015) in Brazil, investigated the effects of 29 *Trichoderma* isolates in inhibiting the growth of *Mycosphaerella fijiensis*, which causes black Sigatoka disease in bananas. Out of all 29 isolates, *T. atroviride* has shown the potential to control this disease in which, the ability to control the disease is almost the same as fungicide Azoxystrobin.

Another study conducted by Chen et al. (2016) in China found that another *Trichoderma* isolate, *T. gamsii*, is a promising biocontrol agent against several soil-borne pathogens that cause root rot disease, such as *Phoma herbarum*, *Fusarium flocciferum*, *Scytalidium lignicola*, and *Epicocum nigrum*, on *Panax notoginseng*. The *P. notoginseng* roots treated with *T. gamsii* were found to remain healthy throughout the experiment. The treatment of *T. gamsii* with chemical fertilizers also showed that this fungus can grow in

concentration levels of up to 20%. A study conducted by Barari (2016) in Iran was conducted both in a controlled environment (in vitro) and greenhouse (in vivo), and both showed positive results of *Trichoderma* effects towards the tomato plant pathogens, *Fusarium oxysporum*. The study has proven the effectiveness of *Trichoderma* inoculation in inhibiting the mycelial growth of *F. oxysporum*, which directly limits wilting incidence and helps accelerate tomato growth and yield. A later study conducted by Patel and Saraf (2017) in India also discovered that inoculation of *T. asperellum* into the soil has shown positive results toward the growth of tomatoes and the incidence of wilting by *F. oxysporum*.

Trichoderma is not only effective in promoting plant growth and inhibiting soil-borne pathogens but also effective in slowing down postharvest diseases spread, such as anthracnose, caused by *Colletotrichum gloeosporioides* as shown in a study from Mexico. The inoculation of *T. viride* before the inoculation of *C. gloeosporioides* and *T. asperellum* at the same time as the inoculation of *C. gloeosporioides* showed that these *Trichoderma* strains have the highest efficiency in slowing down the disease on papaya. The inoculation of these fungi also did not change the papaya colour, which shows the potential of these fungi to be used as a postharvest treatment for papaya, which indirectly allows the papaya to be stored longer (Valenzuela et al., 2015).

2.8 Importance Value of Species and Its' Relationship with Reforestation

Understanding the importance and dominance of species within a community structure is crucial for assessing the ecosystem's dynamics. The IVI has always been used to compare and classify the species that predominated in the plots or areas (Mohd Hasmadi et al., 2017). It is calculated by summing the relative density and relative dominance values of a species. This provides a single value that represents the species' overall significance within

the community. A higher IVI suggests that the species is both numerically abundant and ecologically influential in terms of resource usage or space occupancy. Abundance plays a role in vegetation surveys, unveiling, accentuating, and giving precedence to communities beyond the tree category (Bhadra & Pattanayak, 2016). Species dominance within a plot is also measured by the IVI. For the tree community, dominance is appropriate due to the larger girths of tree species. A species with a high IVI is dominant in the plot in terms of its contribution to both density and dominance, which has a big impact on the community's structure (Mohd Hasmadi et al., 2017). Consequently, the IVI of species in both trees and other communities should be assessed distinctly, accounting for dominance and abundance separately (Bhadra & Pattanayak, 2016).

A study by Nguyen et al. (2014) in the Philippines focused on the IVI as a crucial factor in assessing stand composition and structure, particularly in the plantation areas. Within the studied plantation areas, they noticed a change in IVI of species in the areas. This change illustrated changes in several species' relative abundance and dominance over time. This change in IVI reflects changes in the dynamics of the plant community, including things like species establishment, competition, and perhaps management techniques. The observed change in IVI implies that the environmental factors present in the plantation regions had an impact on the development and growth of different species. Changes in IVI may be a sign of how a species is adjusting to its environment, including interactions with other species or changes in the soil's properties or light availability.

The IVI also assists in comprehending species' functions, determining whether they are suitable for planting, and making defensible choices to promote ecosystem health and restoration initiatives (Asigbaase et al., 2019). The results of Asigbaase et al. (2019) study

in Ghana found that a species' suitability for planting in a specific environment can be determined using the IVI. The researchers could determine which species were naturally surviving in the area and hence had a higher possibility for successful establishment through planting by calculating IVI. Species with a high IVI in a particular area are also found to be more likely ecologically adapted to the local conditions, including soil type, climate, and interactions with other species. This ecological adaptation increases the likelihood of successful growth and survival if these species are introduced through planting.

Besides that, in their study in Indonesia, Erry Wiryani et al. (2018) found that IVI is a helpful statistic to evaluate how various species contribute to ecological services. It aids in assessing the relative contributions of species to processes like the management of water, the cycling of nutrients, and the supply of habitat. The IVI can, therefore, support decision-making in planning land use, reforestation, and ecosystem restoration. Managers can prioritise the conservation or planting of those species for the health and resilience of the ecosystem by knowing which species have greater importance values.

In contrast, a lower IVI value was also found to have an implication of conservation, as found by Maua et al. (2020) in Kenya and Reshad et al. (2020) in Ethiopia. They discovered that species with lower IVI values were typically less abundant and less dominant in the ecosystem. The loss of their habitat, competition from other species, or other stressors may be the issues these species are struggling with. Threatening species with low IVI values can alter the ecosystem functioning and have an impact on other species that depend on them. They also emphasized that species with low IVI values indicate the need for conservation strategies.

2.9 Biomass and Its' Contribution to Reforestation

Forest biomass is the entire mass of live and dead organic matter in a forested ecosystem, including trees, bushes, plants, and decomposing material on the forest floor (Duncanson et al., 2019). It is an important parameter for effective forest management and climate change mitigation. Accurate estimation of forest biomass contributes to better forest management. Changes in biomass over time can assist in identifying patterns in forest growth, health, and production. When forests are managed properly and remain untouched, they continue to sequester carbon, assisting in the reduction of greenhouse gas concentrations in the atmosphere. Monitoring variations in biomass is critical for determining how effective forests are at sequestering carbon and contributing to global climate change initiatives (Rajeev & Singh, 2020). It was shown in a study by Fedorov et al. (2023) that forest biomass increases with the successional stages. At the same time, the carbon content in the forest stands, root biomass, and soil organic matter also increased with the growth of the tree.

The forest biomass can be measured using two methods i.e., destructive and non-destructive methods (Vashum & Jayakumar, 2012). The destructive method entails harvesting trees in a specific location to weigh the various components of the harvested tree, such as the branch, leaves, and trunk. This method, however, could be more practical for large-scale investigation and is inapplicable to degraded forests. On the other hand, the non-destructive method then applies a different approach. It involves a non-felling method. The estimation was carried out by measuring DBH, height, volume, and wood density. The biomass was then calculated using the allometric equations. However, this method is as reliable as the destructive method. The non-destructive method can also be carried out using

remote imagery (Kumar & Mutanga, 2017). Among different types of data, LiDAR (Light Detection and Ranging) is a modern remote sensing technology that has gained popularity in biomass estimation. LiDAR data may be used to estimate forest biomass by analysing the height and density of plants. The 3D nature of LiDAR data allows for precise measurements of tree height, canopy structure, and even individual tree volume. LiDAR's capacity to offer accurate information about forest structure and biomass distribution has made it a significant tool for measuring forest health, carbon storage, and ecosystem dynamics without inflicting environmental damage, aiding sustainable forest management practices.

Reforestation is an effort to restore a degraded forest based on a reference natural ecosystem (Di Sacco et al., 2021). Reforestation attempts to counteract the negative effects of deforestation, land degradation, and habitat loss by attempting to mimic the characteristics of the reference ecosystem. The markers of success become more visible as the forestry project goes beyond its earliest stages. The abundant growth of trees and vegetation is reflected in biomass, which is the total mass of living organic matter above ground. The changing forest structure, which includes tree height, density, and spatial layout, illustrates the formation of a diversified and balanced ecosystem. Biodiversity restoration, as evidenced by the reintroduction of native species and increased species richness, demonstrates the ecosystem's resilience and potential to maintain a diverse range of flora and fauna. The improvement of ecosystem functioning, such as nutrient cycling, water control, and carbon sequestration, is also noteworthy, highlighting the reforested area's importance in supporting broader biological and climatic processes. These numerous indicators interact and change, providing a holistic picture of reforestation progress and the favourable trajectory towards ecological rejuvenation and sustainability.

2.10 Summary

This chapter reviewed past studies relating to reforestation. Reforestation is categorized into two methods namely, natural regeneration and assisted reforestation by replanting trees and experimental interventions such as mycorrhizal fungi and *Trichoderma* (MF-T) inoculation to promote growth. Both methods are faced with both human and ecological issues and challenges. However, several successful implementations of reforestation for example, in Malaysia, indicate a high possibility of another successful project. Learning from the past, improvement of reforestation methods is a must to beat the fast deforestation rate.

CHAPTER 3

METHODOLOGY

3.1 Overview of Methodology Chapter

The methodology chapter is divided into two sections namely, (a) Experiment 1: Predicting the Potential Species for Reforestation Based on Natural Regeneration Status, Importance Value and Standing Biomass, and (b) Experiment 2: The Effect of Mycorrhizal Fungi and *Trichoderma* Application with Different Fertilizer Types and Amounts on *Durio zibethinus* and *Artocarpus heterophyllus* Growth. Each section is further divided into three sub-sections i.e., (i) study area, (ii) materials and methods, and (iii) data analysis.

3.2 Predicting the Potential Species for Reforestation Based on Natural Regeneration Status, Importance Value and Standing Biomass

3.2.1 Study Area of Experiment 1

The regeneration study was carried out at Jagoi Heritage Forest (JHF) starting from December 2017. JHF is located in the Bau District of Sarawak with an approximate location of N 01° 22', E 110° 02' (Figure 2.1). The average relative humidity and temperature in JHF were 81.02% and 29.77°C, respectively.

Jagoi Heritage areas consist of the old settlement area and more than 400 hectares of primary and secondary forest (Sarok & Britin, 2016). The total gazetted areas, including the agroforest areas, is approximately 800 hectares. The conservation area is self-managed by the Jagoi community under an organization named Jagoi Area Development Committee

(JADC), a working committee of the Jagoi Heritage Society, in collaboration with the Bau District office.

A previous plant inventory done by Redim (2012) found a large number of tall trees in the undisturbed areas along the water bodies in Mount Jagoi with the most abundant species was *Cinnamomum* sp. The study also found an abundant number of *Rubroshorea* sp. and *Artocarpus odoratissimus* in the logged over part of Mount Jagoi. A study by Migas (2012) found that different forest types in Mount Jagoi i.e., undisturbed mixed-dipterocarp, logged-over dipterocarp, and heath forest, displayed different species composition. Another study by Sayok et al. (2015) found more than 400 individual trees and plants along the main trail of Mount Jagoi. A study by Ripen and Noweg (2016) then found a total of 117 species of plants with economic and cultural relevance in the Jagoi area. Another study by Toaiang and Sayok (2019) recorded 64 species of non-timber forest products (NTFPs) from JHF areas. Besides that, JHF also harbours valuable plant resources with medical importance, such as those found by Baling et al. (2017) and Patrick et al. (2023). Both studies have recorded 34 and 60 species of medicinal plants found in the Jagoi area, respectively. These studies provide a great opportunity for various conservation-based research to be conducted in JHF due to its high biodiversity.

The JHF is a heterogenous forest, which is a mix of four forest types. A pilot survey was conducted to define the forest types and criteria. Due to the nature of JHF being a heterogenous forest, there is no clear boundary between different forest types. Hence, the total area for each forest type cannot be specified. Accordingly, the forest is classified based on age, previous land use, and existing vegetation. The primary forest (PF) can be distinguished from the secondary forest through the level of disturbance. It usually has no

evident anthropological or natural disturbances (Food and Agriculture Organization of the United Nations [FAO], 2020). The PF of JHF is located at the highest elevation at 352 meters above sea level (Laman et al., 2014). A total of two PF areas has been surveyed i.e., the lower summit of Jagoi Mountain (N 1°21'35.90" E 110° 2'13.36") and Spolup Hill (N 1° 20' 50.676" E 110° 2' 27.312") as shown in Table 3.1 and Figure 3.1.

On the other hand, the secondary forests are located by the previous Serasot settlement, which is located at Sungai Opit. The old secondary forests (OSF) are estimated to be more than 40 years old. The forests were formed after shifting cultivation activities and later being abandoned (Sarok & Britin, 2016). Rice farming used to be Bidayuh's main agricultural activity before they shifted to cash crops such as rubber and pepper (Rubis, 2017). There were five sampling sites i.e., Sg. Opit riverine forest (N 01° 36.701' E 110° 11.735'); Jagoi OSF (N 1° 21' 38.4084" E 110° 2' 9.074"); secondary forest along Sg. Ngirunas (N 1° 21' 44.028" E 110° 1' 49.332"); Kampung Serasot OSF (N 1° 22' 3.36" E 110° 2' 36.852"); and Ngirunas dam OSF (N 1° 23' 21.8004" E 110° 0' 54").

The young secondary forests (YSF) are then described by the local guide as secondary forests aged less than 40 years old. Some of these areas also experienced shifting cultivation less than five years ago, while some were cultivated with *Hevea brasiliensis* in the past and left to regenerate (Baling et al., 2017). There were four sampling sites for the YSF i.e., Kg. Serasot YSF (N 01° 21' 48.2" E 110° 02' 30.2"), Sg. Ngirunas YSF (N 1° 21' 55.8324" E 110° 1' 53.872"), SALCRA Serasot plantation (N 1° 22' 56.964" E 110° 5' 24.18"), and plantation forest at the southern side of SALCRA Serasot plantation (N 1° 23' 56.4" E 110° 2' 19.788").

Finally, the agroforests (AF) are distinguished from the other forest types through a number of fruit trees such as *Durio zibethinus* and *Artocarpus integer*, being cultivated in the areas (Laman et al., 2014). The AF has been included as one of the forest types, as the area is a mix of fruit and forest trees. There were also traces of native forest tree species found mixed in the area. There were three sampling sites involved i.e., Kg. Pinomu Duyoh AF (N 1° 20' 40.7148" E 110° 2' 25.962"), Jagoi AF (N 1° 21' 49.7376" E 110° 2' 4.888"), and Kg. Serasot AF (N 1° 22' 1.704" E 110° 2' 36.06").

Table 3.1: Location and Forest Types of the Study Sites in Jagoi Heritage Forest (JHF)

Forest Types	Site Description	Geographic Location	No. of Quadrats
PF	Spolup Hill PF, located at southwest of Jagoi OSF (Kg. Duyoh trail)	N 1° 20' 50.676" E 110° 2' 27.312"	7
	Jagoi PF, located at northwest of Jagoi OSF (Kg. Plaman Buow trail)	N 1°21'35.90" E 110° 2'13.36"	
OSF	Sg. Opit riverine forest, located at Kg. Serasot, age approximately >50 years old	N 01° 36.701' E 110° 11.735'	18
	Jagoi OSF (Kg. Duyoh trail)	N 1° 21' 38.4084" E 110° 2' 9.074"	
	Secondary forest along Sg. Ngirunas, age approximately 60-70 years old	N 1° 21' 44.028" E 110° 1' 49.332"	
	Kg. Serasot OSF (headwaters of Sg. Opit), age approximately 40 years old	N 1° 22' 3.36" E 110° 2' 36.852"	
	Ngirunas dam OSF	N 1°21'26.92" E 110° 1'48.99"	
YSF	Kg. Serasot YSF, along the way to Manis dam, age approximately < 20 years old	N 01° 21' 48.2" E 110° 02' 30.2"	16
	Sg. Ngirunas YSF (trail to Ngirunas dam)	N 1° 21' 55.8324" E 110° 1' 53.872"	
	SALCRA Serasot plantation, riparian secondary forest, Sg. Sibomuo	N 1° 22' 56.964" E 110° 5' 24.18"	

Table 3.1 continued

Forest Types	Site Description	Geographic Location	No. of Quadrats
YSF	Plantation forest at the southern side of SALCRA Serasot plantation	N 1° 23' 56.4" E 110° 2' 19.788"	
AF	Kg. Pinomu Duyoh AF	N 1° 20' 40.7148" E 110° 2' 25.962"	11
	Jagoi AF, located at the foot of Jagoi PF (Kg. Plaman Buow trail)	N 1° 21' 49.7376" E 110° 2' 4.888"	
	Kg. Serasot AF at Tibawang Sauh, age approximately > 60 years old	N 1° 22' 1.704" E 110° 2' 36.06"	

Note: PF – Primary forest, OSF – Old secondary forest, YSF – Young secondary forest, AF - Agroforest

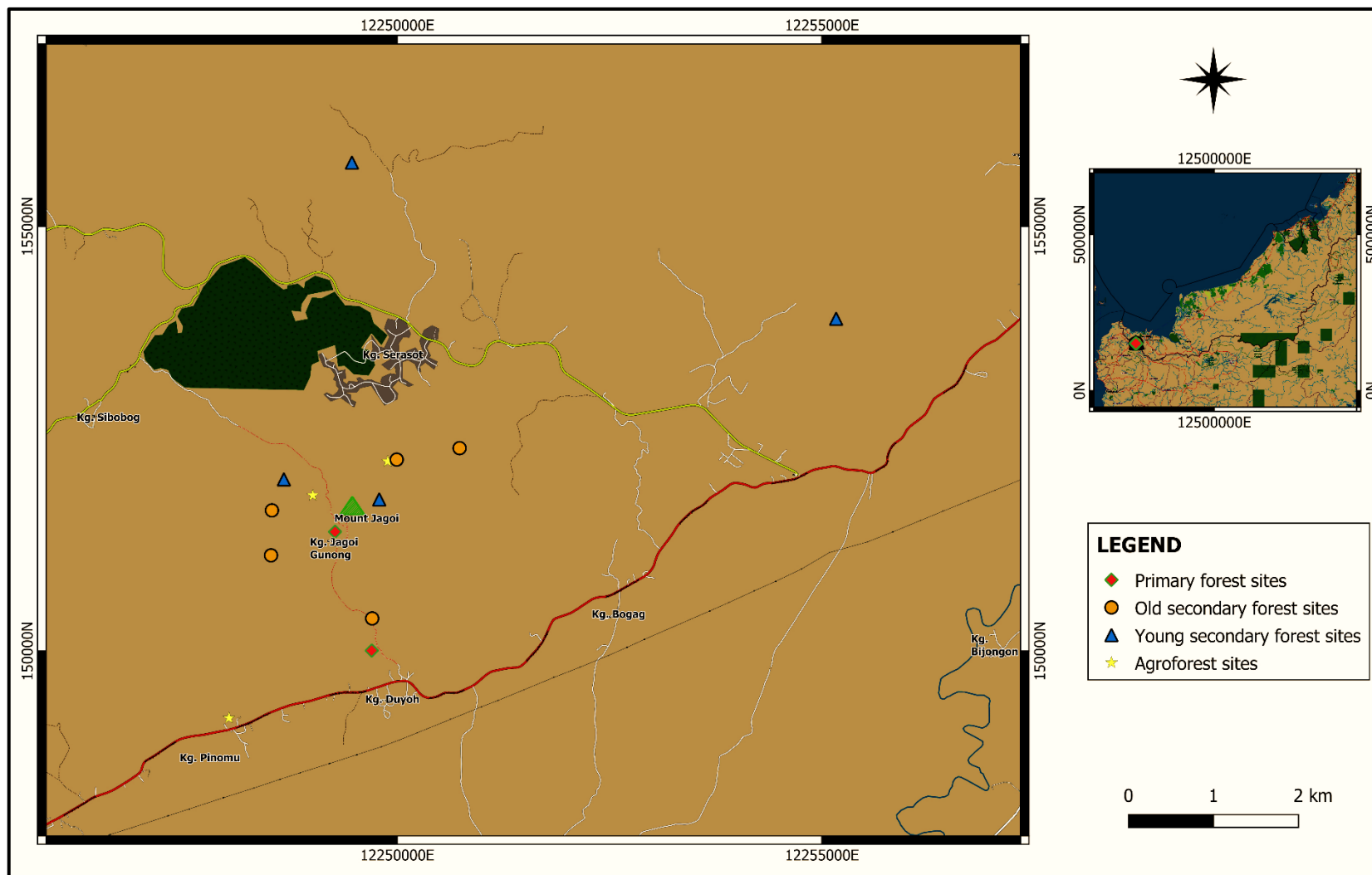


Figure 3.1: Map of Study Areas within the Jagoi Heritage Forest

3.2.2 Materials and Methods of Experiment 1

The study involved a descriptive research design to measure the ecological attributes and predict the success of reforestation. The research design involved the forest inventory method to observe and describe the forest's natural regeneration status at the study sites. Systematic sampling has been carried out at all study sites using the nested quadrat method. The nested quadrat method is a feasible method to sample trees, seedlings, saplings, litter, and soil at the same time. It is recommended that the suitable quadrat sizes to measure different vegetation sizes in tropical forests are between 100 square metres and 1000 square metres (Faber-Langendoen et al., 2014). Several different quadrat sizes were used at the same location of a sampling point, as shown in Figure 3.2. The nested quadrat consisted of three different quadrat sizes i.e., main quadrat (20 m x 20 m), first mini quadrat (5 m x 5 m), and second mini quadrat (1 m x 1 m).

Firstly, only trees (height >3 m tall, DBH $\geq$ 5 cm) were measured in the main quadrat. Next, saplings (height 91 cm -3 m tall) were measured in the first mini-quadrat and finally, seedlings (height < 90 cm) in the second mini quadrat. A total of 52 (20 m x 20 m) quadrats have been placed systematically at every 10 m intervals, with seven in PF, 18 in OSF, 16 in YSF, and 11 in AF (Table 3.1). The total sampling area is 20, 800 m²/2.08 ha.

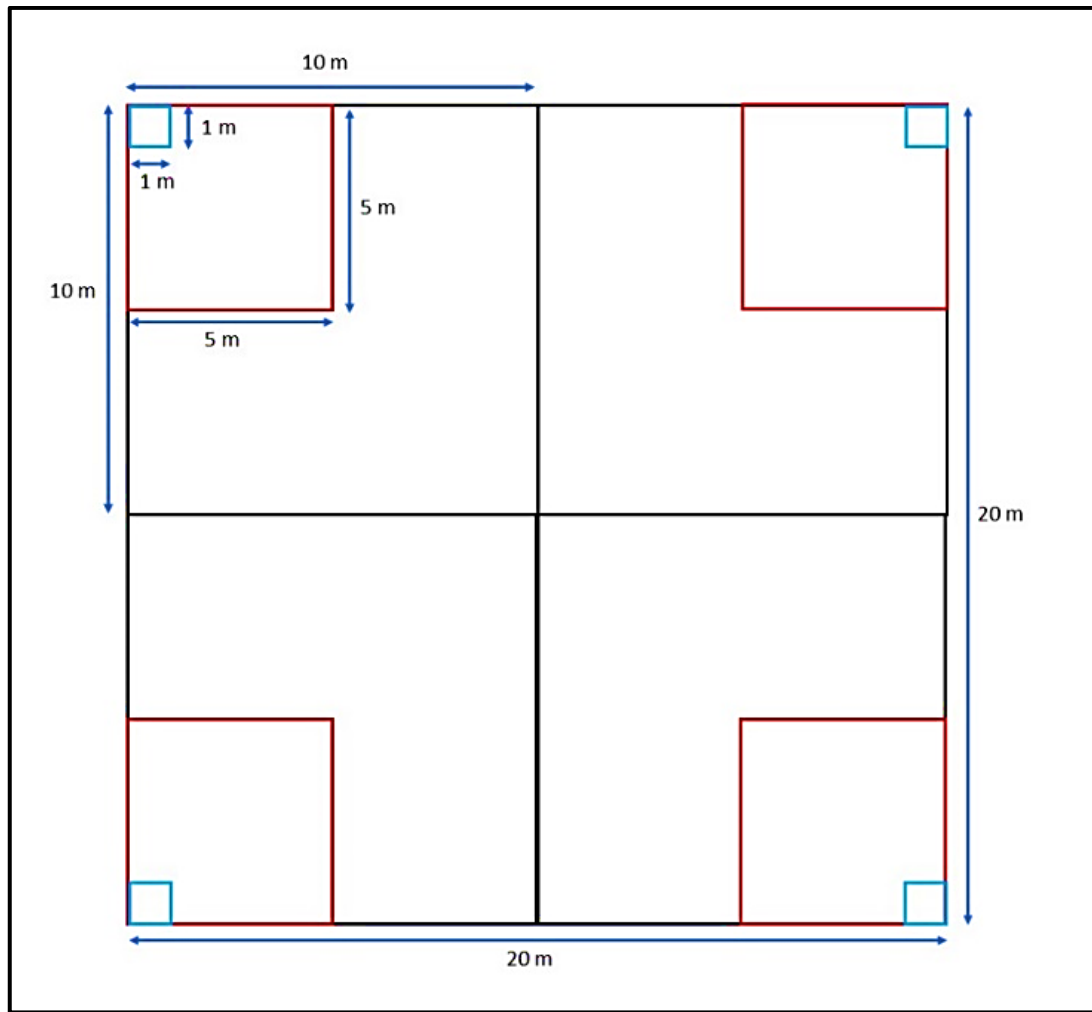


Figure 3.2: Nested Quadrat Sampling

Source: Adapted from Asrat & Tesfaye (2013) and Faber-Langendoen et al. (2014)

The experiment involved the multi-aged regeneration survey to measure the vegetation structure. The species name, height and diameter at breast height (DBH) or stem diameter of seedlings, saplings and trees have been recorded for all woody plant species (Aliyi et al., 2015). The data for different growth forms namely, species name or local name, DBH, and height, were recorded accordingly. The identification of trees in the field was assisted by several local correspondents. The trees were mostly identified up to their local names. The scientific names then were identified based on several references namely,

Soerianegara and Lemmens (1993), Lemmens et al. (1995), Jensen (1999), Soepadmo et al. (2002), and Jawa and Paul Chai (2007). Leaf samples were also collected and cross-checked with samples from Sarawak Herbarium at the Research, Development and Innovation Division, Forest Department Sarawak.

3.2.3 Data Analysis of Experiment 1

The data analysis of Experiment 1 is divided into three sections namely, (a) the forest diversity, (b) differences between the natural regeneration status, importance value, and standing biomass in four forest types, and (c) potential tree species for mixed-planting reforestation. The first section describes the method of data analysis for tree species composition and diversity in JHF. The second section describes the method of data analysis used to describe the differences between the natural regeneration status, importance value (IV), and standing biomass (SB). Finally, the third section describes the method of data analysis to determine the potential native species from JHF to be planted for mixed-planting reforestation in degraded areas around Bau District.

3.2.3.1 Analysis of Forest Diversity

Study on tree species composition and diversity is important to provide information on the forest structure and function (Forrester & Bauhus, 2016). Shannon-Wiener diversity, was used to estimate the diversity of trees in an area (Magurran, 2004). Menhinick richness was used to measure the total number of species in the community and Pielou's evenness index was used to show how evenly the individuals in a community are spread over different species. The calculation of diversity, richness and evenness values also contributes knowledge for forest management, conservation, and preservation efforts. The Shannon-Wiener diversity index considers the number of species as well as their distribution in a

specific area (Daly et al., 2018). Sensitivity analysis was carried out by calculating diversity indices individually for various sets of sample locations in order to mitigate any potential effects of various sampling locations on diversity values (Kumar et al., 2022). The formula for the diversity of a species (H'), species richness (S) and evenness (E) are highlighted as follows (Magurran, 2004);

$$\text{Diversity of a species } (H') = - \sum_{i=1}^R \ln(pi) \quad \text{Equation 3.1}$$

in which,

pi is the proportion of individuals that belong to species I and

R is the number of species in the sample

A much easier formula for Shannon-Wiener diversity index is.

$$\text{Shannon-Wiener diversity index } (H') = \frac{N \ln N - \sum (ni \ln ni)}{N} \quad \text{Equation 3.2}$$

in which,

N is the total number of species and n_i is the number of individuals in species i

$$\text{Menhinick richness index } (S) = \frac{\text{No.of species}}{\sqrt{\text{Total individual}}} \quad \text{Equation 3.3}$$

$$\text{Pielou's evenness index } (E) = \frac{H'}{H_{\max}} \text{ in which, } H_{\max} = \ln(S) \quad \text{Equation 3.4}$$

* Evenness ranges between 0 to 1, with 1 being complete evenness.

3.2.3.2 Analysis of Differences Between the Natural Regeneration Status, Importance Value, and Standing Biomass in Four Forest Types

Firstly, the natural regeneration status of tree species in each study site was determined by calculating the density of seedling: sapling: tree per species. The density of seedlings: saplings: and tree is one of the important factors in determining the regeneration potential of a given area (Aliyi et al., 2015). The natural regeneration status was determined by adapting the method by Sarkar and Devi (2014), Kuma and Shibru (2015), Khaine et al. (2018) and Rawat et al. (2018) in which,

1. ‘Good regeneration’: seedlings & saplings $\geq$ tree, or if sapling absent, seedling $\geq$ tree, or if seedling absent, sapling $\geq$ tree
2. ‘Fair regeneration’: seedlings $>$ or $<$ saplings $\leq$ tree,
3. ‘Poor regeneration’: if only saplings and seedlings are present, and
4. ‘No regeneration’: if only tree is present.

The mathematical calculation of the basal area (BA), dominance, relative dominance, density, relative density, frequency, relative frequency, and IV were later conducted to determine the dominant tree species which may have the potential for reforestation (Aliyi et al., 2015).

A basal area is the cross-sectional area of all the stems in a stand at breast height. It is an important parameter to measure the crowdedness of a stand of forests, the dominance of species and the relative importance of species (Aliyi et al., 2015). The mathematical formula for BA, dominance and relative dominance following Bhadra and Pattanayak (2017) are;

$$\text{Basal area (BA)} = \sum (D/2)^2, \text{ where D is diameter at breast-height} \quad \text{Equation 3.6}$$

$$\text{Dominance} = \frac{\text{Total basal area}}{\text{Total area sampled (ha)}} \quad \text{Equation 3.7}$$

$$\text{Relative dominance} = \frac{\text{Dominance of a species}}{\text{Total dominance}} \times 100 \quad \text{Equation 3.8}$$

The woody species density is also an important parameter for forest monitoring and evaluation, and to determine the natural regeneration status of a forest (Aliyi et al., 2015). It is defined as the number of plants of a specific species per unit area. The mathematical formula for density and relative density following Bhadra and Pattanayak (2017) are;

$$\text{Density} = \frac{\text{Number of a species}}{\text{Total area sampled (ha)}} \quad \text{Equation 3.9}$$

$$\text{Relative density} = \frac{\text{Density of a species}}{\text{Total density of all species}} \times 100 \quad \text{Equation 3.10}$$

Frequency is defined as the probability of finding a plant species in each area. It is hypothesized that the higher the frequency, the more important that plant species is in that given area. The mathematical formula for frequency and relative frequency following Bhadra and Pattanayak (2017);

$$\text{Frequency} = \frac{\text{Areas of plots in which species occur}}{\text{Total area sampled (ha)}} \times 100 \quad \text{Equation 3.11}$$

$$\text{Relative frequency} = \frac{\text{Frequency of tree species}}{\text{Frequency of all tree species}} \times 100 \quad \text{Equation 3.12}$$

Importance value is important to compare the ecological significance of each woody species. The higher the IV is, the higher the phytosociological structure of species in that area and the highest value of a species indicates the most dominant species in that area. The mathematical formula for IV is as follows (Bhadra & Pattanayak, 2017);

$$\text{IV} = R. \text{density} + R. \text{frequency} + R. \text{dominance} \quad \text{Equation 3.13}$$

The site-specific equation for the tree's and seedling/sapling's SB was calculated according to Kenzo et al. (2009) and Karyati et al. (2021).

Primary forest	$TSB = \exp ((2.196 \times \ln (DBH)) - 1.201)$	Equation 3.14
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(Karyati et al., 2021)

Old secondary forest	$TSB = \exp (2.59 \times \ln (DBH) - 2.75)$	Equation 3.15
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(Karyati et al., 2021)

Young secondary forest	$TSB = 0.0829 \times DBH^{43}$	Equation 3.16
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(Kenzo et al., 2009)

Seedling/sapling	$SSB \text{ or } \ln (y) = 2.4014 \times \ln (\text{diameter at the surface ground}) - 3.411$	Equation 3.17
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(Karyati et al., 2021)

Total standing biomass	$SB = TSB + SSB$	Equation 3.18
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* Units for standing biomass are kg, cm for DBH. TSB: Tree's standing biomass, SSB: Seedling/sapling standing biomass, SB: Total standing biomass, DBH: Diameter at breast height

Next, a Kruskal-Wallis H test was conducted to determine whether there are any statistically significant differences between the means of natural regeneration status, IV, and SB between four forest types. The Kruskal-Wallis H test is a nonparametric test equal to one-way ANOVA analysis (Pallant, 2005). It is used to determine the statistical difference between two or more groups of independent variables on the dependent variable. The mathematical formula for the Kruskal-Wallis H test, as shown by Ostertagová et al. (2014), is as follows;

$$H = \frac{12}{N(N+1)} \sum_{i=1}^k \frac{R_i^2}{n_i} - 3(N+1) \quad \text{Equation 3.19}$$

in which, $N = \sum_{i=1}^k n_i$, n_i is the data from i^{th} group (level) and j^{th} observation, R_i is the sum of the ranks in the i^{th} sample

Finally, mean-rank analysis was conducted to determine the difference in means of the natural regeneration status, IV, and SB between four forest types. Mean rank analysis was used to conduct a whole set of mean comparisons between groups (Pallant, 2005).

3.2.3.3 Analysis of Potential Tree Species to be Used for Mixed-Planting Reforestation

The selection of the potential species for mixed-planting reforestation in the degraded areas involved three ecological criteria namely, natural regeneration status, IV, and SB. The statistical analysis of Indicator species analysis (ISA) was conducted using PC-ORD to determine the potential species. Species with the highest indicator value then were cross matched with their natural regeneration status from their respective forest type.

ISA generates a maximum indicator value for each species by combining relative species abundance and frequency of occurrence concurrently (Severns & Sykes, 2020). Species with the highest indicator values (ranging from 0 to 100) are assigned to one group. A value of 100 represents a perfect indicator species and 0 represents a species with no indicator value. The mathematical formula for ISA is;

$$IV_{kj} = 100 (RA_{kj} \times RF_{kj}) \quad \text{Equation 3.20}$$

in which, IV_{kj} is the indicator value for each species j in each group k . RA_{kj} is the relative species abundance and RF_{kj} is the frequency of occurrence.

The indicator value is the result of two proportions measurements, the mean relative abundance of species in each group (RA_{kj}) and the relative frequency of each species in each group (RF_{kj}), which are then multiplied by 100 to get an indicator value.

Next, the mathematical formula for relative species abundance, RA_{kj} is;

$$RA_{kj} = X_{kj} / \sum_{k=1}^g X_{kj} \quad \text{Equation 3.21}$$

in which, g is the total number of groups and X is mean species abundance.

Last but not least, the data must first be converted into a presence-absence matrix in order to calculate the frequency of occurrence (RF_{kj}). The RF_{kj} then is calculated following the mathematical formula;

$$RF_{kj} = \sum_{i=1}^{n_k} b_{ijk} / n_k \quad \text{Equation 3.22}$$

in which, n_k is the number of samples in group k and b represents the species presence or absence.

When a species is assigned to a single group from a collection of groups, the highest indicator value for that species is called IV_{max} . Through Monte Carlo (MC) randomizations, which typically involve at least 1, 000 randomizations and reassign sample unit values, significance testing for IV_{max} is carried out. The IV_{max} p-value is determined by the frequency with which the IV_{max} from MC randomizations matches or exceeds the IV_{max} from the nonrandomized, original data set for each MC randomization.

3.3 The Effect of Mycorrhizal Fungi and *Trichoderma* Application with Different Fertilizer Types and Amounts on *Durio zibethinus* and *Artocarpus heterophyllus* Growth

3.3.1 Study Area of Experiment 2

The research was conducted under the greenhouse at UNIMAS Real Living Lab. The average temperature and humidity of the area are 32.8°C and 976.6% respectively. The greenhouse was built with a size of 4 x 11 m. Polyethylene shade cloth B70 was used to control the light penetration (approximately 50% - 60% intensity).

3.3.2 Materials and Methods of Experiment 2

Experimental research was designed to investigate the effect of mycorrhizal fungi and *Trichoderma* (MF-T) with different types and amounts of fertilizer toward the growth of *D. zibethinus* and *A. heterophyllus*. The study involved three main field activities namely, (1) site preparation and planting, (2) treatment of seedlings, and (3) data collection and seedling maintenance. The time taken to conduct these activities was 16 months.

The plants were treated using the Nutri-Life Platform, a bioinoculant product purchased from NuEarth Sdn. Bhd. The product consists of four arbuscular mycorrhizal fungi (AMF) species from the *Glomus* and five *Trichoderma* strains in powder form (Appendix 2).

The selected tree species for this study were *D. zibethinus* and *A. heterophyllus*. *D. zibethinus* belongs to the Malvaceae family, a climatic and seasonal tropical fruit mostly found in Malaysia, Indonesia, Thailand and the Philippines (Ho & Bhat, 2015). Conversely,

A. heterophyllus belongs to the Moraceae family and is commonly cultivated in Malaysia, Indonesia, Thailand, the Philippines, Bangladesh and India (Goswami & Chacrabati, 2015).

A pilot study was carried out prior to the experiment using *D. zibethinus* and *A. heterophyllus* and several forest tree species, including *Dryobalanops aromatica*, *Dipterocarpus rigidus*, and *Lithocarpus turbinatus*. These tree species were chosen for the pilot study due to seed availability at the time of study. *Durio zibethinus* and *Artocarpus heterophyllus* seeds were collected from several places in the Bau district. Alternatively, *D. aromatica*, *D. rigidus*, and *L. turbinatus* seeds were collected from the JHF area. After the sowing process, most of the forest tree species seeds did not germinate, and the remainder died within several months. Only *D. zibethinus* and *A. heterophyllus* showed good germination rates. Hence, these species were selected for the main experiment.

The site preparation and planting were carried out in August 2017. The first step was the treatment of topsoil and sand with fungicide. Fungicide was sprayed and mixed into the soil to kill natural fungi in the soil and sand. Then, the *D. zibethinus* and *A. heterophyllus* seeds were sown in small polyethylene bags with prepared potting materials of two parts of topsoil with one part of sand and one part of compost (Mbora et al., 2008). After two months of planting, the seedlings were fertilized using one spoon of fermented chicken dung + humic acid fertilizer. The fertilization was carried out once a month to maintain and keep the seedlings healthy. The seedlings were also watered daily to keep the plant roots moist.

The seedlings, then were transplanted into bigger polyethylene bags (14 cm x 14 cm) after they reached a height of approximately one foot. The potting material for the big polyethylene bag was a mixture of two parts of topsoil and one part of sand. The potting material was also treated with fungicide to kill the natural fungi in the soil and sand. The

seedlings were watered immediately, and after that the watering was reduced to two to three days apart or as the need arose (Universiti Putra Malaysia [UPM], 2012). The plants were then arranged in a randomized complete block design (RCBD) with ten replications for each tree and seven treatments, as shown in Figure 3.3. The seedlings were arranged 50 cm apart to avoid overlapping and crowding.

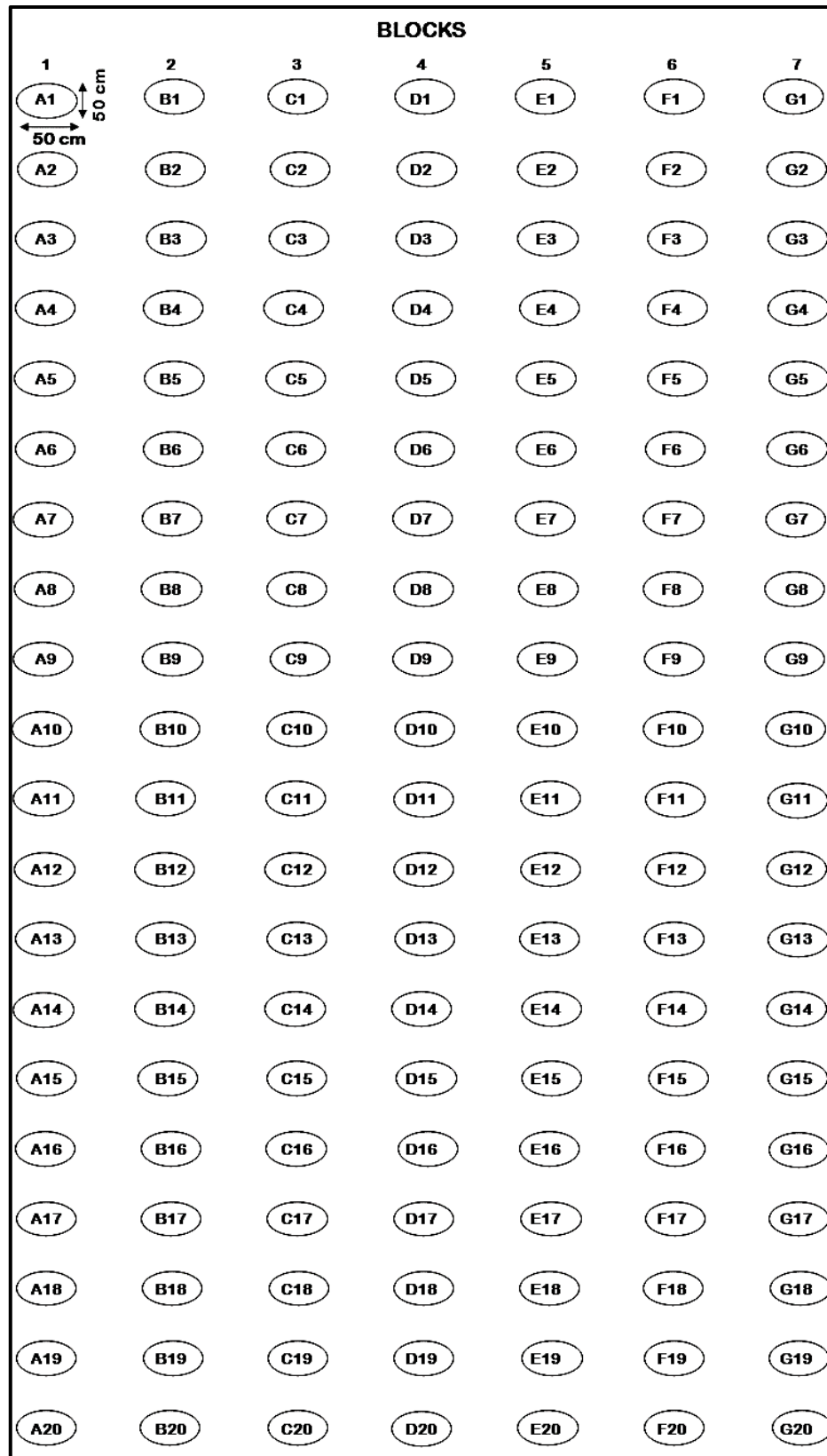


Figure 3.3: Randomized Complete Block Design

Notes: *Letters A, B, C, D, E, F and G represent treatments.

**Plants A1-A10 represent *D. zibethinus*, plants A11-A20 represent *A. heterophyllus* etc.

After the seedlings had been transplanted, the initial data of the seedling height and stem diameter were recorded. The environmental factors of light intensity, relative humidity and temperature, and the soil factors of pH and moisture content were also recorded every time the data collection was carried out. The second data was collected after one month of the first treatment and the subsequent data was carried out for another 10 months.

Subsequently, the first treatment was carried out. Treatment with MF-T involved the process of incorporating the inoculant into the potting materials near the plant root system (Amaranthus et al., 2009). The inoculant was dissolved in water at a rate of 200 grams/10 litre and then was sprayed into the potting materials. After two weeks, the fertilizer was applied using the fertilizer placement method, which involves applying the fertilizer on the subsurface of potting materials in a shallow band around the plants (Nkebiwe et al., 2016). The seedlings were treated with two types of fertilizer i.e., organic fertilizer (chicken dung) and chemical fertilizer (N15-P15-K15-TE), at the interval of six months for one year. The amount of organic and chemical fertilizer used was adapted from (UPM, 2012). There were seven types of treatment used in the study, including control treatment. The control treatment (2 parts topsoil + 1 part sand) was not subjected to any fertilization and inoculation of MF-T. The list of treatments is shown in Table 3.2.

Table 3.2: Seven Types of Treatments Used in the Study

Symbols	Treatments
A	2 parts topsoil + 1 part sand + 50 g OF + MF-T
B	2 parts topsoil + 1 part sand + 100 g OF + MF-T
C	2 parts topsoil + 1 part sand + 50 g CF + MF-T
D	2 parts topsoil + 1 part sand + 100 g CF + MF-T
E	2 parts topsoil + 1 part sand + 100 g OF
F	2 parts topsoil + 1 part sand + 100 g CF
G	Control: 2 parts topsoil + 1 part sand

*OF: Organic fertilizer, CF: Chemical fertilizer, MF-T: Mycorrhizal fungi and *Trichoderma*

The summary of materials and methodology for Experiment 2 is shown in Figure

3.4.

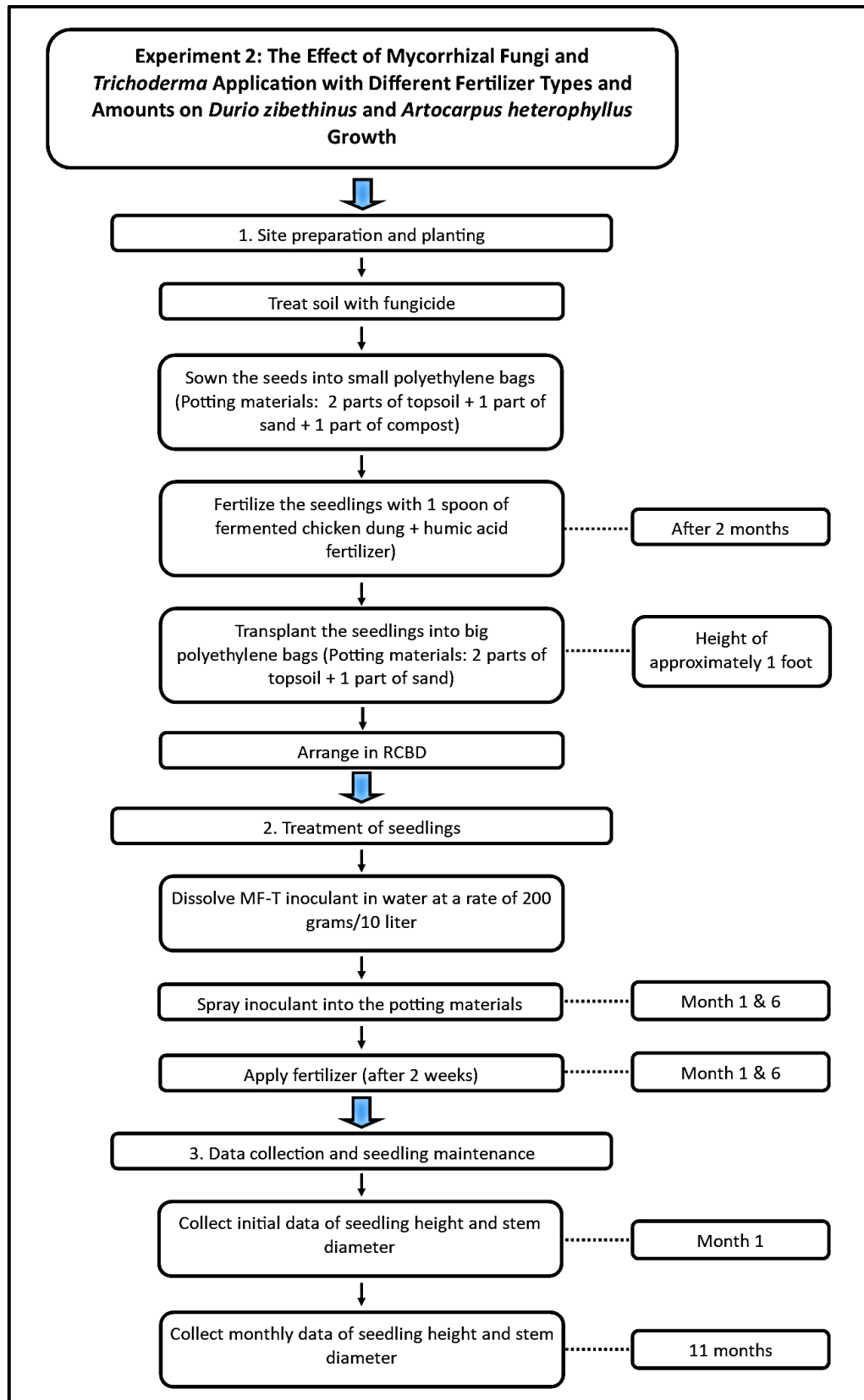


Figure 3.4: Flow Chart of Materials and Methods for Experiment 2

3.3.3 Data Analysis of Experiment 2

Firstly, the estimated marginal means height and stem diameter of *D. zibethinus* and *A. heterophyllus* were plotted against seven treatments. The mean plots are extremely useful to describe the pattern of means resulting from different treatments in the sample in a descriptive manner.

Further analysis to explore the interaction effect between the treatments and different species of tree on growth rate was then conducted through factorial ANOVA analysis. Factorial ANOVA analysis is used to compare the means across two or more independent variables and assess the effects of the independent variables on a single dependent variable. It also can be used to assess the combined effects of the independent variables on the dependent variable (Boncina, 2011). The type of plant, type of fertilizer and fertilizer's amount (independent variables) were manipulated to determine their effects on the growth rate, i.e., height and stem diameter (dependent variable) of the seedlings.

The separate effect of treatments on species of tree was then analysed using the ANOVA analysis. The variance in mean height and stem diameter (dependent variables) were compared between different treatments (independent variables) for both *D. zibethinus* and *A. heterophyllus*.

Tukey post-hoc analysis was later conducted to determine the difference in means of the height and stem diameter between different treatments. Post-hoc comparisons analysis is used to conduct a whole set of mean comparisons between groups, indicated by the F-ratio value (Pallant, 2005).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Overview of Results and Discussion Chapter

The results and discussion chapter are divided into two sections namely, (a) Experiment 1: Predicting the Potential Species for Reforestation Based on Natural Regeneration Status, Importance Value and Standing Biomass, and (b) Experiment 2: The Effect of Mycorrhizal Fungi and *Trichoderma* Application with Different Fertilizer Types and Amounts on *Durio zibethinus* and *Artocarpus heterophyllus* Growth.

Section one describes three main findings from Experiment 1 namely, (i) the forest diversity, (ii) differences between the natural regeneration status, importance value, and standing biomass in different forest types, and (iii) potential tree species for mixed-planting reforestation. Subsequently, past studies were compared and discussed based on the current findings.

Section two then describes two main findings from Experiment 2 namely, (i) profile plots of *Durio zibethinus* and *Artocarpus heterophyllus* growth and (ii) the interaction effect between treatments and species of tree on height and stem diameter. Finally, the findings were compared and discussed with past studies.

4.2 Predicting the Potential Species for Reforestation Based on Natural Regeneration Status, Importance Value and Standing Biomass

4.2.1 The Forest Diversity

A total of 8,321 trees' individuals, including the seedling, sapling, and mature trees were recorded for the study. A total of 63 (excluding the Unknown species) families of trees, represented by 260 species is recorded from the study area (Appendix 4). The most species-rich family is Myrtaceae, with 24 species, followed by Dipterocarpaceae, with 19 species.

There is a difference between the highest value and the lowest value of the estimated number of trees per ha and species measured in the study (Table 4.1). The highest estimated number of trees per ha is in the old secondary forest (OSF) which is 4,890. OSF also has the highest number of species (153). Vice versa, primary forest (PF) has the lowest estimated number of trees per ha (3,418) and species (95).

Despite the difference in the estimated number of trees per ha and species, agroforest (AF) showed the highest value of richness ($S = 3.59$), and OSF showed the lowest ($S = 2.58$). However, all forest types show high evenness values, which is almost in complete evenness ($E = 1.0$). A high value of richness and evenness does not necessarily indicate high diversity, as shown in Table 4.1. The highest species diversity value is found in both young secondary forest (YSF) and AF ($H' = 4.10$) and the PF shows the lowest species diversity value ($H' = 3.75$). The difference between the highest and lowest species diversity values is quite big (0.35), indicating a high difference in species composition in different forest types.

Table 4.1: The Descriptive Analysis to Compare Species Diversity Between Four Forest Types in Jagoi Heritage Forest (JHF)

Forest Types	Total Trees	Estimated No. of Trees per ha	No. of Species	Species Richness (S)	Evenness (E)	Diversity (H')
Primary forest	957	3, 418	95	3.07	0.82	3.75
Old secondary forest	3, 521	4, 890	153	2.58	0.79	3.98
Young secondary forest	2, 320	3, 625	143	2.97	0.83	4.10
Agroforest	1, 523	3, 461	140	3.59	0.83	4.10

4.2.2 Differences Between the Natural Regeneration Status, Importance Value, and Standing Biomass in Different Forest Types

A Kruskal-Wallis H test was conducted to see whether there is a difference in tree natural regeneration status, importance value (IV), and standing biomass (SB) between four forest types. Table 4.2 reveals that there is two statistically significant difference at the $p < 0.05$ level. The first significant difference is in the IV between four forest types, $X^2 (3) = 12.24$, $p = 0.01$. The second significant difference between the forest types is in the SB, $X^2 (3) = 27.29$, $p < 0.05$. This indicates that there are differences in species IV and SB between different forest types in JHF. The chi-square value of SB (Chi-square = 27.29) is higher than IV (Chi-Square = 12.24), indicating a higher difference in SB between PF, OSF, YSF, and AF in JHF.

Table 4.2: Kruskal-Wallis H Test to Determine the Differences Between Natural Regeneration Status, Importance Value, and Standing Biomass in Different Forest Types

Factors	Dependent Variable	Chi-square	df	Significance Value ($p < 0.05$)
Forest Types	Natural regeneration status	5.65	3	0.13
	Importance value	12.24	3	0.01*
	Standing biomass	27.29	3	0.00*

Mean rank analysis, as presented in Table 4.3, shows that the PF has the highest mean rank of IV (455.95), and the AF has the lowest mean rank (381.00). Besides that, PF also has the highest mean rank of SB (504.75), and AF has the lowest mean rank (376.01). These results indicate that PF has the highest species IV and SB than the other forest types, with the biggest difference between the PF and the AF.

Table 4.3: Mean Rank Analysis to Determine the Difference in Means of the Natural Regeneration Status, Importance Value, and Standing Biomass Between Four Different Forest Types

Dependent Variable	Forest Types	N	Mean Rank
Natural regeneration status	PF	120	428.20
	OSF	300	409.61
	YSF	232	425.35
	AF	204	460.04
	Total	856	
Importance value	PF	120	455.95
	OSF	300	453.75
	YSF	232	423.42
	AF	204	381.00
	Total	856	

Table 4.3 continued

Dependent Variable	Forest Types	N	Mean Rank
Standing biomass	PF	120	504.75
	OSF	300	455.66
	YSF	232	400.10
	AF	204	376.01
	Total	856	

Notes: PF – Primary forest, OSF – Old secondary forest, YSF – Young secondary forest, AF – Agroforest
 N – represents the total number of species occurrence in the sampling quadrats per forest types (Appendix 5)

4.2.3 Potential Tree Species to be Used for Mixed-Planting Reforestation

The results of Indicator species analysis (ISA) based on IV found 12 tree species from three forest types with significant p-values ($p < 0.05$) and high indicator values (Table 4.4). The cross-matched between the indicator values and natural regeneration status was then narrowed to four species with high indicator values and good regeneration. The species are *Dipterocarpus* sp. (Mean = 31.80, $p < 0.05$) from PF and *Archidendron jiringa* (Mean = 38.00, $p < 0.05$), *Garcinia mangostana* (Mean = 28.30, $p = 0.04$), and *Parkia speciosa* (Mean = 30.60, $p = 0.04$) from AF.

Table 4.4: Potential Species Estimated to Successfully Survive of Each Forest Type (Based on Importance Value and Natural Regeneration Status)

No.	Species	Forest Types	Indicator Value for Randomized Group		Significance Value ($p < 0.05$)	Natural Regeneration Status
			Mean	SD		
1.	<i>Allantospermum borneense</i>	PF	31.90	16.84	0.04	No regeneration
2.	<i>Aporosa benthamiana</i>	PF	29.90	16.25	0.02	No regeneration

Table 4.4 continued

No.	Species	Forest Types	Indicator Value for Randomized Group		Significance Value ($p < 0.05$)	Natural Regeneration Status
			Mean	SD		
3.	<i>Archidendron jiringa</i>	AF	38.00	13.81	0.00	Good regeneration
4.	<i>Breynia racemosa</i>	YSF	36.70	17.75	0.01	Fair regeneration
5.	<i>Dipterocarpus sarawakensis</i>	PF	40.90	19.45	0.01	Fair regeneration
6.	<i>Dipterocarpus</i> sp.	PF	31.80	15.82	0.00	Good regeneration
7.	<i>Durio zibethinus</i>	AF	36.50	16.09	0.02	Fair regeneration
8.	<i>Endospermum diadenum</i>	YSF	41.60	12.70	0.01	Fair regeneration
9.	<i>Garcinia mangostana</i>	AF	28.30	14.9	0.04	Good regeneration
10.	<i>Lithocarpus ewyckii</i>	PF	31.80	16.65	0.01	Fair regeneration
11.	<i>Macaranga caladiifolia</i>	AF	39.40	12.97	0.04	Fair regeneration
12.	<i>Parkia speciosa</i>	AF	30.60	14.75	0.04	Good regeneration

Notes: PF – Primary forest, YSF – Young secondary forest, AF – Agroforest

The results of ISA based on SB then found 10 tree species from three forest types with significant p -values ($p < 0.05$) and high indicator values (Table 4.5). The cross-matched between the indicator values and natural regeneration status then narrowed two species with high indicator values and good regeneration i.e., *Dipterocarpus* sp. (Mean = 31.70, $p < 0.05$) from PF and *A. jiringa* (Mean = 38.70, $p < 0.05$) from AF. Both species were also listed in the previous results, indicating the higher potential of *Dipterocarpus* sp. and *A. jiringa* for

mixed-planting reforestation compared to the other species due to their high indicator values and good regenerations.

Table 4.5: Potential Species Estimated to Successfully Survive at Each Forest Type (Based on Standing Biomass and Natural Regeneration Status)

No.	Species	Forest Types	Indicator Value for Randomized Group		Significance Value (p < 0.05)	Natural Regeneration Status
			Mean	SD		
1.	<i>Allantospermum borneense</i>	PF	31.00	15.93	0.03	No regeneration
2.	<i>Aporosa benthamiana</i>	PF	29.20	13.50	0.01	No regeneration
3.	<i>Archidendron jiringa</i>	AF	38.70	13.67	0.00	Good regeneration
4.	<i>Breynia racemosa</i>	YSF	36.10	16.17	0.01	Fair regeneration
5.	<i>Dipterocarpus sarawakensis</i>	PF	40.10	18.34	0.01	Fair regeneration
6.	<i>Dipterocarpus</i> sp.	PF	31.70	15.75	0.00	Good regeneration
7.	<i>Durio zibethinus</i>	AF	36.70	16.45	0.01	Fair regeneration
8.	<i>Endospermum diadenum</i>	YSF	41.00	12.02	0.01	Fair regeneration
9.	<i>Lithocarpus ewyckii</i>	PF	30.80	15.92	0.01	Fair regeneration
10.	<i>Macaranga caladiifolia</i>	AF	39.60	13.08	0.04	Fair regeneration

Notes: PF – Primary forest, YSF – Young secondary forest, AF – Agroforest

4.2.4 Discussion of Experiment 1

The result of forest diversity shows a difference in species diversity between PF, OSF, YSF, and AF in JHF. There is a big difference between the forest types with the highest species diversity (YSF and AF) and the lowest (PF). This result answers the first research question of how big the difference in species diversity between PF, OSF, YSF, and AF in JHF. The forest diversity and richness results indicate that the difference in species richness and diversity may be due to the difference in forest types. Thus, the null hypothesis is rejected, and the alternative hypothesis is accepted. The species diversity differs between PF, OSF, YSF, and AF in JHF.

Similar to the current study, Ifo et al. (2016) from the Republic of Congo found that AF has a higher species diversity than PF, and secondary forest has the lowest species diversity depending on the level of degradation. A study conducted in the Atlantic semideciduous forest also presented a similar result in which, the younger secondary forests have higher species richness as compared to the older secondary forests due to the rapid regeneration (Bertacchi et al., 2016). The similar species diversity between the AF and the secondary forest was also found by Quazi and Ticktin (2016), although the AF is often blamed for causing biodiversity loss. This also indicates the potential of AF to play an important role in conserving biodiversity.

Contrastingly, Gonçalves et al. (2017) and Mugwedi et al. (2017) found that the undisturbed PF were more diverse than the secondary forests of different ages. The study by Manuel et al. (2018) then reported that the OSF showed a higher species richness as compared to the YSF. This may be due to the simultaneous growth of fast-growing pioneer and shade-tolerant species after several years of forest recovery. The stand age may not

necessarily be the main factor influencing the floristic composition (Mugwedi et al., 2017). Climatic factors may be one of the decisive factors contributing to the difference in the results (Gonçalves et al., 2017). The difference in species diversity may also be influenced by other environmental parameters, including soil conditions (Yeboah et al., 2016).

The result also may be influenced by the level of disturbance, which Rahayu et al. (2015) stated that forest disturbance contributes to the rapid regeneration of the light-demanding trees, shrubs, and herbs due to the canopy opening. A similar study by Mesquita et al. (2015) also showed that the species richness in the clear-cut forests increases threefold faster than the abandoned pastures, with a lack of disturbance. This agrees with the present study in which, the secondary forests in Jagoi are more diverse than the PF. Nevertheless, severe forest disturbance may contribute to the low value of species richness and diversity (Astiani, 2016). Excessive disturbances such as illegal forest produce harvesting, mass grazing, and trampling resulted in poor regeneration (Gautam et al., 2016). This was also shown in Atsbha et al. (2019) study, in which repeated disturbance by humans and livestock in grazing areas has resulted in low diversity value compared to the protected areas with less disturbance. A study by Sistla et al. (2016) also found that the difference in species richness may be attributed to land utilization. Their results showed a difference in species richness between the three land uses, in which the secondary forest and AF show high species richness as compared to the pastureland.

The result of differences between the natural regeneration status, IV, and SB found two significant differences between different forest types, which are IV and SB. However, SB has the biggest difference, indicated by a higher chi-square value and lower p-value. The differences in IV and SB between PF, OSF, YSF, and AF show that the biggest differences

are between PF and AF. This answers the second research question of how big the difference is, between the natural regeneration status, IV, and SB. The null hypothesis is then rejected. The IV and SB differ between PF, OSF, YSF, and AF in JHF.

A similar result was found in the three different ages of secondary forests in Sabal, Sri Aman, Sarawak. The diameter at breast height (DBH) and height of trees increase over the abandonment period and directly increase the volume and basal area (BA) per hectare area. The species composition in different forest ages may be the contributor to these differences (Karyati et al., 2017). This was also found by Pamoengkas et al. (2019) in their study in central Kalimantan, Indonesia. They suggested that the biggest difference between PF and AF may be due to the dominance of climax species found in the PF. The climax species were found to be more dominant than the pioneer species, commonly found abundant in the secondary and AF. These indicate the importance of understanding the tree species growth rates in different forest ages and types to predict the change in biomass, structure, and diversity of forests (Chi et al., 2017).

Land-use history plays a major role in the forest recovery of secondary forests, as shown in Atkinson and Marín-spiotta (2015) in the Virgin Islands, United States of America. The ten-year-old secondary forest was found to have greater stem density and yet lower BA, biomass, and species richness than the 40-year-old secondary forests. The differences were driven by the dominance of the nitrogen-fixing species in the soil. The recovery of land post-agriculture was slow in the early years due to a lack of nitrogen-fixing species in the soil but increased rapidly subsequently. A similar result was also found in the Amazon rainforest in which, there is an increase in stem density and BA in both the abandoned clear-cuts and pasture lands. However, there is a lack of species accumulation and ecosystem services in

the pasturelands due to continuous disturbance (Mesquita et al., 2015). The anthropological and natural disturbances may be the contributors to the decrease in tree density and BA distribution, as found by Borogayary et al. (2018).

Climatic factors such as annual precipitation also influence the rate of forest recovery over the years of recovery, such as in the Neotropical secondary forests in Thailand (Ueda et al., 2017). The annual precipitation and temperature have negative impacts on the tree BA and biomass, as shown by Khan et al. (2019) in the Mongolian forests. The negative impacts suggest the need to select suitable species with a strong adaptive nature toward any climatic change.

The prediction of potential tree species to be used for mixed-planting reforestation results then found that *Dipterocarpus* sp. and *A. jiringa* have the highest indicator values (based on IV and SB) and have good natural regeneration status. This result answers the third research question on what the potential native species from JHF is to be used for mixed-planting reforestation in degraded areas. The alternative hypothesis is then accepted in which, only two species are found to have potential for mixed-planting reforestation in degraded areas.

Dipterocarpus sp. belongs to the family of Dipterocarpaceae and produces a relatively strong and durable timber (Wong, 2002). *Dipterocarpus* genus usually regenerates under shade, but as it grows, it demands more light (Susilowati et al., 2021). A study by Toma et al. (2001) at East Kalimantan found that *D. confertus* and *D. cornutus* seedlings grow naturally in a burnt-over forest canopy. *Dipterocarpus confertus* showed growth height in canopy gaps. In contrast, *D. cornutus* showed height growth in shaded areas. The difference in growth between the seedlings was also often found abundant around the mother

trees. The genus was considered one of the ten dominant species at the seedling level as found in West Papua, Indonesia (Mahmud et al., 2019). These species in different environments demonstrated that dipterocarp species can potentially be used to restore disturbed forests. A study by Hashim et al. (2015) then suggested that *Dipterocarpus* sp. be planted in the medium rotation plantation due to its nature of being a shade tolerant species. Alternate row planting techniques can be used to combine two or more tree species.

In a study in Dulahazara, Bangladesh, Mohitul Hossain (2012) found that *D. turbinatus* has a 40.00% chance of being germinated in a deforested land. The chance of *D. turbinatus* to germinate in a deforested land was comparable to *Acacia auriculiformis* (46.66%), *Syzygium grande* (56.66%), and *Swietenia mahagoni* (50.00%). A similar study by Millet et al. (2013) in Vietnam found that *D. alatus* and *D. dyeri* showed a high survival rate (more than 90.00%) one year after being interplanted in a plantation area. The seedlings were interplanted among several species, such as *Afzelia xylocarpa*, *Dalbergia bariensis*, *Hopea odorata*, and *Anthoshorea roxburghii*. All species also showed high survival rates except for *D. costatus* (36.00%). Although the seedlings have been replanted among the pioneer trees in the area and kept separate from the existing trees, they showed good growth performance. Due to their excellent growth, the seedlings appear to have successfully acclimated to their new habitat and are thriving even in the presence of the pioneer trees. By reducing competition for resources, the separation from the old trees probably helped to facilitate their growth. This successful outcome shows how effective the planting approach was and is encouraging for the future growth of the seedlings into mature trees. Their favourable growth trajectory has been influenced by the careful placement management and support given to these young plants. The study suggested that continuing development and assimilation into the current ecosystem will depend on ongoing monitoring and care.

The result also found that *A. jiringa* has a potential for mixed-planting reforestation. *Archidendron jiringa* belongs to the family of Fabaceae (Bunawan et al., 2013). The wood of *A. jiringa* is often used locally for light construction including, joinery, fencing, kitchenware, and boxes (Sosef et al., 1998). A study in Sumatra, Indonesia, among the local farmers in rubber smallholdings found that they preferred fruit tree species such as *A. jiringa* more compared to forest tree species (Hesti et al., 2014). It is cultivated for its fruit and can naturally regenerate during the fallow season.

A previous study by Azani et al. (2005) examined the growth characteristics and performance of numerous plant species, including *A. jiringa*, planted at a severely degraded landfill area in Ayer Hitam Forest Reserve. The study discovered that when planted among pioneer plants in the area and kept apart from existing trees, *A. jiringa* showed good growth performance. The seedlings demonstrated positive development and adapted well to their new surroundings despite the potential difficulties of living among old trees. Another study by Amin et al. (2022) found that *A. jiringa* exhibited a considerable germination rate of 50.00% when planted in the ex-limestone mining area. Additionally, *A. jiringa* demonstrated the fastest germination rates among the studied plant species, taking only three days for germination to occur. This study suggests that *A. jiringa* is well-suited for growth in ex-limestone mining lands, and its quick germination rate may make it a favourable choice for reforestation efforts in such areas. However, they also suggested that further research may be needed to explore the potential benefits of using *A. jiringa* for ecological restoration projects and its contribution to biodiversity conservation.

4.3 The Effect of Mycorrhizal Fungi and *Trichoderma* Application with Different Fertilizer Types and Amounts on *Durio zibethinus* and *Artocarpus heterophyllus* Growth

4.3.1 Profile Plots of *Durio zibethinus* and *Artocarpus heterophyllus* Growth

The profile plots of the estimated marginal mean height and stem diameter were then plotted to determine the suitable amount of organic (OF) and chemical fertilizer (CF) with mycorrhizal fungi and *Trichoderma* (MF-T) inoculation for *D. zibethinus* and *A. heterophyllus* cultivation. Figure 4.1 shows the estimated marginal means of *D. zibethinus* and *A. heterophyllus*' height. The profile diagram shows that both *D. zibethinus* and *A. heterophyllus* reacted in different ways with different treatments. The highest estimated marginal mean of *D. zibethinus*' height is at 100 g OF with MF-T (Mean = 65.52) and *A. heterophyllus*' height is at 50 g OF with MF-T (Mean = 113.77).

The result also found that the mean height of both plants when treated with CF and MF-T is lower than the treatment with OF and MF-T. The result indicates that the OF's application with MF-T promotes plants' height more than the use of CF. The treatment with OF and CF alone also shows lower mean height for both plants except for *A. heterophyllus*, which shows higher mean height when treated with 100 g OF.

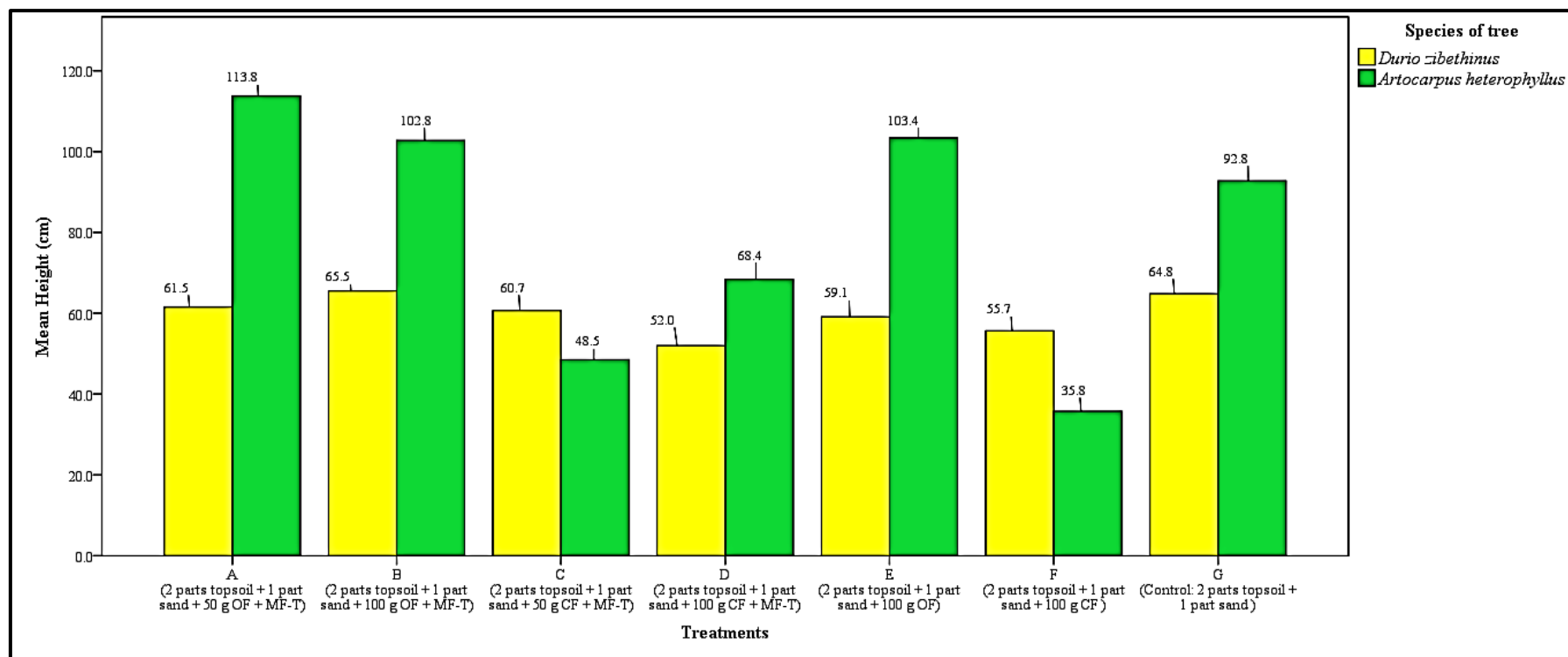


Figure 4.1: Profile Diagram of Estimated Marginal Mean Height

The prediction of marginal mean height found that only the increase in OF amount with MF-T's inoculation will increase the mean height of both plants (Figure 4.2). A significant difference in mean height increment along the increase in OF amount + MF-T is also found between *D. zibethinus* and *A. heterophyllus*. The mean height of *A. heterophyllus* increases with the increase in OF amount. However, the mean height of *D. zibethinus* increases slightly to almost none with the increase in OF amount. The result also shows that an increase of CF with MF-T, OF, and CF's amount will result in the decrease of means of both plants' height.

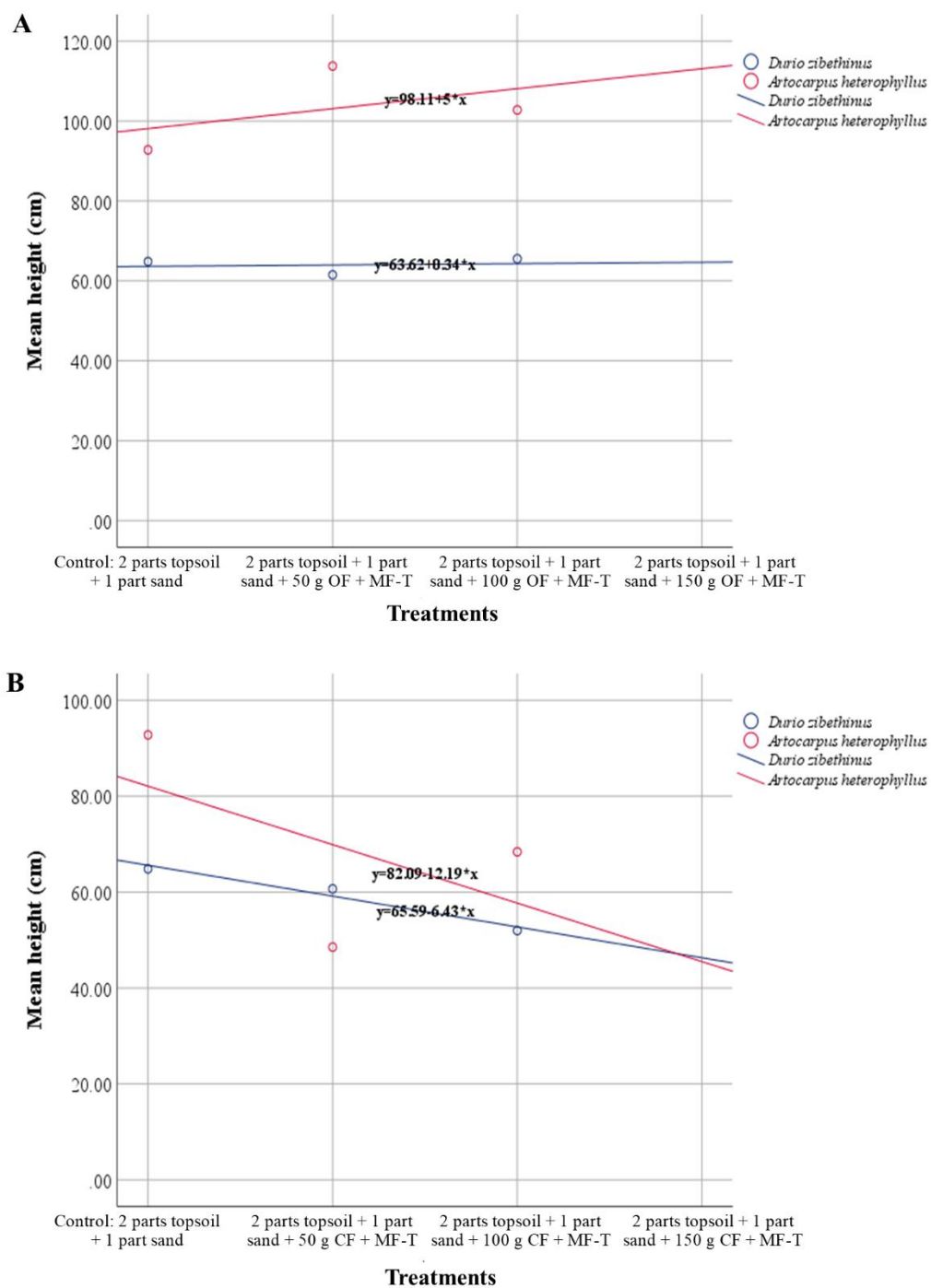


Figure 4.2: Predicted Marginal Mean Height

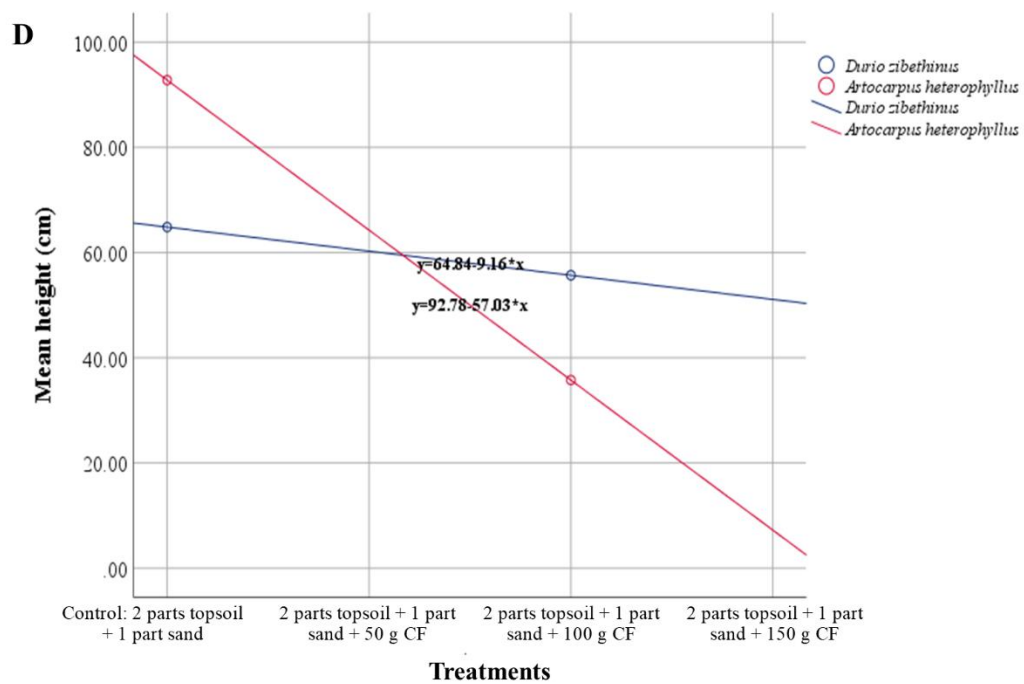
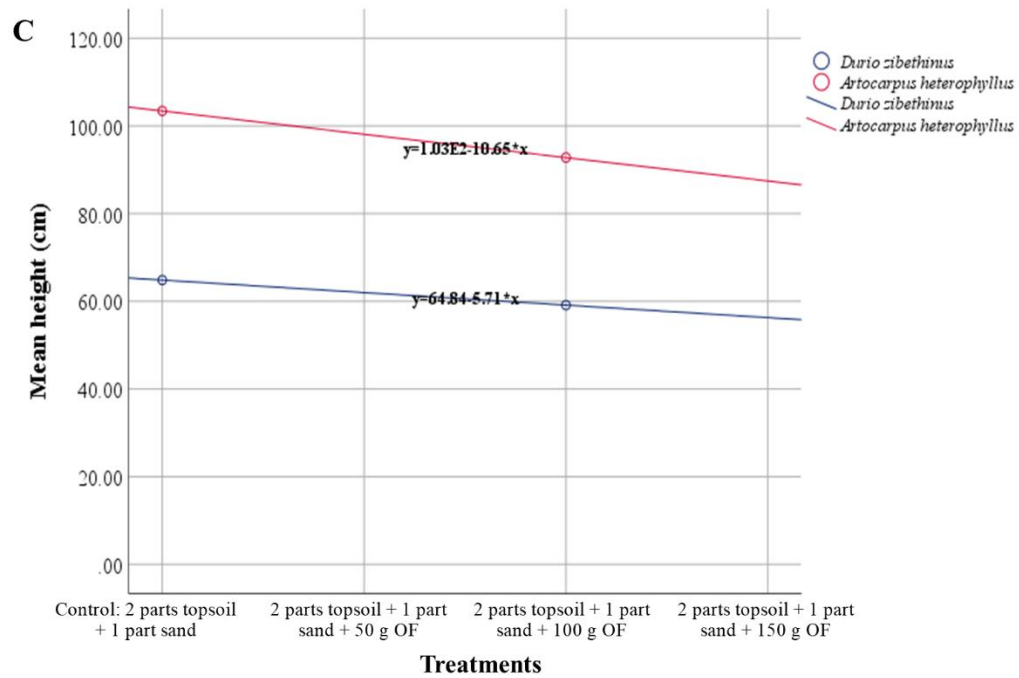


Figure 4.2 continued

Figure 4.3 of the estimated marginal mean stem diameter shows that the highest estimated marginal mean of *D. zibethinus*' diameter is at 100 g CF with MF-T (Mean = 7.15). However, the highest estimated marginal mean of *A. heterophyllus*' diameter is 50 g OF with MF-T (Mean = 8.98). The *A. heterophyllus*' mean diameter is higher when treated with OF and MF-T compared to treatment with CF with MF-T, OF, and CF. On the contrary, *D. zibethinus*' diameter varies with different treatments.

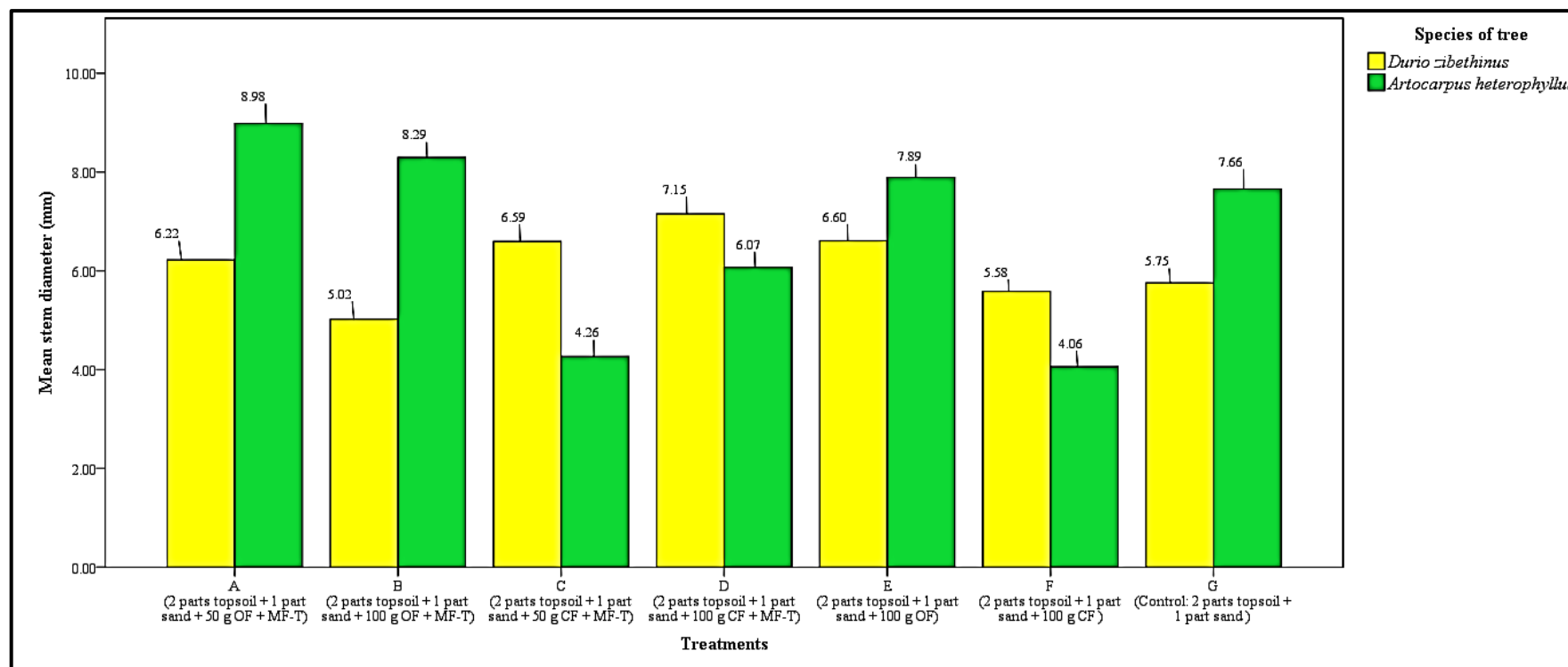


Figure 4.3: Profile Diagram of Estimated Marginal Mean Stem Diameter

Different from the previous result, the prediction of marginal mean stem diameter found that the increase in OF amount, regardless of MF-T inoculation, will increase the *A. heterophyllus*' mean stem diameter. However, the increment is small. On the contrary, the increase of CF amount, regardless of MF-T inoculation, will result in a great decrease in *A. heterophyllus*' mean diameter. This indicates that *A. heterophyllus*' needs more OF than CF to boost its stem diameter growth.

However, the prediction of *D. zibethinus*' mean stem diameter varies with different treatments. The greatest difference in mean stem diameter can be found in CF with MF-T treatment. The mean diameter increases greatly along with the increase of CF amount with MF-T. This indicates that *D. zibethinus*' needs more CF amount with MF-T to boost its stem diameter growth.

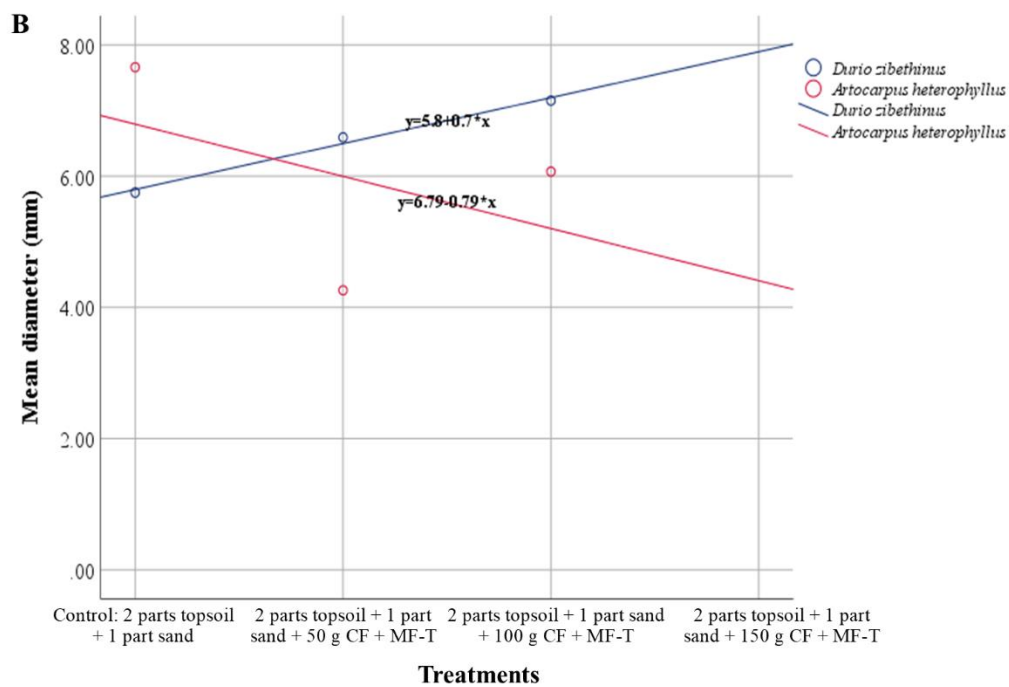
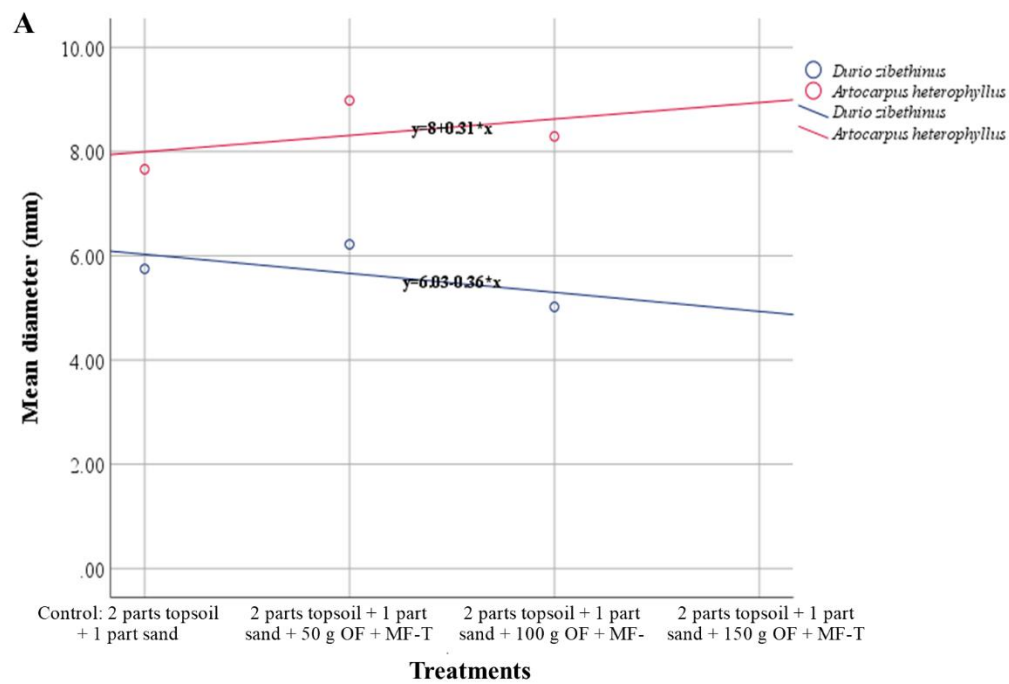


Figure 4.4: Predicted Marginal Mean Stem Diameter

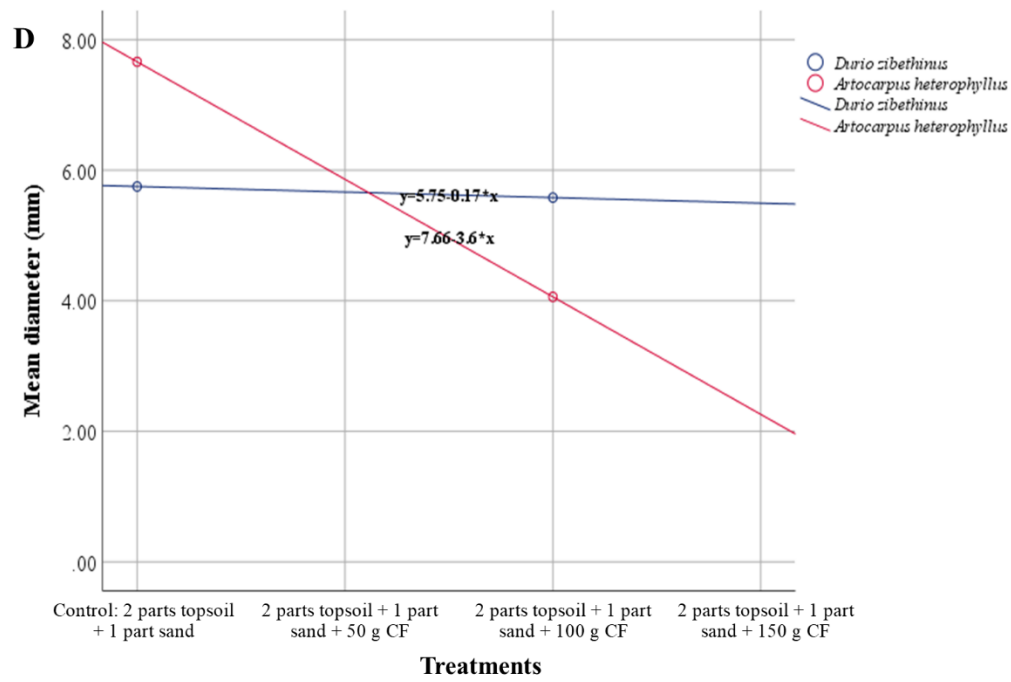
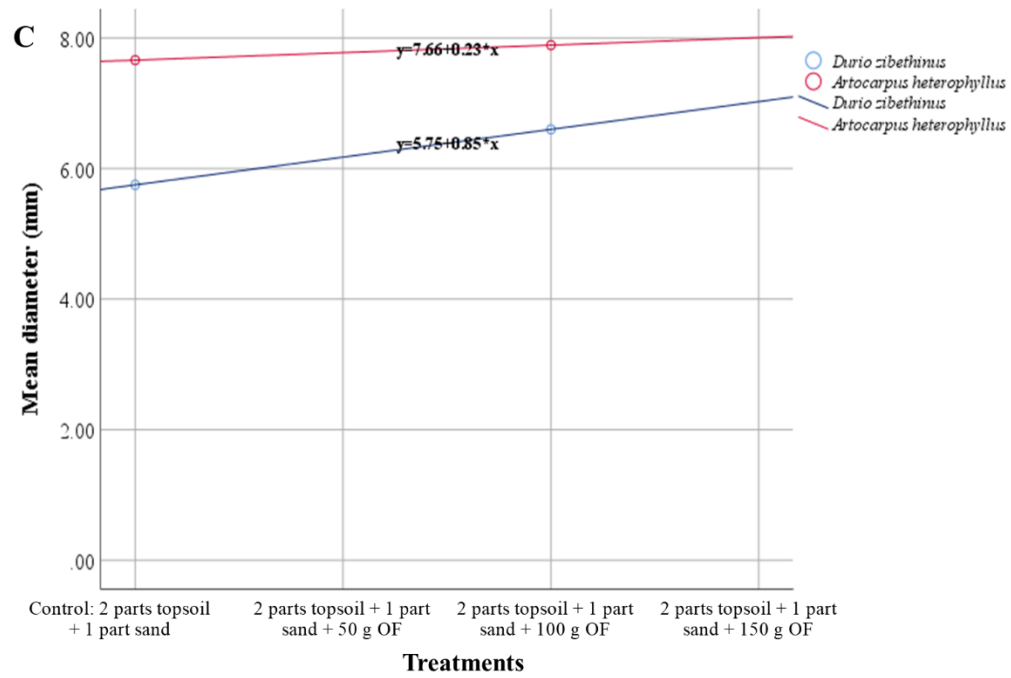


Figure 4.4 continued

Different treatments have different effects on height and stem diameter. The results indicate that plant species and their growth parameters reacted differently toward the treatments.

4.3.2 Interaction Effect Between Treatments and Plant Species on Height and Stem Diameter

A factorial ANOVA was conducted to explore the interaction effect between seven treatments and two types of plants on height and stem diameter (Table 4.6). The result indicates that there are statistically significant differences between treatments versus species of tree on height ($F [6,154] = 12.44, p < 0.05$) and stem diameter ($F [6,154] = 5.57, p < 0.05$). The adjusted R squared told us that 57% of the variance in height is attributable to treatment and species of tree, indicating a strong relationship between the factors and the height of plants. However, only 23% of the variance in stem diameter is attributable to treatment and species of tree, indicating a weak relationship between the factors and stem diameter.

Table 4.6: A Factorial ANOVA Analysis to Explore the Interaction Effect Between Seven Treatments and Two Types of Plants on Height and Stem Diameter

Factors	Dependent Variable	df, Error	F	Significance Value ($p < 0.05$)	Adjusted R Squared
Treatments versus species of tree	Height	6, 154	12.44	0.00*	0.57
	Stem diameter	6, 154	5.57	0.00*	0.23

Tukey post-hoc analysis was further conducted to determine the differences in mean height and stem diameter between different treatments (Table 4.7). There are 12 significant differences in height between different treatments. The highest mean difference in height is between treatments A and F (Mean = 41.93 cm). This indicates that the inoculation of MF-

T with 50 g OF produces a more efficient result in maximizing the height growth of both *D. zibethinus* and *A. heterophyllus* as compared to 100 g CF.

On the other hand, there are three significant differences in stem diameter between different treatments. The highest mean stem diameter is also between treatments A and F (Mean difference = 2.78 mm). This also may indicate that the application of MF-T with 50 g OF is more efficient in maximizing the growth of stem diameter for both plant species. Both the height and stem diameter results show that treatment of 50 g OF with MF-T is the most suitable treatment for the successful establishment of *D. zibethinus* and *A. heterophyllus*.

Table 4.7: Tukey Post-Hoc Analysis to Determine the Difference in Means of the Height and Stem Diameter Between Different Treatments

Treatments		Height		Stem Diameter	
A	B	Mean Difference (A-B)	Significance Value (p < 0.05)	Mean Difference (A-B)	Significance Value (p < 0.05)
A	B	3.50	1.00	0.94	0.80
	C	33.04	0.00*	2.17	0.02*
	D	27.45	0.00*	0.99	0.76
	E	6.37	0.91	0.36	1.00
	F	41.93	0.00*	2.78	0.00*
	G	8.83	0.69	0.90	0.83
B	A	-3.50	1.00	-0.94	0.80
	C	29.54	0.00*	1.23	0.53
	D	23.95	0.00*	0.05	1.00
	E	2.87	1.00	-0.59	0.98
	F	38.43	0.00*	1.84	0.09
	G	5.33	0.96	-0.05	1.00

Table 4.7 continued

Treatments		Height		Stem Diameter	
A	B	Mean Difference (A-B)	Significance Value (p < 0.05)	Mean Difference (A-B)	Significance Value (p < 0.05)
C	A	-33.04	0.00	-2.17	0.02
	B	-29.54	0.00	-1.23	0.53
	D	-5.59	0.95	-1.18	0.57
	E	-26.68	0.00	-1.82	0.10
	F	8.89	0.69	0.61	0.97
	G	-24.21	0.00	-1.28	0.48
D	A	-27.45	0.00	-0.99	0.76
	B	-23.95	0.00	-0.05	1.00
	C	5.59	0.95	1.18	0.57
	E	-21.09	0.00	-0.64	0.96
	F	14.48	0.13	1.79	0.11
	G	-18.62	0.02	-0.09	1.00
E	A	-6.37	0.91	-0.36	1.00
	B	-2.87	1.00	0.59	0.98
	C	26.68	0.00*	1.82	0.10
	D	21.09	0.00*	0.64	0.96
	F	35.56	0.00*	2.43	0.01*
	G	2.47	1.00	0.54	0.98
F	A	-41.93	0.00	-2.78	0.00
	B	-38.43	0.00	-1.84	0.09
	C	-8.89	0.69	-0.61	0.97
	D	-14.48	0.13	-1.79	0.11
	E	-35.56	0.00	-2.43	0.01
	G	-33.10	0.00	-1.89	0.08

Table 4.7 continued

Treatments		Height		Stem Diameter	
A	B	Mean Difference (A-B)	Significance Value ($p < 0.05$)	Mean Difference (A-B)	Significance Value ($p < 0.05$)
G	A	-8.83	0.69	-0.90	0.83
	B	-5.33	0.96	0.05	1.00
	C	24.21	0.00*	1.28	0.48
	D	18.62	0.02*	0.09	1.00
	E	-2.47	1.00	-0.54	0.98
	F	33.10	0.00*	1.89	0.08

Notes: A (2 parts topsoil + 1 part sand + 50 g OF + MF-T); B (2 parts topsoil + 1 part sand + 100 g OF + MF-T); C (2 parts topsoil + 1 part sand + 50 g CF + MF-T); D (2 parts topsoil + 1 part sand + 100 g CF + MF-T); E (2 parts topsoil + 1 part sand + 100 g OF); F (2 parts topsoil + 1 part sand + 100 g CF); G (Control: 2 parts topsoil + 1 part sand)

OF = Organic Fertilizer, CF = Chemical Fertilizer, MF-T = Mycorrhizal fungi and *Trichoderma*

4.3.3 Discussion of Experiment 2

The first result found that the application of organic and chemical fertilizer with MF-T affected the growth (height and stem diameter) of *D. zibethinus* and *A. heterophyllus* differently. Descriptively, the fertilization with OF and inoculation of MF-T promotes both plant height more than CF. In contrast, there is no fixed effect on the stem diameter of both plants when treated with different treatments. The results answer the first research question i.e., how does the application of organic and chemical fertilizer with MF-T affect the growth (height and stem diameter) of *D. zibethinus* and *A. heterophyllus*. Thus, the null hypothesis is rejected. There are significant differences in the height and stem diameter of *D. zibethinus* and *A. heterophyllus* when treated with OF and CF with MF-T.

The second result then found that the most suitable amount of organic and chemical fertilizer with MF-T for a successful establishment of *D. zibethinus* and *A. heterophyllus* is

50 g OF with MF-T. This treatment shows a major effect on growth (height and stem diameter) for both plants, compared to 100 g CF. This then answers the final research question of what is the suitable amount of organic and chemical fertilizer with MF-T for a successful establishment of *D. zibethinus* and *A. heterophyllus*. Thus, the null hypothesis is rejected. Not all treatments help to accelerate the height and stem diameter of *D. zibethinus* and *A. heterophyllus*.

The manipulation of soil nutrient content is important to predict the growth of plants on large-scale reforestation (Fayle et al., 2015). The height and diameter of plant stem, which determine the growth of plants, is directly influenced by the root length and its ability to absorb the nutrients (Harahap et al., 2018). Both MF-T have shown their potential to enhance the plants' nutrient uptake and promote plant growth activity, as shown in various past studies.

A similar result is shown by Castilo et al. (2019) in the Philippines found that the co-inoculation of *Glomus* spp. and *Trichoderma harzianum* has resulted in an increase in banana seedling height, stem diameter and root weight. This shows the potential of co-inoculation using both species with less or without fertilizer application. A study in Iraq by Matrood et al. (2020) also found that the combination of *G. mosseae* and *T. harzianum* has improved the fresh and dry weight root of *Cucumis sativus*. The combination also showed an antagonistic reaction against the fungal pathogen *Alternaria alternata*. The latest study by Nafady et al. (2022) in Egypt showed that the combination of mycorrhizal fungi and *T. harzianum* has a significant positive impact on tomato growth. The tomato shoot length and dry weight were found to increase by 42% and 131%, respectively as compared to the control treatment.

Separately, Duaja et al. (2019) showed the effect of indigenous mycorrhizal fungi i.e. *Glomus* sp., inoculation with fertilizer toward oil palm growth in Indonesia. It was discovered that the inoculation of indigenous *Glomus* sp. with only 75% of the recommended Phosphorus fertilizer promotes oil palm growth in former coal mining soil. This shows that the amount of fertilizer used decreases with the inoculation of *Glomus* sp. A study carried out in China by Khan et al. (2021), also found that the inoculation of arbuscular mycorrhizal fungi (AMF) inoculant containing *Rhizophagus intraradices* with ammonium nitrate increases the aboveground biomass of *Leymus chinensis* 16.7% more than the non-fertilized plant.

A study by Jaitieng et al. (2021) in Thailand also found that the inoculation of *Glomus* sp. with rock phosphate fertilizer has increased the robusta coffee's root colonization as compared to the non-inoculated plant, thus promoting Phosphorus uptake and immunity in the inoculated plant. Besides that, another study by Tian et al. (2019) in China also showed that the inoculation of *G. intraradices* in the *Panax ginseng* has increased root colonization. This eventually will lead to higher roots chemical and functional activities, increased good bacterial species, and protection from pathogenic fungi. A different study by Gao et al. (2020), then found that the combination of AMF, growth-promoting bacteria, and OF also helped in enhancing maize growth, yield-increasing, and promoting nutrient uptake.

Trichoderma's application with OF also has shown an increase in soil's chemical and biological properties, which directly affects plant growth and its' susceptibility toward pests and diseases (Li et al., 2017). The inoculation of *Trichoderma* with goat manure in Thailand has shown an increase in *D. zibethinus* seedlings' biomass compared to the untreated seedlings (Wibowo et al., 2018). A study conducted by Soldan et al. (2018) also

found that *Eugenia pyriformis* has shown an increase in growth only with *Trichoderma* inoculation, irrespective of the chemical fertilizer application. The mixture of *Trichoderma* with vermicompost also has been shown to increase the length and diameter of gladiolus flower stems (da Cruz et al., 2018). The other study by França et al. (2017), also found that the inoculation of *Trichoderma* along with chemical fertilization increased the rice biomass as compared to the untreated control.

On the other hand, there are also studies focusing on the effectiveness of the CF and OF mixture with *Trichoderma* in promoting plant growth. A study by Bokhtiar et al. (2016) found that the enrichment of pressmud with *Trichoderma* with 75% and 50% of the CF produces the same yield growth with enriched pressmud and 100% CF. Another study by Pang et al. (2017) also found a similar result in which, the growth of tomato is maximized when treated with 75% amount of CF with OF enriched by *Trichoderma*, as compared to the 100% amount of CF and 75% amount of CF mixed with OF only.

Apart from promoting plant growth, other past studies also showed that the inoculation of *Trichoderma* is targeted to restrain pests and disease attacks on plants. *Trichoderma viride* was found to be effective in inhibiting *Rhizopus artocarp*i, which causes fruit and inflorescence rot of *A. heterophyllus* (Dalavi et al., 2017). *Trichoderma* also shows antagonistic effects towards *Fusarium*, which often causes leaf wilt (Tao et al., 2015). The application of decomposer (bioameliorant) combined with biofertilizers and *Trichoderma* also has shown decreasing brown spot, sheath rice blight, and bacterial leaf blight diseases on paddy (Simarmata et al., 2016). The incidence of Sclerotinia stem rot, which is caused by *S. sclerotiorum* fungi on canola were also shown to decrease before the application of

Trichoderma with a reduced amount of chemical fungicide which, the result is similar to the application of 100% chemical fungicide (Hu et al., 2016).

These have further supported the effort to reduce the reliance on CF and pesticides. Excessive use of CF and pesticides may lead to high soil salinity, which eventually causes salt stress and induces plant growth (Rubio et al., 2017). The application of a full amount of CF with *Trichoderma* also has caused stunting of growth in wheat due to ammonia toxicity (Mahato et al., 2018). Thus, the application of main *Trichoderma* strains such as *T. harzianum* and *T. gamsii*, which have proven effective in tolerating high CF concentration, is important to reverse the effect of excessive fertilization (Chen et al., 2016).

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Overview of Conclusion and Recommendations Chapter

This study covers both methods of reforestation, which are the natural regeneration method and the replanting method. The first experiment predicted the potential species for reforestation based on natural regeneration status, importance value (IV), and standing biomass (SB). The study focused on the potential of native tree species in Jagoi Heritage Forests (JHF) for reforestation of degraded areas. There were three research questions developed i.e., (i) How big is the difference of species diversity between primary forest (PF), old secondary forest (OSF), young secondary forest (YSF), and agroforest (AF) in JHF, (ii) How big is the difference, between the natural regeneration status, IV, and SB, and (iii) What are the potential native species from JHF to be used for mixed-planting reforestation in degraded areas around Bau District?

The conclusion chapter summarizes the findings of Experiment 1 according to three study objectives namely, (i) To compare the diversity of trees between four different forest types namely PF, OSF, YSF, and AF in JHF, (ii) To determine the differences between the natural regeneration status, IV, and SB, and (iii) To determine the potential tree species for mixed-planting reforestation in degraded areas around Bau District using the ecological criteria i.e., natural regeneration status, IV, and SB.

The second experiment investigated the potential of mycorrhizal fungi and *Trichoderma* (MF-T) in accelerating the growth of plants and, at the same time, accelerating reforestation. This study also aimed to establish the suitable amount of organic (OF) and

chemical fertilizer (CF) with MF-T application for *Durio zibethinus* and *Artocarpus heterophyllus* cultivation. There were two research questions developed i.e., (i) How does the application of organic and chemical fertilizer with MF-T affect the growth (height and stem diameter) of *D. zibethinus* and *A. heterophyllus*, and (ii) What is the suitable amount of organic and chemical fertilizer with MF-T for a successful establishment of *D. zibethinus* and *A. heterophyllus*?

The conclusion chapter summarizes the findings of Experiment 2 according to two study objectives namely, i) to analyse the effect of organic and chemical fertilizer with MF-T application on the growth (height and stem diameter) of *D. zibethinus* and *A. heterophyllus* and ii) to determine the suitable amount of organic and chemical fertilizer with MF-T for *D. zibethinus* and *A. heterophyllus* cultivation.

5.2 Conclusion

The first experiment was conducted to predict the potential native tree species for reforestation using the natural regeneration status, IV, and SB. This approach provides a valuable predictive tool for selecting appropriate species that can thrive in reforestation efforts, taking into consideration the existing ecological conditions.

The result for the first objective, which is to compare the diversity of trees between four different forest types of JHF, found that the YSF and AF have higher species diversity as compared to the other forest types. This finding is instrumental in informing reforestation strategies, as it emphasizes the potential of these forest types to contribute to ecosystem restoration with their naturally higher species diversity.

The second objective, which was to determine the differences between the natural regeneration status, IV, and SB, then showed that there are two significant differences in the importance value and standing biomass. The discovery emphasizes the complex interactions between these factors and their dynamic responses to different ecological circumstances. Planning and managing reforestation require making informed decisions, which require an understanding of these variances.

Last but not least, the third objective is to determine the potential tree species for mixed-planting reforestation in degraded areas around Bau District using the ecological criteria i.e., natural regeneration status, IV, and SB. The study has found that *Dipterocarpus* sp. and *Archidendron jiringa* fit all the requirements of the potential species. *Dipterocarpus* sp. has a history of being planted in reforestation areas. However, *A. jiringa* has never been planted for reforestation. Yet, it shows a good potential for reforestation in degraded areas. This finding provides beneficial guidance on how to choose species that have the qualities required for effective replanting in degraded areas.

Overall, the findings show the significance of measuring the vegetation structure to determine the environmental change related to forest disturbance. The measure of forest regeneration does not only provide information on the species diversity but also predicts the potential native species for reforestation.

The second experiment investigated the potential of MF-T in accelerating the growth of plants and, at the same time, accelerating reforestation. The first objective which is, to analyse the effect of organic and chemical fertilizer with MF-T application on the growth (height and stem diameter) of *D. zibethinus* and *A. heterophyllus* has shown that both fertilizers with MF-T application helps in accelerating the height and stem diameter of both

plant species. However, the trend of growth for both plants differs according to different treatments. The co-inoculation of MF-T in the soil helps increase the plants' nutrient uptake and promotes the plants' growth. This indicates the potential of this method to be conducted in large-scale reforestation works.

Finally, the second objective which is, to determine the suitable amount of organic and chemical fertilizer with MF-T for *D. zibethinus* and *A. heterophyllus* cultivation has found that the co-inoculation of MF-T with 50 g OF promotes the plants' growth more effectively. These findings are important to provide an alternative to the conventional method from the past reforestation method. The OF's utilization with the inoculation of MF-T will help to reduce the dependencies on CF and accelerate the growth of the trees.

Conclusively, reforestation can be achieved through two methods namely, natural regeneration and experimental manipulation during replanting. The natural regeneration method can be practised as a change of the old reforestation practises of using introduced exotic species and monoculture planting. The existing forest, such as JHF, provides an ample supply of seedlings or wildings for reforestation in other degraded areas. Predicting the potential species based on the tree's natural regeneration status, IV, and SB forecast the successful establishment of the selected species in a new area. On the other hand, the replanting method can be advanced through co-inoculation of MF-T with OF. This method helps in promoting plant growth and recovers the soil's chemical and biological properties. It also helps in reducing dependencies on CF, as found in this study, as only half of the OF amount is needed for plant growth when MF-T is applied.

5.3 Recommendations

Both experiments can be merged to advance the study of the growth of the potential native tree species. Trial planting of the listed species and manipulating the soil and environmental conditions can be conducted simultaneously. The selection of species should also be conducted along with the climate and site suitability of the reforestation area. Annual precipitation and soil chemical and physical properties tests can be conducted to further narrow the suitability of the selected species. The difference in seedling growth and survivability between wildings and seeds of the listed species can also be manipulated to determine the success of reforestation using native tree species.

5.4 Contributions of Study

The contributions of this study can be divided into two i.e., academic, and industrial applications. Firstly, this study contributes to the knowledge of forest conservation and restoration. The results of this study can be used as a basis for future reforestation studies, as mentioned in the previous section.

The results of this study will also contribute to the local and national forest management, in line with the Malaysian government's five-year plan which is, to plant 100 million trees by 2025. The listed native tree species from the JHF in the first experiment have shown that the Jagoi forest has an ample supply of trees for reforestation in other degraded areas within the Jagoi area. This will also help in saving the cost of reforestation as they do not have to buy trees from other places, as previously done in JHF. However, as suggested in the previous section, further studies to determine the suitability of the species are recommended, especially if there is an attempt for reforestation outside of the Jagoi area.

The result of the second experiment will also contribute to agroforestry and environmental management. Not only that the application of *Trichoderma* can boost the tree's growth, but it will also reduce the dependencies on CF, thus reducing the incidence of soil and water pollution.

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APPENDICES

Appendix 1: Vegetation Structure Data Spreadsheet

Site: Quadrat No.:			Light Intensity: Relative Humidity: Temperature:	
Tree No.	Species	Status	Stem Diameter/ DBH (cm)	Height (meter)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
Etc.				
		1 – Seedlings 2 – Saplings 3 – Trees		

Appendix 2: *Trichoderma* sp. Product (Nutri-Life Platform)



NTS
Nutri-Tech Solutions®



**MICROBIAL
PRODUCTS**

Nutri-Life Platform®

NEW IMPROVED BLEND – ADDITIONAL STRAINS
The biological base of problem-free agriculture.

Huge numbers of Arbuscular Mycorrhizal Fungi (AMF) (4 species) and *Trichoderma* (5 strains) together in one breakthrough blend. Root health is plant health and these organisms are the essence of healthy roots.

BENEFITS

- Australian Certified Organic (ACO) Registered Farm Input 456AI.
- Builds humus – Glomalin produced by AMF generates 1/3 of the world's soil carbon.
- Increase root zone with all of the associated benefits.
- Can reduce fertiliser requirements through improved nutrient uptake.
- Boosts phosphate and zinc availability.
- Lifts calcium levels in plants.
- Improves bio-balance and associated plant resilience in the root zone.
- Serves as a synergist to improve nitrogen fixation.

PACKAGING:

200 g, 1 kg,
100 x 1 kg
Product Code:
NLPLAT



**Nutrition
Farming®**

**Australian
Organic Registered
Farm Input**
ALLOWED INPUT 456AI

Nutri-Life Platform®

APPLICATION RATES

Broadacre Seed Treatment:

50 g/ha mixed in sufficient water for good coverage (approximately 5 – 10 L/tonne of seed).

Seed-Start™ is a synergistic nutrition-based treatment which should be used with Platform® for optimum response. Slowly add Seed-Start™ at 3 – 5 L/tonne of seed to the Platform® solution before applying this mixture to the seed (total mixture is not to exceed 15 L/tonne).

Soil Application:

40 – 200 g/ha

Up to 1 kg/ha for Golf Greens

Dissolve 200 grams in 10 L of water, stir well and add to the fertigation/spray tank. Agitate throughout application. Do not apply with fertilisers containing high levels of soluble phosphate. Do not store pre-mixed product.

Horticulture

Use sufficient water to wash product into the top 2 – 4 cm of soil.

Pasture

Ideally apply product before rain (or irrigation) to achieve incorporation to 3 mm.

Liquid Inject:

50 g/ha. Include with Springboard™ at recommended rates for best results.

Seedling/Runner Treatment:

Dip seedlings/runners/tubestock in a solution containing 50 grams of Platform® per 100 L of water. Stir solution regularly throughout process.

COMPOSITION

Contains Arbuscular Mycorrhizal Fungi (AMF) and *Trichoderma* species.

IMPORTANT

See www.nutri-tech.com.au/platform for details of pesticides which are not compatible with Platform®. Contains live organisms. Do not mix with fungicides/bactericides, toxic chemicals or soil fumigants. Sanitise spray tank before application. All microbial products should be added to the tank last after all other inputs have been diluted. Ideally, apply in the late afternoon. Do not exceed 60 psi. While handling and applying microbial products protective clothing, gloves and face masks should be worn. Wash hands after use.

INSTRUCTIONS

Platform® forms a suspension when mixed with water (i.e. it does not dissolve). Constant agitation is required during application to prevent equipment blockages. Platform® spore sizes can be up to 260 µm (0.26 mm) therefore it is recommended that an in-line filtration system of 30 mesh (0.5 mm) be fitted to ensure delivery lines are free of contaminants. Ensure there are no places in the hosing which may sag and cause product to settle if left for a period of time. Flushing of lines after use will also prevent contamination.

STORAGE & HANDLING

Immuno-compromised persons (e.g. those undergoing chemotherapy) should not handle or be exposed to microbial products. While handling, brewing and applying microbial products protective clothing, gloves and face masks should be worn. Contains live organisms. Avoid aerosols generated by aeration. Store in cool, dry place away from sunlight and below 30°C (preferably under refrigeration). Use as soon as possible after opening but if this cannot be achieved then refrigerate remainder immediately after use and use within 3 months. Contamination of contents may occur at any time after opening and NTS takes no responsibility for opened product not used immediately. DO NOT FREEZE.

YOUR LOCAL NTS DISTRIBUTOR:

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Nutri-Life Platform®

SOME COMMERCIAL SPECIES THAT WILL BENEFIT FROM A PLATFORM® INOCULATION:

Acacia, Agapanthus, Alder, Almond, Apple, Apricot, Araucaria, Artichoke, Ash, Asparagus, Avocado, Bamboo, Banana, Barley, Bayberry, Bean, Begonia, Black Cherry, Blackberry, Black Locust, Blue Gramma, Box Elder, Boxwood, Brazilian Rubber, Bulbs (all), Burning Bush, Cacao, Cactus, Camellia, Carrisa, Carrot, Cassara, Ceanothus, Cedar, Celery, Cherry, Chinese Tallow, Chrysanthemum, Citrus (all), Clover, Coconut, Coffee, Coral Tree, Corn, Cotton, Cottonwood, Cowpea, Crab Tree, Creosote Bush, Cucumber, Currant, Cypress, Dodwood, Eggplant, Eucalyptus, Fern, Fescue, Fig, Forsythia, Fountain Grass, Fuschia, Gardenia, Garlic, Geranium, Grape-raisin, Grape-table, Grape-wine, Green Ash, Guayule, Hibiscus, Holly, Impatiens, Jojoba, Juniper, Kiwi, Leek, Lettuce, Ligustrum, Magnolia, Mahonia, Maiden Grass, Mango, Maples (all), Marigold, Mesquite, Millet, Mimosa, Mondo Grass, Morning Glory, Mountain Laurel, Nasturtium, Okra, Olive, Olive Palm, Onion, Pacific Yew, Palms (all), Pampas Grass, Passion Fruit, Papaya, Paw Paw, Peach, Peanut, Pecan, Pepper, Pistachio, Pittosporum, Plum, Podocarpus, Poinsettia, Potato, Rephiolepis, Raspberry, Redwood, Rice, Rock Melon, Rose, Ryegrass, Sagebrush, Salt Bush, Sequoia, Snapdragon, Sourwood, Soybean, Spengeri Fern, Squash, Strawberry, Sudan Grass, Sugar Cane, Sumac, Sunflower, Sweet Gum, Sweet Potato, Sycamore, Taxus, Tea, Tobacco, Tomato, Wheat, Water Melon.

SOME COMMERCIAL SPECIES THAT DO NOT BENEFIT FROM PLATFORM® INOCULANT:

Arctostaphylos, Azalea, Beet, Birch Blueberries, Brassicas, Canola, Carnation, Douglas-fir, Fir, Hazelnut, Heath, Hemlock, Larch, Macadamia, Oak, Orchid, Pine, Poplar, Protea, Rhododendron, Rush, Sedge, Spruce, Walnut.

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Appendix 3: Data Collection Spreadsheet

Block	Plant/ Measurement	Height (cm)	Diameter (mm)	No. of Leaves
1	A1			
	A2			
	A3			
	A4			
	A5			
	A6			
	A7			
	A8			
	A9			
	A10			
	A11			
	A12			
	A13			
	A14			
	A15			
	A16			
	A17			
	A18			
	A19			
	A20			
2	B2			
	Etc.			

Appendix 4: List of Tree Species Recorded in JHF

No.	Family name	Scientific name		Local name
1.	Achariaceae	i.	<i>Pangium edule</i>	Poyang
2.	Actinidiaceae	i.	<i>Saurauia acuminata</i>	Kalibodok
3.	Anacardiaceae	i.	<i>Camptosperma auriculatum</i>	Totang
		ii.	<i>Camptosperma coriaceum</i>	Totang manuk
		iii.	<i>Gluta wallichii</i>	Plaus
		iv.	<i>Mangifera griffithii</i>	Asuom jobung
		v.	<i>Mangifera pajang</i>	Asuom bowang
		vi.	<i>Mangifera</i> sp. 1	Asuom
		vii.	<i>Mangifera</i> sp. 2	Asuom ramuk
		viii.	<i>Mangifera</i> sp. 3	Asuom simasang
		ix.	<i>Mangifera torquenda</i>	Asuom motan
		x.	<i>Pentaspadon motleyi</i>	Ploju
		xi.	<i>Pentaspadon</i> sp.	Ploju rotan
4.	Anisophylleaceae	i.	<i>Anisophyllea disticha</i>	Pijulud
		ii.	<i>Anisophyllea</i> sp. 1	Mopu
		iii.	<i>Anisophyllea</i> sp. 2	Ngilian
5.	Annonaceae	i.	<i>Goniothalamus uvarioides</i>	Kinamai
		ii.	<i>Goniothalamus velutinus</i>	Kinamai roii
		iii.	<i>Polyalthia cauliflora</i>	Selukai
		iv.	<i>Polyalthia</i> sp.	Sinotan
		v.	<i>Xylopi ferruginea</i>	Binyokad
6.	Apocynaceae	i.	<i>Alstonia scholaris</i>	Gitiek
		ii.	<i>Alstonia spatulata</i>	Ngitatok
		iii.	<i>Dyera costulata</i>	Grituong
7.	Aquifoliaceae	i.	<i>Ilex hypoglauca</i>	Sapo
8.	Asteraceae	i.	<i>Vernonia arborea</i>	Mupuot
9.	Bonnetiaceae	i.	<i>Ploiarium alternifolium</i>	Silumah
10.	Burseraceae	i.	<i>Canarium</i> sp. 1	Pokuok
		ii.	<i>Canarium</i> sp. 2	Pudun bokuk
		iii.	<i>Dacryodes rostrata</i>	Kemayau
		iv.	<i>Dacryodes</i> sp. 1	Orin
		v.	<i>Dacryodes</i> sp. 2	Seladah
		vi.	<i>Santiria</i> sp.	Seladah
11.	Calophyllaceae	i.	<i>Calophyllum canum</i>	Bintangor merah
		ii.	<i>Calophyllum floribundum</i>	Bintangor kuning
		iii.	<i>Calophyllum</i> sp.	Bintangor

Appendix 4 continued

No.	Family name	Scientific name		Local name
11.	Calophyllaceae	iv.	<i>Calophyllum woodii</i>	Sibung
		v.	<i>Mesua ferrea</i>	Tungus
		vi.	<i>Mesua</i> sp.	Nguos
12.	Cannabaceae	i.	<i>Gironniera nervosa</i>	Medang kasap
13.	Celastraceae	i.	<i>Bhesa paniculata</i>	Bhesa
14.	Chrysobalanaceae	i.	<i>Parastemon urophyllus</i>	Sri'eng
15.	Clusiaceae	i.	<i>Garcinia mangostana</i>	Sikuk
		ii.	<i>Garcinia nitida</i>	Konis
		iii.	<i>Garcinia parvifolia</i>	Ngitorup / Sigongang
		iv.	<i>Garcinia</i> sp.	Pijarik
16.	Cornaceae	i.	<i>Alangium javanicum</i>	Moran
17.	Dilleniaceae	i.	<i>Dillenia borneensis</i>	Du'od
		ii.	<i>Dillenia excelsa</i>	Buan kaking
		iii.	<i>Dillenia suffruticosa</i>	Buan
18.	Dipterocarpaceae	i.	<i>Dipterocarpus cuspidatus</i>	Keruing sisip
		ii.	<i>Dipterocarpus fagineus</i>	Keruing isit
		iii.	<i>Dipterocarpus kunstleri</i>	Naguog
		iv.	<i>Dipterocarpus obtusifolius</i>	Ngipakuoh
		v.	<i>Dipterocarpus sarawakensis</i>	Keruing
		vi.	<i>Dipterocarpus</i> sp.	Damar
		vii.	<i>Dryobalanops beccarii</i>	Rodan
		viii.	<i>Hopea ferruginea</i>	Kowan
		ix.	<i>Rubroshorea beccariana</i>	Obang
		x.	<i>Rubroshorea bullata</i>	Obang kingi (meranti)
		xi.	<i>Rubroshorea coriacea</i>	Jo jag
		xii.	<i>Rubroshorea curtisii</i>	Kabang tuan
		xiii.	<i>Rubroshorea macrophylla</i>	Kabang
		xiv.	<i>Rubroshorea macroptera</i>	Sirieng
		xv.	<i>Rubroshorea palembanica</i>	Kabang asuk
		xvi.	<i>Rubroshorea stenoptera</i>	Kabang stuliet
		xvii.	<i>Shorea ladiana</i>	Jo jag dien
		xviii.	<i>Upuna borneensis</i>	Pinyaoh
		xix.	<i>Vatica</i> sp.	Kowan
19.	Ebenaceae	i.	<i>Diospyros buxifolia</i>	Kayu malam
		ii.	<i>Diospyros foxworthyi</i>	Unguon olan
		iii.	<i>Diospyros piscicapa</i>	Tuboh

Appendix 4 continued

No.	Family name	Scientific name		Local name
20.	Elaeocarpaceae	i.	<i>Elaeocarpus nitidus</i>	Songoh
		ii.	<i>Elaeocarpus sphaeroblastus</i>	Tamang
21.	Euphorbiaceae	i.	<i>Croton</i> sp.	Tupai
		ii.	<i>Elateriospermum tapos</i>	Pala so'ie / Ropi
		iii.	<i>Endospermum diadenum</i>	Ngibulan
		iv.	<i>Hevea brasiliensis</i>	Jotu'
		v.	<i>Homalanthus populneus</i>	Kali banuok
		vi.	<i>Macaranga caladiifolia</i>	Binua
		vii.	<i>Macaranga gigantea</i>	Badad
		viii.	<i>Macaranga</i> sp.	Purang
		ix.	<i>Mallotus repandus</i>	Towi
		x.	<i>Mallotus</i> sp.	Krumai
		xi.	<i>Pimelodendron griffithianum</i>	Perah ikan
		xii.	<i>Pimelodendron</i> sp.	Ngipodos
22.	Fabaceae	i.	<i>Archidendron borneense</i>	Kali piti
		ii.	<i>Archidendron jiringa</i>	Joring
		iii.	<i>Cassia</i> sp.	Bigow
		iv.	<i>Dialium indum</i>	Kronyih
		v.	<i>Fordia splendidissima</i>	Mobi (kayu sugi)
		vi.	<i>Koompassia excelsa</i>	Do'oh
		vii.	<i>Koompassia malaccensis</i>	Pas bogeh / Menggris
		viii.	<i>Ormosia bancana</i>	Saga hutan
		ix.	<i>Parkia speciosa</i>	Potah
23.	Fagaceae	i.	<i>Castanopsis motleyana</i>	Bongan
		ii.	<i>Lithocarpus echinifer</i>	Keraki
		iii.	<i>Lithocarpus ewyckii</i>	Keraki boras
		iv.	<i>Lithocarpus</i> sp.	Ngisadag
		v.	<i>Lithocarpus turbinatus</i>	Keraki kodad
24.	Gentianaceae	i.	<i>Fagraea racemosa</i>	Ngitanuk
25.	Gnetaceae	i.	<i>Gnetum gnemon</i>	Dodah
26.	Hypericaceae	i.	<i>Cratoxylum arborescens</i>	Gironggang
		ii.	<i>Cratoxylum formosum</i>	Ngidodot
		iii.	<i>Cratoxylum glaucum</i>	Tuma kiriep
27.	Irvingiaceae	i.	<i>Allantospermum borneense</i>	Ras
28.	Ixonanthaceae	i.	<i>Ixonanthes beccarii</i>	Lidian
		ii.	<i>Ixonanthes</i> sp.	Ngibisak

Appendix 4 continued

No.	Family name	Scientific name		Local name
29.	Lamiaceae	i.	<i>Clerodendrum</i> sp.	Kalipoit
		ii.	<i>Vitex pubescens</i>	Ngiliwat
30.	Lauraceae	i.	<i>Actinodaphne</i> sp.	Medang payung
		ii.	<i>Alseodaphne</i> sp. 1	Medang
		iii.	<i>Alseodaphne</i> sp. 2	Medang lusu
		iv.	<i>Eusideroxylon zwageri</i>	Kayu besi
		v.	<i>Lindera</i> sp.	Pora
		vi.	<i>Litsea cordata</i>	Medang burung
		vii.	<i>Litsea garciae</i>	Kalak
		viii.	<i>Litsea gracilipes</i>	Medang keli
		ix.	<i>Litsea grandis</i>	Tiburus badong
		x.	<i>Litsea lancifolia</i>	Tiburus
		xi.	<i>Litsea nidularis</i>	Medang putih
		xii.	<i>Litsea resinosa</i>	Tiburus kalak
		xiii.	<i>Litsea</i> sp. 1	Tiburus birieh
		xiv.	<i>Litsea</i> sp. 2	Tiburus sari / Panasari
		xv.	<i>Litsea</i> sp. 3	Medang mengkurat
		xvi.	<i>Litsea</i> sp. 4	Medang kuning
		xvii.	<i>Litsea</i> sp. 5	Medang
31.	Lecythidaceae	i.	<i>Barringtonia</i> sp.	Rakut
32.	Loganiaceae	i.	<i>Norrisia major</i>	Bi'ih
33.	Magnoliaceae	i.	<i>Talauma</i> sp.	Ngilogang
34.	Malvaceae	i.	<i>Commersonia bartramia</i>	Tunuong
		ii.	<i>Durio zibethinus</i>	Dien
		iii.	<i>Microcos</i> sp.	
		iv.	<i>Pterospermum</i> sp.	Bayur
		v.	<i>Sterculia</i> sp.	Melebu
		vi.	<i>Theobroma cacao</i>	Koko
35.	Melastomataceae	i.	<i>Bellucia pentamera</i>	Jambu manuk
		ii.	<i>Kibessia coriacea</i>	Bah boit
		iii.	<i>Melastoma polyanthum</i>	
		iv.	<i>Memecylon</i> sp. 1	Tulang kada
		v.	<i>Memecylon</i> sp. 2	Timaas
36.	Meliaceae	i.	<i>Aglaia</i> sp.	Proju jerat
		ii.	<i>Lansium domesticum</i>	Rasot
		iii.	<i>Lansium parasiticum</i>	Poriet
37.	Monimiaceae	i.	<i>Kibara coriacea</i>	Paas
38.	Moraceae	i.	<i>Artocarpus anisophyllus</i>	Bitowak

Appendix 4 continued

No.	Family name	Scientific name		Local name
38.	Moraceae	ii.	<i>Artocarpus elasticus</i>	Boyuh / Ti'en
		iii.	<i>Artocarpus integer</i>	Tibodak
		iv.	<i>Artocarpus kemando</i>	Puduh
		v.	<i>Artocarpus nitidus</i>	Kolon
		vi.	<i>Artocarpus tamaran</i>	Boyuh dorod
		vii.	<i>Ficus aurata</i>	Topuok
		viii.	<i>Ficus brunneoaurata</i>	Popan
		ix.	<i>Ficus geocharis</i>	Pidorih / Timu
		x.	<i>Ficus grossularioides</i>	
		xi.	<i>Ficus racemosa</i>	
		xii.	<i>Ficus</i> sp. 1	Popuok
		xiii.	<i>Ficus</i> sp. 2	Dunuk
39.	Myristicaceae	i.	<i>Gymnacranthera</i> sp. 1	Pang
		ii.	<i>Gymnacranthera</i> sp. 2	Pang (buah besar)
		iii.	<i>Gymnacranthera</i> sp. 3	Pang (malam)
		iv.	<i>Horsfieldia</i> sp.	Pang birieh
		v.	<i>Knema latifolia</i>	Pang bonar
		vi.	<i>Knema</i> sp. 1	Pang bulu
		vii.	<i>Knema</i> sp. 2	Pang songot
		viii.	<i>Knema</i> sp. 3	Pang
		ix.	<i>Myristica</i> sp.	Pang manuk
40.	Myrtaceae	i.	<i>Syzygium arcuatinervium</i>	Bah lesu
		ii.	<i>Syzygium jambos</i>	Bah jambu
		iii.	<i>Syzygium kunstleri</i>	Bah mopu'
		iv.	<i>Syzygium leucoxylon</i>	Bah birieh
		v.	<i>Syzygium monticola</i>	Bah boru
		vi.	<i>Syzygium polyanthum</i>	Bah bunggang
		vii.	<i>Syzygium sarawakensis</i>	Bah sengkurat
		viii.	<i>Syzygium</i> sp. 1	Bah
		ix.	<i>Syzygium</i> sp. 2	Bah
		x.	<i>Syzygium</i> sp. 3	Bah
		xi.	<i>Syzygium</i> sp. 4	Bah
		xii.	<i>Syzygium</i> sp. 5	Bah
		xiii.	<i>Syzygium</i> sp. 6	Bah
		xiv.	<i>Syzygium</i> sp. 7	Bah
		xv.	<i>Syzygium</i> sp. 8	Ngisilian
		xvi.	<i>Syzygium</i> sp. 9	Bah songot
		xvii.	<i>Syzygium</i> sp. 10	Bah so'ie

Appendix 4 continued

No.	Family name	Scientific name		Local name
40.	Myrtaceae	xviii.	<i>Syzygium</i> sp. 11	Bah daun besar
		xix.	<i>Syzygium</i> sp. 12	Bah
		xx.	<i>Syzygium</i> sp. 13	Bah daun halus
		xxi.	<i>Syzygium</i> sp. 14	Bah daun panjang
		xxii.	<i>Syzygium</i> sp. 15	Ngisiliet
		xxiii.	<i>Tristaniopsis whiteana</i>	Limuban
		xxiv.	<i>Whiteodendron moultonianum</i>	Kawi
41.	Ochnaceae	i.	<i>Euthemis minor</i>	Owid
42.	Olacaceae	i.	<i>Ochanostachys amentacea</i>	Imbah
		ii.	<i>Strombosia ceylanica</i>	Belian landak
43.	Oxalidaceae	i.	<i>Sarcotheca</i> sp.	Pieng
44.	Pentaphylacaceae	i.	<i>Adinandra borneensis</i>	Simupak
		ii.	<i>Adinandra dumosa</i>	Semopak
		iii.	<i>Eurya acuminata</i>	Sinakan
45.	Phyllanthaceae	i.	<i>Aporosa benthamiana</i>	Botung
		ii.	<i>Aporosa</i> sp. 1	Ngisiluk
		iii.	<i>Aporosa</i> sp. 2	Sisong
		iv.	<i>Baccaurea angulata</i>	Gelumbing
		v.	<i>Baccaurea macrocarpa</i>	Bitongun / Sonuong / Topui
		vi.	<i>Baccaurea maingayi</i>	Botung
		vii.	<i>Baccaurea motleyana</i>	Rame
		viii.	<i>Baccaurea polyneura</i>	Potik
		ix.	<i>Baccaurea pubera</i>	Pijirak
		x.	<i>Baccaurea</i> sp.	Botut
		xi.	<i>Breynia racemosa</i>	Nyam
		xii.	<i>Breynia</i> sp.	Nyam badak
		xiii.	<i>Cleistanthus</i> sp.	Mobi
		xiv.	<i>Glochidion macrostigma</i>	Menyam
		xv.	<i>Glochidion</i> sp. 1	Nyah
		xvi.	<i>Glochidion</i> sp. 2	Nyah birieh
		xvii.	<i>Glochidion</i> sp. 3	Nyah mopu'
46.	Podocarpaceae	i.	<i>Decussocarpus motleyi</i>	Medang buluh
47.	Polygalaceae	i.	<i>Xanthophyllum amoenum</i>	Bijorin
		ii.	<i>Xanthophyllum</i> sp. 1	Bijorin manuk
		iii.	<i>Xanthophyllum</i> sp. 2	Ngisabi
48.	Primulaceae	i.	<i>Ardisia javanica</i>	Japak

Appendix 4 continued

No.	Family name	Scientific name		Local name
49.	Rhizophoraceae	i.	<i>Pellacalyx lobbii</i>	Dangoh
50.	Rubiaceae	i.	<i>Canthium umbelligerum</i>	Bokol
		ii.	<i>Ixora</i> sp.	O'nieg
		iii.	<i>Nauclea</i> sp.	Atap
		iv.	<i>Psychotria viridiflora</i>	Pijar
		v.	<i>Timonius lasianthoides</i>	Tulang oyung
		vi.	<i>Timonius</i> sp.	Kurang
		vii.	<i>Urophyllum</i> sp.	Ngibisak / Sabar bubu
51.	Rutaceae	i.	<i>Citrus aurantiifolia</i>	Limau
		ii.	<i>Euodia glabra</i>	Bitopu
52.	Salicaceae	i.	<i>Flacourtia jangomas</i>	Biaya
		ii.	<i>Flacourtia rukam</i>	Poyak
53.	Sapindaceae	i.	<i>Nephelium cuspidatum</i>	Porod
		ii.	<i>Nephelium lappaceum</i>	Rimutan hutan
		iii.	<i>Nephelium maingayi</i>	Pijuan / Prutan
		iv.	<i>Nephelium ramboutan-ake</i>	Sibu dodah
		v.	<i>Pometia pinnata</i>	Kasai
54.	Sapotaceae	i.	<i>Palaquium gutta</i>	Jotu birieh
		ii.	<i>Palaquium obovatum</i>	Jotu' rigu
		iii.	<i>Palaquium</i> sp. 1	Jotu bakak
		iv.	<i>Palaquium</i> sp. 2	Jotu papiek
55.	Simaroubaceae	i.	<i>Eurycoma longifolia</i>	Pudun naga / Tongkat ali
56.	Staphyleaceae	i.	<i>Turpinia sphaerocarpa</i>	Ngidumam
57.	Stemonuraceae	i.	<i>Cantleya corniculata</i>	Bidaru
		ii.	<i>Stemonurus</i> sp.	Semburok
58.	Symplocaceae	i.	<i>Symplocos</i> sp.	Ruboh
59.	Tetramelaceae	i.	<i>Octomeles sumatrana</i>	Benuang
60.	Thymelaeaceae	i.	<i>Aetoxylon sympetalum</i>	Tabak
		ii.	<i>Gonystylus</i> sp.	Ramin bukit
61.	Ulmaceae	i.	<i>Trema occidentalis</i>	
62.	Urticaceae	i.	<i>Leucosyke</i> sp.	Kerangan
63.	Vitaceae	i.	<i>Leea indica</i>	Pokuluang
64.	Unknown	i.	<i>Unknown 1</i>	Jaga
65.	Unknown	ii.	<i>Unknown 2</i>	Ngitikie
66.	Unknown	iii.	<i>Unknown 3</i>	Onop
67.	Unknown	iv.	<i>Unknown 4</i>	Otuk
68.	Unknown	v.	<i>Unknown 5</i>	Sidawas

Appendix 4 continued

No.	Family name	Scientific name		Local name
69.	Unknown	vi.	<i>Unknown 6</i>	Sidokie
70.	Unknown	vii.	<i>Unknown 7</i>	Sirunang
71.	Unknown	viii.	<i>Unknown 8</i>	Tokung

Notes: Unknown species – Identified up to local name only

Appendix 5: Total Number of Species Occurrence in the Sampling Quadrats per Forest Types

Species	Forest Types			
	PF	OSF	YSF	AF
<i>Actinodaphne</i> sp.	0	0	1	0
<i>Adinandra borneensis</i>	1	1	1	0
<i>Adinandra dumosa</i>	1	2	2	2
<i>Aetoxylon sympetalum</i>	1	1	0	0
<i>Aglaia</i> sp.	0	0	1	0
<i>Alangium javanicum</i>	0	1	0	2
<i>Allantospermum borneense</i>	2	2	0	0
<i>Alseodaphne</i> sp. 1	0	0	1	0
<i>Alseodaphne</i> sp. 2	0	0	1	0
<i>Alstonia scholaris</i>	1	3	1	2
<i>Alstonia spatulata</i>	2	3	4	2
<i>Anisophyllea disticha</i>	2	1	2	2
<i>Anisophyllea</i> sp. 1	0	1	0	0
<i>Anisophyllea</i> sp. 2	1	3	0	0
<i>Aporosa benthamiana</i>	2	0	1	0
<i>Aporosa</i> sp. 1	0	3	1	1
<i>Aporosa</i> sp. 2	0	0	0	1
<i>Archidendron borneense</i>	0	2	4	1
<i>Archidendron jiringa</i>	0	2	3	3
<i>Ardisia javanica</i>	0	2	3	1
<i>Artocarpus anisophyllus</i>	1	1	2	0
<i>Artocarpus elasticus</i>	2	5	3	2
<i>Artocarpus integer</i>	2	5	3	3
<i>Artocarpus kemando</i>	2	5	4	2
<i>Artocarpus nitidus</i>	2	4	2	2
<i>Artocarpus tamaran</i>	1	3	1	1
<i>Baccaurea angulata</i>	0	1	0	2
<i>Baccaurea macrocarpa</i>	2	3	0	3
<i>Baccaurea maingayi</i>	0	4	2	1
<i>Baccaurea motleyana</i>	1	0	0	1
<i>Baccaurea polyneura</i>	0	0	1	1
<i>Baccaurea pubera</i>	1	2	0	0
<i>Baccaurea</i> sp.	0	2	3	1
<i>Barringtonia</i> sp.	0	0	2	1
<i>Bellucia pentamera</i>	1	1	1	3
<i>Bhesa paniculata</i>	0	0	1	0
<i>Breynia racemosa</i>	0	0	4	1

Appendix 5 continued

Species	Forest Types			
	PF	OSF	YSF	AF
<i>Breynia</i> sp.	0	1	1	0
<i>Calophyllum canum</i>	1	0	0	0
<i>Calophyllum floribundum</i>	1	0	0	0
<i>Calophyllum</i> sp.	1	1	1	0
<i>Calophyllum woodii</i>	2	3	1	1
<i>Campnosperma auriculatum</i>	1	4	2	2
<i>Campnosperma coriaceum</i>	0	3	2	0
<i>Canarium</i> sp. 1	1	2	1	0
<i>Canarium</i> sp. 2	1	1	0	0
<i>Canthium umbelligerum</i>	0	2	1	1
<i>Cantleya corniculata</i>	2	3	1	0
<i>Cassia</i> sp.	0	0	0	1
<i>Castanopsis motleyana</i>	0	1	1	2
<i>Citrus aurantiifolia</i>	0	0	0	1
<i>Cleisanthus</i> sp.	0	1	0	0
<i>Cleistanthus</i> sp.	2	2	3	0
<i>Clerodendrum</i> sp.	1	0	0	0
<i>Commersonia bartramia</i>	0	0	3	1
<i>Cratoxylum arborescens</i>	0	3	1	0
<i>Cratoxylum formosum</i>	1	3	4	3
<i>Cratoxylum glaucum</i>	0	1	0	1
<i>Croton</i> sp.	0	1	0	0
<i>Dacryodes rostrata</i>	0	0	0	1
<i>Dacryodes</i> sp. 1	0	1	0	0
<i>Dacryodes</i> sp. 2	0	0	0	1
<i>Decussocarpus motleyi</i>	0	0	0	1
<i>Dialium indum</i>	1	1	1	0
<i>Dillenia borneensis</i>	1	3	0	0
<i>Dillenia excelsa</i>	2	4	2	2
<i>Dillenia suffruticosa</i>	0	1	1	2
<i>Diospyros buxifolia</i>	0	0	0	1
<i>Diospyros foxworthyi</i>	1	2	1	3
<i>Diospyros piscicapa</i>	0	2	1	1
<i>Dipterocarpus cuspidatus</i>	1	1	0	0
<i>Dipterocarpus fagineus</i>	1	0	0	0
<i>Dipterocarpus kunstleri</i>	0	1	0	0
<i>Dipterocarpus oblongifolius</i>	2	2	0	0
<i>Dipterocarpus obtusifolius</i>	1	0	0	0

Appendix 5 continued

Species	Forest Types			
	PF	OSF	YSF	AF
<i>Dipterocarpus sarawakensis</i>	2	1	0	1
<i>Dryobalanops beccarii</i>	1	3	2	1
<i>Durio zibethinus</i>	0	2	1	3
<i>Dyera costulata</i>	0	1	0	0
<i>Elaeocarpus nitidus</i>	1	2	2	0
<i>Elaeocarpus sphaeroblastus</i>	0	0	0	1
<i>Elateriospermum tapos</i>	0	2	2	2
<i>Endospermum diadenum</i>	1	3	4	2
<i>Euodia glabra</i>	1	1	2	1
<i>Eurya acuminata</i>	0	4	3	2
<i>Eurycoma longifolia</i>	0	0	0	1
<i>Eusideroxylon zwageri</i>	1	0	0	0
<i>Euthemis minor</i>	0	1	1	0
<i>Fagraea racemosa</i>	0	1	0	0
<i>Ficus aurata</i>	0	1	1	0
<i>Ficus brunneoaurata</i>	0	1	2	1
<i>Ficus gecharis</i>	0	2	0	1
<i>Ficus grossularioides</i>	0	0	1	0
<i>Ficus racemosa</i>	0	0	1	0
<i>Ficus</i> sp. 1	1	2	0	1
<i>Ficus</i> sp. 2	0	0	0	1
<i>Flacourtia jangomas</i>	0	1	0	0
<i>Flacourtia rukam</i>	0	0	1	2
<i>Fordia splendidissima</i>	1	0	0	0
<i>Garcinia mangostana</i>	0	0	0	2
<i>Garcinia nitida</i>	0	3	3	1
<i>Garcinia parvifolia</i>	1	2	1	2
<i>Garcinia</i> sp.	1	1	0	1
<i>Gironniera nervosa</i>	0	0	2	1
<i>Glochidion macrostigma</i>	0	0	0	1
<i>Glochidion</i> sp. 1	0	2	1	1
<i>Glochidion</i> sp. 2	0	0	1	0
<i>Glochidion</i> sp. 3	0	1	1	0
<i>Gluta wallichii</i>	2	3	1	2
<i>Gnetum gnemon</i>	2	4	0	3
<i>Goniothalamus uvarioides</i>	0	3	1	1
<i>Goniothalamus velutinus</i>	0	0	0	1
<i>Gonystylus</i> sp.	0	0	0	1

Appendix 5 continued

Species	Forest Types			
	PF	OSF	YSF	AF
<i>Gymnacranthera</i> sp. 1	1	2	1	1
<i>Gymnacranthera</i> sp. 2	1	0	0	0
<i>Gymnacranthera</i> sp. 3	1	0	0	0
<i>Hevea brasiliensis</i>	1	4	3	2
<i>Homalanthus populneus</i>	0	2	2	3
<i>Hopea ferruginea</i>	1	3	0	0
<i>Horsfieldia</i> sp.	0	1	2	1
<i>Ilex hypoglauca</i>	0	1	1	3
<i>Ixonanthes beccarii</i>	0	4	2	1
<i>Ixonanthes</i> sp.	0	0	1	1
<i>Ixora</i> sp.	0	2	2	1
<i>Kibara coriacea</i>	1	1	0	0
<i>Kibessia coriacea</i>	0	0	2	0
<i>Knema latifolia</i>	0	4	2	1
<i>Knema</i> sp. 1	0	1	0	0
<i>Knema</i> sp. 2	0	1	0	0
<i>Knema</i> sp. 3	0	0	1	0
<i>Koompassia excelsa</i>	1	0	0	0
<i>Koompassia malaccensis</i>	1	0	0	0
<i>Lansium domesticum</i>	0	0	1	2
<i>Lansium parasiticum</i>	0	0	1	0
<i>Leea indica</i>	0	1	2	0
<i>Leucosyke</i> sp.	0	0	1	0
<i>Lindera</i> sp.	0	0	0	1
<i>Lithocarpus echinifer</i>	2	3	4	2
<i>Lithocarpus ewyckii</i>	2	2	0	0
<i>Lithocarpus</i> sp.	0	0	1	0
<i>Lithocarpus turbinatus</i>	1	0	0	0
<i>Litsea cordata</i>	0	0	1	0
<i>Litsea garciae</i>	0	0	0	1
<i>Litsea gracilipes</i>	0	0	0	1
<i>Litsea grandis</i>	0	0	1	0
<i>Litsea lancifolia</i>	2	3	3	3
<i>Litsea nidularis</i>	0	0	1	0
<i>Litsea resinosa</i>	1	0	0	0
<i>Litsea</i> sp. 1	1	0	0	1
<i>Litsea</i> sp. 2	1	0	0	0
<i>Litsea</i> sp. 3	0	0	1	0

Appendix 5 continued

Species	Forest Types			
	PF	OSF	YSF	AF
<i>Litsea</i> sp. 4	0	0	1	0
<i>Litsea</i> sp. 5	0	0	1	1
<i>Macaranga caladiifolia</i>	0	3	3	3
<i>Macaranga gigantea</i>	0	0	1	1
<i>Macaranga</i> sp.	1	0	0	0
<i>Mallotus repandus</i>	0	1	1	1
<i>Mallotus</i> sp.	0	1	0	1
<i>Mangifera graffithii</i>	0	0	0	1
<i>Mangifera griffithii</i>	0	1	0	0
<i>Mangifera pajang</i>	0	0	0	1
<i>Mangifera</i> sp. 1	0	2	0	1
<i>Mangifera</i> sp. 2	0	0	0	1
<i>Mangifera</i> sp. 3	0	0	0	1
<i>Mangifera torquenda</i>	0	1	0	1
<i>Melastoma polyanthum</i>	0	0	1	0
<i>Memecylon</i> sp. 1	2	3	0	1
<i>Memecylon</i> sp. 2	1	2	0	0
<i>Mesua ferrea</i>	1	0	0	0
<i>Mesua</i> sp.	1	2	0	0
<i>Microcos</i> sp.	0	0	1	0
<i>Myristica</i> sp.	1	0	0	0
<i>Nauclea</i> sp.	0	3	2	0
<i>Nephelium cuspidatum</i>	1	0	0	1
<i>Nephelium lappaceum</i>	0	1	0	1
<i>Nephelium maingayi</i>	0	1	1	1
<i>Nephelium ramboutan-ake</i>	0	0	1	3
<i>Norrisia major</i>	0	4	2	1
<i>Ochanostachys amentacea</i>	1	3	0	1
<i>Octomeles sumatrana</i>	0	1	0	0
<i>Ormosia bancana</i>	0	1	0	0
<i>Palaquium gutta</i>	2	3	3	1
<i>Palaquium obovatum</i>	0	0	1	2
<i>Palaquium</i> sp. 1	0	1	0	0
<i>Palaquium</i> sp. 2	0	0	1	0
<i>Pangium edule</i>	0	1	0	0
<i>Parastemon urophyllus</i>	1	1	0	1
<i>Parkia speciosa</i>	0	0	0	2
<i>Pellacalyx lobbii</i>	0	2	1	2

Appendix 5 continued

Species	Forest Types			
	PF	OSF	YSF	AF
<i>Pentaspadon motleyi</i>	1	3	3	1
<i>Pentaspadon</i> sp.	0	0	0	1
<i>Pimelodendron griffithianum</i>	0	0	1	1
<i>Pimelodendron</i> sp.	0	3	3	2
<i>Ploiarium alternifolium</i>	0	1	0	1
<i>Polyalthia cauliflora</i>	0	0	1	0
<i>Polyalthia</i> sp.	2	3	0	0
<i>Pometia pinnata</i>	1	2	1	2
<i>Psychotria viridiflora</i>	0	2	2	0
<i>Pterospermum</i> sp.	0	0	1	0
<i>Santiria</i> sp.	0	0	1	0
<i>Sarcotheca</i> sp.	0	0	1	0
<i>Saurauia acuminata</i>	1	2	1	1
<i>Rubroshorea beccariana</i>	0	1	1	1
<i>Rubroshorea bullata</i>	0	1	0	0
<i>Rubroshorea coriacea</i>	1	1	0	0
<i>Rubroshorea curtisii</i>	0	1	0	0
<i>Rubroshorea macrophylla</i>	1	2	1	2
<i>Rubroshorea macroptera</i>	0	1	0	1
<i>Rubroshorea palembanica</i>	0	0	1	0
<i>Rubroshorea stenoptera</i>	0	0	1	0
<i>Shorea ladiana</i>	1	1	0	0
<i>Stemonurus</i> sp.	0	0	2	1
<i>Sterculia</i> sp.	0	1	0	0
<i>Strombosia ceylanica</i>	0	0	1	0
<i>Symplocos</i> sp.	0	0	0	1
<i>Syzygium arcuatinervium</i>	0	0	1	0
<i>Syzygium jambos</i>	0	0	1	0
<i>Syzygium kunstleri</i>	2	4	3	2
<i>Syzygium leucoxylon</i>	2	5	3	2
<i>Syzygium monticola</i>	1	3	1	1
<i>Syzygium polyanthum</i>	0	0	1	0
<i>Syzygium sarawakensis</i>	0	0	1	0
<i>Syzygium</i> sp. 1	0	0	0	1
<i>Syzygium</i> sp. 2	0	1	0	0
<i>Syzygium</i> sp. 3	0	1	0	0
<i>Syzygium</i> sp. 4	0	0	0	1
<i>Syzygium</i> sp. 5	1	0	0	0

Appendix 5 continued

Species	Forest Types			
	PF	OSF	YSF	AF
<i>Syzygium</i> sp. 6	0	0	1	0
<i>Syzygium</i> sp. 7	1	0	0	1
<i>Syzygium</i> sp. 8	0	1	1	1
<i>Syzygium</i> sp. 9	0	1	1	2
<i>Syzygium</i> sp. 10	0	1	1	0
<i>Syzygium</i> sp. 11	0	1	0	0
<i>Syzygium</i> sp. 12	0	0	1	0
<i>Syzygium</i> sp. 13	0	1	1	0
<i>Syzygium</i> sp. 14	0	0	1	0
<i>Syzygium</i> sp. 15	0	1	0	0
<i>Talauma</i> sp.	0	0	2	0
<i>Theobroma cacao</i>	0	0	0	1
<i>Timonius lasianthoides</i>	0	3	4	2
<i>Timonius</i> sp.	0	1	0	0
<i>Trema occidentalis</i>	0	0	1	0
<i>Tristaniopsis whiteana</i>	1	2	1	0
<i>Turpinia sphaerocarpa</i>	0	1	2	2
<i>Upuna borneensis</i>	0	1	0	0
<i>Urophyllum</i> sp.	0	3	1	2
<i>Vatica</i> sp.	1	0	0	0
<i>Vernonia arborea</i>	1	1	2	2
<i>Vitex pubescens</i>	0	1	3	2
<i>Whiteodendron moultonianum</i>	0	0	0	1
<i>Xanthophyllum amoenum</i>	1	2	0	1
<i>Xanthophyllum</i> sp. 1	1	0	1	0
<i>Xanthophyllum</i> sp. 2	0	0	0	1
<i>Xylopia ferruginea</i>	1	2	1	2
Unknown 1	0	0	0	1
Unknown 2	0	0	0	1
Unknown 3	0	1	0	1
Unknown 4	1	2	0	0
Unknown 5	0	0	0	1
Unknown 6	0	1	0	0
Unknown 7	1	0	0	0
Unknown 8	0	1	0	0
TOTAL	118	295	232	200

Notes: Unknown species – Identified up to local name only

PF – Primary forest; OSF – Old secondary forest; YSF – Young secondary forest; AF - Agroforest

Appendix 6: Natural Regeneration Status of Plant Species by Forest Types

Forest Types	Species	No. of Individuals			Natural Regeneration Status
		Sapling	Seedling	Tree	
Primary forest	<i>Adinandra borneensis</i>	1	0	0	Poor regeneration
	<i>Adinandra dumosa</i>	0	0	2	No regeneration
	<i>Aetoxylon sympetalum</i>	2	2	1	Good regeneration
	<i>Allantospermum borneense</i>	0	0	9	No regeneration
	<i>Alstonia scholaris</i>	0	0	1	No regeneration
	<i>Alstonia spatulata</i>	5	0	0	Poor regeneration
	<i>Anisophyllea disticha</i>	6	3	0	Poor regeneration
	<i>Anisophyllea</i> sp. 2	6	3	2	Good regeneration
	<i>Aporosa benthamiana</i>	0	0	8	No regeneration
	<i>Artocarpus anisophyllus</i>	0	0	2	No regeneration
	<i>Artocarpus elasticus</i>	0	0	7	No regeneration
	<i>Artocarpus integer</i>	5	1	18	Fair regeneration
	<i>Artocarpus kemando</i>	1	1	5	Fair regeneration
	<i>Artocarpus nitidus</i>	4	2	2	Good regeneration
	<i>Artocarpus tamaran</i>	0	0	15	No regeneration
	<i>Baccaurea macrocarpa</i>	1	0	6	Fair regeneration
	<i>Baccaurea motleyana</i>	0	0	1	No regeneration
	<i>Baccaurea pubera</i>	0	0	6	No regeneration
	<i>Bellucia pentamera</i>	0	0	1	No regeneration
	<i>Calophyllum canum</i>	1	0	0	Poor regeneration
	<i>Calophyllum floribundum</i>	1	0	0	Poor regeneration
	<i>Calophyllum</i> sp.	0	0	1	No regeneration
	<i>Calophyllum woodii</i>	8	5	3	Good regeneration
	<i>Camptosperma auriculatum</i>	1	3	3	Good regeneration
	<i>Canarium</i> sp. 1	5	0	6	Fair regeneration
	<i>Canarium</i> sp. 2	1	1	1	Good regeneration
	<i>Cantleya corniculata</i>	12	0	28	Fair regeneration
	<i>Cleistanthus</i> sp.	6	1	3	Good regeneration
	<i>Clerodendrum</i> sp.	0	0	1	No regeneration
	<i>Cratoxylum formosum</i>	1	0	0	Poor regeneration
	<i>Dialium indum</i>	0	0	2	No regeneration
	<i>Dillenia borneensis</i>	0	0	2	No regeneration
	<i>Dillenia excelsa</i>	1	0	5	Fair regeneration

Appendix 6 continued

Forest Types	Species	No. of Individuals			Natural Regeneration Status
		Sapling	Seedling	Tree	
Primary forest	<i>Diospyros foxworthyi</i>	4	5	9	Fair regeneration
	<i>Dipterocarpus cuspidatus</i>	2	0	1	Good regeneration
	<i>Dipterocarpus fagineus</i>	0	0	1	No regeneration
	<i>Dipterocarpus obtusifolius</i>	0	0	1	No regeneration
	<i>Dipterocarpus sarawakensis</i>	1	1	26	Fair regeneration
	<i>Dipterocarpus</i> sp.	18	3	18	Good regeneration
	<i>Dryobalanops beccarii</i>	0	0	3	No regeneration
	<i>Elaeocarpus nitidus</i>	0	0	1	No regeneration
	<i>Endospermum diadenum</i>	0	0	1	No regeneration
	<i>Euodia glabra</i>	1	0	3	Fair regeneration
	<i>Eusideroxylon zwageri</i>	0	0	2	No regeneration
	<i>Ficus</i> sp. 1	0	0	3	No regeneration
	<i>Fordia splendidissima</i>	1	0	1	Good regeneration
	<i>Garcinia parvifolia</i>	0	1	2	Fair regeneration
	<i>Garcinia</i> sp.	0	0	2	No regeneration
	<i>Gluta wallichii</i>	0	0	8	No regeneration
	<i>Gnetum gnemon</i>	5	0	1	Good regeneration
	<i>Gymnacranthera</i> sp. 1	6	1	12	Fair regeneration
	<i>Gymnacranthera</i> sp. 2	0	0	1	No regeneration
	<i>Gymnacranthera</i> sp. 3	0	0	1	No regeneration
	<i>Hevea brasiliensis</i>	3	0	8	Fair regeneration
	<i>Hopea ferruginea</i>	10	2	10	Good regeneration
	<i>Kibara coriacea</i>	2	0	1	Good regeneration
	<i>Koompassia excelsa</i>	0	0	1	No regeneration
	<i>Koompassia malaccensis</i>	0	0	1	No regeneration
	<i>Lithocarpus echinifer</i>	2	2	7	Fair regeneration
	<i>Lithocarpus ewyckii</i>	1	3	11	Fair regeneration
	<i>Lithocarpus turbinatus</i>	2	0	3	Fair regeneration
	<i>Litsea lancifolia</i>	12	19	10	Good regeneration
	<i>Litsea resinosa</i>	2	0	0	Poor regeneration
	<i>Litsea</i> sp. 1	2	0	0	Poor regeneration

Appendix 6 continued

Forest Types	Species	No. of Individuals			Natural Regeneration Status
		Sapling	Seedling	Tree	
Primary forest	<i>Litsea</i> sp. 2	3	13	1	Good regeneration
	<i>Macaranga</i> sp.	11	4	2	Good regeneration
	<i>Memecylon</i> sp. 1	3	7	5	Good regeneration
	<i>Memecylon</i> sp. 2	1	0	12	Fair regeneration
	<i>Mesua ferrea</i>	0	0	1	No regeneration
	<i>Mesua</i> sp.	0	0	2	No regeneration
	<i>Myristica</i> sp.	1	0	4	Fair regeneration
	<i>Nephelium cuspidatum</i>	0	0	1	No regeneration
	<i>Ochanostachys amentacea</i>	1	1	0	Poor regeneration
	<i>Palaquium gutta</i>	7	13	31	Fair regeneration
	<i>Parastemon urophyllus</i>	2	2	6	Fair regeneration
	<i>Pentaspadon motleyi</i>	1	0	0	Poor regeneration
	<i>Polyalthia</i> sp.	2	0	5	Fair regeneration
	<i>Pometia pinnata</i>	3	3	5	Fair regeneration
	<i>Saurauia acuminata</i>	2	0	0	Poor regeneration
	<i>Rubroshorea coriacea</i>	0	0	1	No regeneration
	<i>Rubroshorea macrophylla</i>	2	0	4	Fair regeneration
	<i>Shorea ladiana</i>	1	0	10	Fair regeneration
	<i>Syzygium kunstleri</i>	25	50	42	Good regeneration
	<i>Syzygium leucoxylon</i>	11	4	13	Fair regeneration
	<i>Syzygium monticola</i>	3	0	3	Good regeneration
	<i>Syzygium</i> sp. 5	40	20	34	Good regeneration
	<i>Syzygium</i> sp. 7	0	0	1	No regeneration
	<i>Tristaniopsis whiteana</i>	0	0	2	No regeneration
	<i>Vatica</i> sp.	1	1	30	Fair regeneration
	<i>Vernonia arborea</i>	0	0	1	No regeneration
	<i>Xanthophyllum amoenum</i>	0	0	4	No regeneration
	<i>Xanthophyllum</i> sp. 1	0	1	2	Fair regeneration
	<i>Xylopia ferruginea</i>	0	0	1	No regeneration
	Unknown 4	1	0	1	Good regeneration
	Unknown 7	0	0	2	No regeneration

Appendix 6 continued

Forest Types	Species	No. of Individuals			Natural Regeneration Status
		Sapling	Seedling	Tree	
Old secondary forest	<i>Adinandra borneensis</i>	0	0	4	No regeneration
	<i>Adinandra dumosa</i>	0	0	55	No regeneration
	<i>Aetoxylon sympetalum</i>	0	0	1	No regeneration
	<i>Alangium javanicum</i>	2	0	1	Good regeneration
	<i>Allantospermum borneense</i>	0	0	9	No regeneration
	<i>Alstonia scholaris</i>	2	0	3	Fair regeneration
	<i>Alstonia spatulata</i>	3	0	8	Fair regeneration
	<i>Anisophyllea disticha</i>	6	0	0	Poor regeneration
	<i>Anisophyllea</i> sp. 1	0	0	2	No regeneration
	<i>Anisophyllea</i> sp. 2	3	1	5	Fair regeneration
	<i>Aporosa</i> sp. 1	2	7	2	Good regeneration
	<i>Archidendron borneense</i>	7	4	6	Good regeneration
	<i>Archidendron jiringa</i>	0	2	1	Good regeneration
	<i>Ardisia javanica</i>	0	8	7	Good regeneration
	<i>Artocarpus anisophyllus</i>	0	0	1	No regeneration
	<i>Artocarpus elasticus</i>	6	9	22	Fair regeneration
	<i>Artocarpus integer</i>	12	13	87	Fair regeneration
	<i>Artocarpus kemando</i>	4	8	42	Fair regeneration
	<i>Artocarpus nitidus</i>	1	1	11	Fair regeneration
	<i>Artocarpus tamaran</i>	0	1	11	Fair regeneration
	<i>Baccaurea angulata</i>	0	2	3	Fair regeneration
	<i>Baccaurea macrocarpa</i>	0	3	4	Fair regeneration
	<i>Baccaurea maingayi</i>	6	15	11	Good regeneration
	<i>Baccaurea pubera</i>	2	0	6	Fair regeneration
	<i>Baccaurea</i> sp.	13	9	30	Fair regeneration
	<i>Bellucia pentamera</i>	5	0	3	Good regeneration
	<i>Breynia</i> sp.	0	0	4	No regeneration
	<i>Calophyllum</i> sp.	0	1	0	Poor regeneration
	<i>Calophyllum woodii</i>	5	7	15	Fair regeneration
	<i>Camptosperma auriculatum</i>	10	18	13	Good regeneration
	<i>Camptosperma coriaceum</i>	14	8	15	Fair regeneration
	<i>Canarium</i> sp. 1	2	0	4	Fair regeneration

Appendix 6 continued

Forest Types	Species	No. of Individuals			Natural Regeneration Status
		Sapling	Seedling	Tree	
Old secondary forest	<i>Canarium</i> sp. 2	0	0	1	No regeneration
	<i>Canthium umbelligerum</i>	2	0	13	Fair regeneration
	<i>Cantleya corniculata</i>	14	2	31	Fair regeneration
	<i>Castanopsis motleyana</i>	0	2	5	Fair regeneration
	<i>Cleistanthus</i> sp.	42	4	13	Good regeneration
	<i>Cratoxylum arborescens</i>	1	0	19	Fair regeneration
	<i>Cratoxylum formosum</i>	0	0	37	No regeneration
	<i>Cratoxylum glaucum</i>	1	0	4	Fair regeneration
	<i>Croton</i> sp.	0	1	0	Poor regeneration
	<i>Dacryodes</i> sp. 1	1	0	0	Poor regeneration
	<i>Dialium indum</i>	1	0	0	Poor regeneration
	<i>Dillenia borneensis</i>	0	0	3	No regeneration
	<i>Dillenia excelsa</i>	5	4	20	Fair regeneration
	<i>Dillenia suffruticosa</i>	38	0	40	Fair regeneration
	<i>Diospyros foxworthyi</i>	6	6	0	Poor regeneration
	<i>Diospyros piscicapa</i>	2	2	5	Fair regeneration
	<i>Dipterocarpus cuspidatus</i>	0	1	1	Good regeneration
	<i>Dipterocarpus kunstleri</i>	2	0	1	No regeneration
	<i>Dipterocarpus sarawakensis</i>	2	0	0	Poor regeneration
	<i>Dipterocarpus</i> sp.	3	0	2	Good regeneration
	<i>Dryobalanops beccarii</i>	10	5	9	Good regeneration
	<i>Durio zibethinus</i>	0	0	2	No regeneration
	<i>Dyera costulata</i>	0	0	1	No regeneration
	<i>Elaeocarpus nitidus</i>	0	0	5	No regeneration
	<i>Elateriospermum tapos</i>	10	10	20	Fair regeneration
	<i>Endospermum diadenum</i>	0	2	27	Fair regeneration
	<i>Euodia glabra</i>	0	0	1	No regeneration
	<i>Eurya acuminata</i>	12	4	5	Good regeneration
	<i>Euthemis minor</i>	0	0	7	No regeneration
	<i>Fagraea racemosa</i>	2	0	9	Fair regeneration
	<i>Ficus aurata</i>	4	0	0	Poor regeneration
	<i>Ficus brunneoaurata</i>	0	0	2	No regeneration
	<i>Ficus gecharis</i>	5	0	0	Poor regeneration
	<i>Ficus</i> sp. 1	1	0	2	Fair regeneration

Appendix 6 continued

Forest Types	Species	No. of Individuals			Natural Regeneration Status
		Sapling	Seedling	Tree	
Old secondary forest	<i>Flacourtia jangomas</i>	2	0	0	Poor regeneration
	<i>Garcinia nitida</i>	1	0	5	Fair regeneration
	<i>Garcinia parvifolia</i>	8	10	8	Good regeneration
	<i>Garcinia</i> sp.	0	0	1	No regeneration
	<i>Glochidion</i> sp. 1	0	0	4	No regeneration
	<i>Glochidion</i> sp. 3	1	0	0	Poor regeneration
	<i>Gluta wallichii</i>	5	0	8	Fair regeneration
	<i>Gnetum gnemon</i>	8	1	1	Good regeneration
	<i>Goniothalamus uvarioides</i>	1	3	0	Poor regeneration
	<i>Gymnacranthera</i> sp. 1	7	0	16	Fair regeneration
	<i>Hevea brasiliensis</i>	61	47	117	Fair regeneration
	<i>Homalanthus populneus</i>	1	48	1	Good regeneration
	<i>Hopea ferruginea</i>	5	1	9	Fair regeneration
	<i>Horsfieldia</i> sp.	1	0	0	Poor regeneration
	<i>Ilex hypoglauca</i>	10	5	10	Good regeneration
	<i>Ixonanthes beccarii</i>	0	0	40	No regeneration
	<i>Ixora</i> sp.	12	2	8	Good regeneration
	<i>Kibara coriacea</i>	0	0	1	No regeneration
	<i>Knema latifolia</i>	4	5	29	Fair regeneration
	<i>Knema</i> sp. 1	1	0	0	Poor regeneration
	<i>Knema</i> sp. 2	0	0	1	No regeneration
	<i>Leea indica</i>	3	3	0	Poor regeneration
	<i>Lithocarpus echinifer</i>	5	4	14	Fair regeneration
	<i>Lithocarpus ewyckii</i>	0	0	3	No regeneration
	<i>Litsea lancifolia</i>	34	24	8	Good regeneration
	<i>Macaranga caladiifolia</i>	3	0	18	Fair regeneration
	<i>Mallotus repandus</i>	0	0	21	No regeneration
	<i>Mallotus</i> sp.	1	0	2	Fair regeneration
	<i>Mangifera griffithii</i>	0	0	1	No regeneration
	<i>Mangifera</i> sp. 1	1	0	6	Good regeneration
	<i>Mangifera torquenda</i>	1	0	0	Poor regeneration
	<i>Memecylon</i> sp. 1	18	3	128	Fair regeneration
	<i>Memecylon</i> sp. 2	1	0	5	Fair regeneration

Appendix 6 continued

Forest Types	Species	No. of Individuals			Natural Regeneration Status
		Sapling	Seedling	Tree	
Old secondary forest	<i>Mesua</i> sp.	0	0	8	No regeneration
	<i>Nauclea</i> sp.	0	8	2	Good regeneration
	<i>Nephelium lappaceum</i>	0	3	3	Good regeneration
	<i>Nephelium maingayi</i>	5	0	2	Good regeneration
	<i>Norrisia major</i>	2	0	22	Fair regeneration
	<i>Ochanostachys amentacea</i>	6	3	6	Good regeneration
	<i>Octomeles sumatrana</i>	0	0	1	No regeneration
	<i>Ormosia bancana</i>	0	12	3	Good regeneration
	<i>Palaquium gutta</i>	9	52	51	Good regeneration
	<i>Palaquium</i> sp. 1	1	0	0	Poor regeneration
	<i>Pangium edule</i>	0	0	3	No regeneration
	<i>Parastemon urophyllus</i>	0	0	2	No regeneration
	<i>Pellacalyx lobbii</i>	0	0	12	No regeneration
	<i>Pentaspadon motleyi</i>	15	133	3	Good regeneration
	<i>Pimelodendron</i> sp.	3	0	8	Fair regeneration
	<i>Ploiarium alternifolium</i>	1	0	2	Fair regeneration
	<i>Polyalthia</i> sp.	5	0	15	Fair regeneration
	<i>Pometia pinnata</i>	22	15	32	Fair regeneration
	<i>Psychotria viridiflora</i>	20	17	4	Good regeneration
	<i>Saurauia acuminata</i>	0	3	6	Fair regeneration
	<i>Rubroshorea beccariana</i>	0	0	9	No regeneration
	<i>Rubroshorea bullata</i>	2	0	2	Good regeneration
	<i>Rubroshorea coriacea</i>	1	0	2	Fair regeneration
	<i>Rubroshorea curtisii</i>	0	0	1	No regeneration
	<i>Rubroshorea macrophylla</i>	4	2	1	Good regeneration
	<i>Rubroshorea macroptera</i>	4	0	5	Fair regeneration
	<i>Shorea ladiana</i>	0	0	2	No regeneration
	<i>Sterculia</i> sp.	13	2	1	Good regeneration
	<i>Syzygium kunstleri</i>	66	192	102	Good regeneration

Appendix 6 continued

Forest Types	Species	No. of Individuals			Natural Regeneration Status
		Sapling	Seedling	Tree	
Old secondary forest	<i>Syzygium leucoxylon</i>	54	212	152	Good regeneration
	<i>Syzygium monticola</i>	3	1	3	Good regeneration
	<i>Syzygium</i> sp. 2	24	19	8	Good regeneration
	<i>Syzygium</i> sp. 3	3	11	4	Good regeneration
	<i>Syzygium</i> sp. 8	1	0	0	Poor regeneration
	<i>Syzygium</i> sp. 9	0	0	3	No regeneration
	<i>Syzygium</i> sp. 10	18	21	24	Fair regeneration
	<i>Syzygium</i> sp. 11	2	0	2	Good regeneration
	<i>Syzygium</i> sp. 13	0	0	3	No regeneration
	<i>Syzygium</i> sp. 15	0	0	2	No regeneration
	<i>Timonius lasianthoides</i>	4	0	17	Fair regeneration
	<i>Timonius</i> sp.	0	0	1	No regeneration
	<i>Tristaniaopsis whiteana</i>	0	0	8	No regeneration
	<i>Turpinia sphaerocarpa</i>	1	3	0	Poor regeneration
	<i>Upuna borneensis</i>	0	0	2	No regeneration
	<i>Urophyllum</i> sp.	5	0	6	Fair regeneration
	<i>Vernonia arborea</i>	0	0	6	No regeneration
	<i>Vitex pubescens</i>	1	0	23	Fair regeneration
	<i>Xanthophyllum amoenum</i>	3	1	5	Fair regeneration
	<i>Xylopi ferruginea</i>	1	0	2	Fair regeneration
	Unknown 3	0	0	1	No regeneration
	Unknown 4	1	0	6	Fair regeneration
	Unknown 6	0	0	3	No regeneration
	Unknown 8	0	0	1	No regeneration
Young secondary forest	<i>Actinodaphne</i> sp.	1	1	1	Good regeneration
	<i>Adinandra borneensis</i>	0	0	26	No regeneration
	<i>Adinandra dumosa</i>	0	0	25	No regeneration
	<i>Aglaia</i> sp.	4	6	1	Good regeneration
	<i>Alseodaphne</i> sp. 1	0	0	4	No regeneration
	<i>Alseodaphne</i> sp. 2	0	1	1	Good regeneration
	<i>Alstonia scholaris</i>	0	0	5	No regeneration
	<i>Alstonia spatulata</i>	24	22	50	Fair regeneration

Appendix 6 continued

Forest Types	Species	No. of Individuals			Natural Regeneration Status
		Sapling	Seedling	Tree	
Young secondary forest	<i>Anisophyllea disticha</i>	1	3	1	Good regeneration
	<i>Aporosa benthamiana</i>	0	0	5	No regeneration
	<i>Aporosa</i> sp. 1	0	0	24	No regeneration
	<i>Archidendron borneense</i>	19	3	9	Good regeneration
	<i>Archidendron jiringa</i>	4	0	2	Good regeneration
	<i>Ardisia javanica</i>	5	9	5	Good regeneration
	<i>Artocarpus anisophyllus</i>	0	0	5	No regeneration
	<i>Artocarpus elasticus</i>	4	0	21	Fair regeneration
	<i>Artocarpus integer</i>	3	0	6	Fair regeneration
	<i>Artocarpus kemando</i>	5	18	39	Fair regeneration
	<i>Artocarpus nitidus</i>	0	0	21	No regeneration
	<i>Artocarpus tamaran</i>	0	0	7	No regeneration
	<i>Baccaurea maingayi</i>	0	2	8	Fair regeneration
	<i>Baccaurea polyneura</i>	1	0	2	Fair regeneration
	<i>Baccaurea</i> sp.	3	0	8	Fair regeneration
	<i>Barringtonia</i> sp.	0	0	9	No regeneration
	<i>Bellucia pentamera</i>	0	0	1	No regeneration
	<i>Bhesa paniculata</i>	0	0	1	No regeneration
	<i>Breynia racemosa</i>	6	1	10	Fair regeneration
	<i>Breynia</i> sp.	1	0	0	Poor regeneration
	<i>Calophyllum</i> sp.	0	0	1	No regeneration
	<i>Calophyllum woodii</i>	1	0	0	Poor regeneration
	<i>Camptosperma auriculatum</i>	2	0	6	Fair regeneration
	<i>Camptosperma coriaceum</i>	28	9	24	Good regeneration
	<i>Canarium</i> sp. 1	3	2	0	Poor regeneration
	<i>Canthium umbelligerum</i>	0	0	1	No regeneration
	<i>Cantleya corniculata</i>	1	0	5	No regeneration
	<i>Castanopsis motleyana</i>	4	1	9	Fair regeneration
	<i>Cleistanthus</i> sp.	1	8	2	Good regeneration
	<i>Commersonia bartramia</i>	7	0	31	Fair regeneration
	<i>Cratoxylum arborescens</i>	0	1	1	Good regeneration
	<i>Cratoxylum formosum</i>	3	0	18	Fair regeneration

Appendix 6 continued

Forest Types	Species	No. of Individuals			Natural Regeneration Status
		Sapling	Seedling	Tree	
Young secondary forest	<i>Dialium indum</i>	0	1	0	Poor regeneration
	<i>Dillenia excelsa</i>	1	1	5	Fair regeneration
	<i>Dillenia suffruticosa</i>	7	3	0	Poor regeneration
	<i>Diospyros foxworthyi</i>	1	0	9	Fair regeneration
	<i>Diospyros piscicapa</i>	0	0	6	No regeneration
	<i>Dryobalanops beccarii</i>	0	0	2	No regeneration
	<i>Durio zibethinus</i>	0	0	2	No regeneration
	<i>Elaeocarpus nitidus</i>	0	0	2	No regeneration
	<i>Elateriospermum tapos</i>	3	0	27	Fair regeneration
	<i>Endospermum diadenum</i>	5	0	31	Fair regeneration
	<i>Euodia glabra</i>	0	0	27	No regeneration
	<i>Eurya acuminata</i>	21	2	5	Good regeneration
	<i>Euthemis minor</i>	0	0	6	No regeneration
	<i>Ficus aurata</i>	0	1	1	Good regeneration
	<i>Ficus brunneoaurata</i>	0	0	8	No regeneration
	<i>Ficus grossularioides</i>	4	0	2	Good regeneration
	<i>Ficus racemosa</i>	0	0	2	No regeneration
	<i>Flacourtia rukam</i>	1	0	1	Good regeneration
	<i>Garcinia nitida</i>	4	1	7	Fair regeneration
	<i>Garcinia parvifolia</i>	3	0	3	Good regeneration
	<i>Gironniera nervosa</i>	10	13	7	Good regeneration
	<i>Glochidion</i> sp. 1	0	0	24	No regeneration
	<i>Glochidion</i> sp. 2	0	0	1	No regeneration
	<i>Glochidion</i> sp. 3	0	0	1	No regeneration
	<i>Gluta wallichii</i>	0	0	1	No regeneration
	<i>Goniothalamus uvarioides</i>	8	0	0	Poor regeneration
	<i>Gymnacranthera</i> sp. 1	0	0	1	No regeneration
	<i>Hevea brasiliensis</i>	86	10	97	Fair regeneration
	<i>Homalanthus populneus</i>	22	4	11	Good regeneration
	<i>Horsfieldia</i> sp.	1	1	4	Fair regeneration
	<i>Ilex hypoglauca</i>	11	0	7	Good regeneration
	<i>Ixonanthes beccarii</i>	1	0	12	Fair regeneration

Appendix 6 continued

Forest Types	Species	No. of Individuals			Natural Regeneration Status
		Sapling	Seedling	Tree	
Young secondary forest	<i>Ixonanthes</i> sp.	0	0	1	No regeneration
	<i>Ixora</i> sp.	7	32	5	Good regeneration
	<i>Kibessia coriacea</i>	1	0	1	Good regeneration
	<i>Knema latifolia</i>	1	0	10	Fair regeneration
	<i>Knema</i> sp. 3	10	2	5	Good regeneration
	<i>Lansium domesticum</i>	0	0	6	No regeneration
	<i>Lansium parasiticum</i>	0	0	4	No regeneration
	<i>Leea indica</i>	22	10	5	Good regeneration
	<i>Leucosyke</i> sp.	6	0	7	Fair regeneration
	<i>Lithocarpus echinifer</i>	4	1	12	Fair regeneration
	<i>Lithocarpus</i> sp.	1	3	2	Good regeneration
	<i>Litsea cordata</i>	3	3	11	Fair regeneration
	<i>Litsea grandis</i>	0	0	1	No regeneration
	<i>Litsea lancifolia</i>	3	1	8	Fair regeneration
	<i>Litsea nidularis</i>	0	0	1	No regeneration
	<i>Litsea</i> sp. 3	0	0	1	No regeneration
	<i>Litsea</i> sp. 4	0	0	1	No regeneration
	<i>Litsea</i> sp. 5	6	4	5	Good regeneration
	<i>Macaranga caladiifolia</i>	4	1	3	Good regeneration
	<i>Macaranga gigantea</i>	1	0	0	Poor regeneration
	<i>Mallotus repandus</i>	7	0	6	Good regeneration
	<i>Melastoma polyanthum</i>	2	0	0	Poor regeneration
	<i>Microcos</i> sp.	0	0	2	No regeneration
	<i>Nauclea</i> sp.	2	0	1	Good regeneration
	<i>Nephelium maingayi</i>	0	0	1	No regeneration
	<i>Nephelium ramboutan-ake</i>	2	3	2	Good regeneration
	<i>Norrisia major</i>	0	0	3	No regeneration
	<i>Palaquium gutta</i>	7	10	10	Good regeneration
	<i>Palaquium obovatum</i>	0	2	1	Good regeneration

Appendix 6 continued

Forest Types	Species	No. of Individuals			Natural Regeneration Status
		Sapling	Seedling	Tree	
Young secondary forest	<i>Palaquium</i> sp. 2	0	0	1	No regeneration
	<i>Pellacalyx lobbii</i>	0	0	1	No regeneration
	<i>Pentaspadon motleyi</i>	38	23	16	Good regeneration
	<i>Pimelodendron griffithianum</i>	12	6	4	Good regeneration
	<i>Pimelodendron</i> sp.	1	1	17	Fair regeneration
	<i>Polyalthia cauliflora</i>	3	0	0	Poor regeneration
	<i>Pometia pinnata</i>	0	0	2	No regeneration
	<i>Psychotria viridiflora</i>	11	10	3	Good regeneration
	<i>Pterospermum</i> sp.	0	0	1	No regeneration
	<i>Santiria</i> sp.	2	0	1	Good regeneration
	<i>Sarcotheca</i> sp.	0	0	1	No regeneration
	<i>Saurauia acuminata</i>	1	0	0	Poor regeneration
	<i>Rubroshorea beccariana</i>	1	0	0	Poor regeneration
	<i>Rubroshorea macrophylla</i>	64	9	12	Good regeneration
	<i>Rubroshorea palembanica</i>	5	3	33	Fair regeneration
	<i>Rubroshorea stenoptera</i>	0	0	1	No regeneration
	<i>Stemonurus</i> sp.	0	1	1	Good regeneration
	<i>Strombosia ceylanica</i>	3	0	2	Good regeneration
	<i>Syzygium arcuatinervium</i>	1	0	0	Poor regeneration
	<i>Syzygium jambos</i>	4	0	3	Good regeneration
	<i>Syzygium kunstleri</i>	145	56	25	Good regeneration
	<i>Syzygium leucoxylon</i>	33	19	27	Good regeneration
	<i>Syzygium monticola</i>	0	0	1	No regeneration
	<i>Syzygium polyanthum</i>	2	0	0	Poor regeneration
	<i>Syzygium sarawakensis</i>	0	0	1	No regeneration
	<i>Syzygium</i> sp. 6	7	27	7	Good regeneration
	<i>Syzygium</i> sp. 8	0	0	23	No regeneration
	<i>Syzygium</i> sp. 9	4	0	1	Good regeneration

Appendix 6 continued

Forest Types	Species	No. of Individuals			Natural Regeneration Status
		Sapling	Seedling	Tree	
Young secondary forest	<i>Syzygium</i> sp. 10	49	17	27	Good regeneration
	<i>Syzygium</i> sp. 12	5	0	2	Good regeneration
	<i>Syzygium</i> sp. 13	0	0	2	No regeneration
	<i>Syzygium</i> sp. 14	1	0	1	Good regeneration
	<i>Talauma</i> sp.	1	0	1	Good regeneration
	<i>Timonius lasianthoides</i>	2	2	11	Fair regeneration
	<i>Trema occidentalis</i>	1	0	1	Good regeneration
	<i>Tristaniopsis whiteana</i>	0	1	13	Fair regeneration
	<i>Turpinia sphaerocarpa</i>	2	0	2	Good regeneration
	<i>Urophyllum</i> sp.	2	0	3	Fair regeneration
	<i>Vernonia arborea</i>	1	1	6	Fair regeneration
	<i>Vitex pubescens</i>	12	1	33	Fair regeneration
	<i>Xanthophyllum</i> sp. 1	0	0	9	No regeneration
	<i>Xylopia ferruginea</i>	0	0	11	No regeneration
Agroforest	<i>Adinandra dumosa</i>	0	0	21	No regeneration
	<i>Alangium javanicum</i>	14	0	10	Good regeneration
	<i>Alstonia scholaris</i>	0	0	5	No regeneration
	<i>Alstonia spatulata</i>	7	4	13	Fair regeneration
	<i>Anisophyllea disticha</i>	8	0	1	Good regeneration
	<i>Aporosa</i> sp. 1	14	1	3	Good regeneration
	<i>Aporosa</i> sp. 2	1	0	0	Poor regeneration
	<i>Archidendron borneense</i>	35	11	0	Poor regeneration
	<i>Archidendron jiringa</i>	5	3	5	Good regeneration
	<i>Ardisia javanica</i>	2	0	0	Poor regeneration
	<i>Artocarpus elasticus</i>	1	0	1	Good regeneration
	<i>Artocarpus integer</i>	7	3	52	Fair regeneration
	<i>Artocarpus kemando</i>	5	6	12	Fair regeneration
	<i>Artocarpus nitidus</i>	0	0	13	No regeneration
	<i>Artocarpus tamaran</i>	0	0	4	No regeneration
	<i>Baccaurea angulata</i>	0	0	8	No regeneration

Appendix 6 continued

Forest Types	Species	No. of Individuals			Natural Regeneration Status
		Sapling	Seedling	Tree	
Agroforest	<i>Baccaurea macrocarpa</i>	6	0	6	No regeneration
	<i>Baccaurea maingayi</i>	0	0	4	No regeneration
	<i>Baccaurea motleyana</i>	0	0	16	No regeneration
	<i>Baccaurea polyneura</i>	0	0	1	No regeneration
	<i>Baccaurea</i> sp.	1	0	0	Poor regeneration
	<i>Barringtonia</i> sp.	1	3	0	Poor regeneration
	<i>Bellucia pentamera</i>	5	1	3	Good regeneration
	<i>Breynia racemosa</i>	0	0	1	No regeneration
	<i>Calophyllum woodii</i>	2	4	2	Good regeneration
	<i>Camptosperma auriculatum</i>	15	1	2	Good regeneration
	<i>Canthium umbelligerum</i>	0	0	1	No regeneration
	<i>Cassia</i> sp.	0	0	2	No regeneration
	<i>Castanopsis motleyana</i>	1	2	12	Fair regeneration
	<i>Citrus aurantiifolia</i>	0	0	2	No regeneration
	<i>Commersonia bartramia</i>	0	0	1	No regeneration
	<i>Cratoxylum formosum</i>	1	1	4	Fair regeneration
	<i>Cratoxylum glaucum</i>	0	0	1	No regeneration
	<i>Dacryodes rostrata</i>	0	0	1	No regeneration
	<i>Dacryodes</i> sp. 2	0	0	1	No regeneration
	<i>Decussocarpus motleyi</i>	0	0	1	No regeneration
	<i>Dillenia excelsa</i>	3	0	11	Fair regeneration
	<i>Dillenia suffruticosa</i>	4	0	51	Fair regeneration
	<i>Diospyros buxifolia</i>	0	0	2	No regeneration
	<i>Diospyros foxworthyi</i>	3	4	3	Good regeneration
	<i>Diospyros piscicapa</i>	0	0	4	No regeneration
	<i>Dipterocarpus sarawakensis</i>	1	0	1	Good regeneration
	<i>Dryobalanops beccarii</i>	0	0	1	No regeneration
	<i>Durio zibethinus</i>	3	1	22	Fair regeneration
	<i>Elaeocarpus sphaeroblastus</i>	2	0	1	Good regeneration
	<i>Elateriospermum tapos</i>	3	0	4	Fair regeneration
	<i>Endospermum diadenum</i>	1	0	4	Fair regeneration
	<i>Euodia glabra</i>	1	0	0	Poor regeneration
	<i>Eurya acuminata</i>	8	0	7	Good regeneration

Appendix 6 continued

Forest Types	Species	No. of Individuals			Natural Regeneration Status
		Sapling	Seedling	Tree	
Agroforest	<i>Eurycoma longifolia</i>	3	1	1	Good regeneration
	<i>Ficus brunneoaurata</i>	0	0	1	No regeneration
	<i>Ficus gecharis</i>	0	1	0	Poor regeneration
	<i>Ficus</i> sp. 1	0	0	2	No regeneration
	<i>Ficus</i> sp. 2	1	0	0	Poor regeneration
	<i>Flacourtia rukam</i>	1	0	2	Fair regeneration
	<i>Garcinia mangostana</i>	8	1	8	Good regeneration
	<i>Garcinia nitida</i>	2	0	4	Fair regeneration
	<i>Garcinia parvifolia</i>	6	0	5	Good regeneration
	<i>Garcinia</i> sp.	0	0	2	No regeneration
	<i>Gironniera nervosa</i>	0	0	3	No regeneration
	<i>Glochidion macrostigma</i>	0	0	6	No regeneration
	<i>Glochidion</i> sp. 1	0	0	3	No regeneration
	<i>Gluta wallichii</i>	1	0	11	Fair regeneration
	<i>Gnetum gnemon</i>	1	1	3	Fair regeneration
	<i>Goniothalamus uvarioides</i>	7	0	0	Poor regeneration
	<i>Goniothalamus velutinus</i>	1	0	0	Poor regeneration
	<i>Gonystylus</i> sp.	0	0	1	No regeneration
	<i>Gymnacranthera</i> sp. 1	1	0	0	Poor regeneration
	<i>Hevea brasiliensis</i>	15	13	67	Fair regeneration
	<i>Homalanthus populneus</i>	2	1	8	Fair regeneration
	<i>Horsfieldia</i> sp.	0	0	4	No regeneration
	<i>Ilex hypoglauca</i>	3	0	3	Good regeneration
	<i>Ixonanthes beccarii</i>	0	0	10	No regeneration
	<i>Ixonanthes</i> sp.	1	0	0	Poor regeneration
	<i>Ixora</i> sp.	2	2	0	Poor regeneration
	<i>Knema latifolia</i>	0	0	1	No regeneration
	<i>Lansium domesticum</i>	0	0	8	No regeneration
	<i>Lindera</i> sp.	1	5	2	Good regeneration
	<i>Lithocarpus echinifer</i>	2	0	17	Fair regeneration
	<i>Litsea garciae</i>	1	4	3	Good regeneration
	<i>Litsea gracilipes</i>	0	0	1	No regeneration
	<i>Litsea lancifolia</i>	1	0	3	Fair regeneration
	<i>Litsea</i> sp. 1	1	3	0	Poor regeneration

Appendix 6 continued

Forest Types	Species	No. of Individuals			Natural Regeneration Status
		Sapling	Seedling	Tree	
Agroforest	<i>Litsea</i> sp. 5	0	0	6	No regeneration
	<i>Macaranga caladiifolia</i>	8	1	20	Fair regeneration
	<i>Macaranga gigantea</i>	0	0	2	No regeneration
	<i>Mallotus repandus</i>	0	0	1	No regeneration
	<i>Mallotus</i> sp.	0	0	1	No regeneration
	<i>Mangifera griffithii</i>	0	0	1	No regeneration
	<i>Mangifera pajang</i>	0	0	1	No regeneration
	<i>Mangifera</i> sp. 1	2	1	2	Good regeneration
	<i>Mangifera</i> sp. 2	0	0	2	No regeneration
	<i>Mangifera</i> sp. 3	0	0	1	No regeneration
	<i>Mangifera torquenda</i>	4	0	0	Poor regeneration
	<i>Memecylon</i> sp. 1	0	2	6	Fair regeneration
	<i>Nephelium cuspidatum</i>	3	0	1	Good regeneration
	<i>Nephelium lappaceum</i>	0	0	6	No regeneration
	<i>Nephelium maingayi</i>	0	0	2	No regeneration
	<i>Nephelium ramboutan-ake</i>	5	1	1	Good regeneration
	<i>Norrisia major</i>	0	0	15	No regeneration
	<i>Ochanostachys amentacea</i>	4	0	0	Poor regeneration
	<i>Palaquium gutta</i>	9	57	5	Good regeneration
	<i>Palaquium obovatum</i>	0	0	3	No regeneration
	<i>Parastemon urophyllus</i>	0	0	1	No regeneration
	<i>Parkia speciosa</i>	2	18	2	Good regeneration
	<i>Pellacalyx lobbii</i>	1	1	0	Poor regeneration
	<i>Pentaspadon motleyi</i>	80	15	1	Good regeneration
	<i>Pentaspadon</i> sp.	0	0	1	No regeneration
	<i>Pimelodendron griffithianum</i>	0	0	3	No regeneration
	<i>Pimelodendron</i> sp.	7	1	0	Poor regeneration
	<i>Ploiarium alternifolium</i>	0	0	2	No regeneration
	<i>Pometia pinnata</i>	0	1	2	Fair regeneration
	<i>Saurauia acuminata</i>	0	0	3	No regeneration
	<i>Rubroshorea beccariana</i>	0	0	25	No regeneration
	<i>Rubroshorea macrophylla</i>	12	2	13	Fair regeneration
	<i>Rubroshorea macroptera</i>	0	0	1	No regeneration

Appendix 6 continued

Forest Types	Species	No. of Individuals			Natural Regeneration Status
		Sapling	Seedling	Tree	
Agroforest	<i>Stemonurus</i> sp.	0	0	3	No regeneration
	<i>Symplocos</i> sp.	4	1	3	Good regeneration
	<i>Syzygium kunstleri</i>	4	3	7	Fair regeneration
	<i>Syzygium leucoxylon</i>	6	1	4	Good regeneration
	<i>Syzygium monticola</i>	0	0	1	No regeneration
	<i>Syzygium</i> sp. 1	5	23	6	Good regeneration
	<i>Syzygium</i> sp. 4	46	6	2	Good regeneration
	<i>Syzygium</i> sp. 7	0	1	1	Good regeneration
	<i>Syzygium</i> sp. 8	75	25	50	Good regeneration
	<i>Syzygium</i> sp. 9	0	0	4	No regeneration
	<i>Syzygium</i> sp. 10	1	0	0	Poor regeneration
	<i>Theobroma cacao</i>	0	0	1	No regeneration
	<i>Timonius lasianthoides</i>	2	0	10	Fair regeneration
	<i>Turpinia sphaerocarpa</i>	2	3	0	Poor regeneration
	<i>Urophyllum</i> sp.	1	0	16	Fair regeneration
	<i>Vernonia arborea</i>	1	0	2	Fair regeneration
	<i>Vitex pubescens</i>	0	0	15	No regeneration
	<i>Whiteodendron moultonianum</i>	0	0	1	No regeneration
	<i>Xanthophyllum amoenum</i>	0	1	2	Fair regeneration
	<i>Xanthophyllum</i> sp. 2	0	0	1	No regeneration
	<i>Xylopia ferruginea</i>	0	0	6	No regeneration
	Unknown 1	5	0	2	Good regeneration
	Unknown 2	0	2	0	Poor regeneration
	Unknown 3	0	0	2	No regeneration
	Unknown 5	2	0	0	Poor regeneration

Notes: Unknown species – Identified up to local name only

Appendix 7: Potential Tree Species Estimated to Successfully Survive at Each Forest Type (Based on Importance Value)

Species	Forest Types	Observed Indicator Value	Indicator Value for Randomized Group		Significance Value (p < 0.05)
			Mean	SD	
<i>Actinodaphne</i> sp.	YSF	25.00	28.20	10.00	0.62
<i>Adinandra borneensis</i>	YSF	19.20	33.40	16.79	0.77
<i>Adinandra dumosa</i>	OSF	18.60	38.50	15.47	0.96
<i>Aetoxylon sympetalum</i>	PF	47.10	31.40	15.53	0.16
<i>Aglaia</i> sp.	YSF	25.00	28.20	10.00	0.62
<i>Alangium javanicum</i>	AF	56.30	33.30	17.36	0.12
<i>Allantospermum borneense</i>	PF	76.30	31.90	16.84	0.04
<i>Alseodaphne</i> sp. 1	YSF	25.00	28.70	10.04	0.66
<i>Alseodaphne</i> sp. 2	YSF	25.00	28.20	10.00	0.62
<i>Alstonia scholaris</i>	AF	31.30	35.30	13.69	0.52
<i>Alstonia spatulata</i>	YSF	55.00	43.20	12.10	0.22
<i>Anisophyllea disticha</i>	PF	48.50	36.00	13.67	0.19
<i>Anisophyllea</i> sp. 1	OSF	20.00	28.70	10.35	1.00
<i>Anisophyllea</i> sp. 2	PF	32.30	31.60	16.30	0.34
<i>Aporosa benthamiana</i>	PF	88.60	29.90	16.25	0.02
<i>Aporosa</i> sp. 1	AF	12.30	34.90	16.08	0.98
<i>Aporosa</i> sp. 2	AF	33.30	29.00	10.21	0.38
<i>Archidendron borneense</i>	YSF	56.10	36.60	14.14	0.11
<i>Archidendron jiringa</i>	AF	77.80	38.00	13.81	0.00
<i>Ardisia javanica</i>	YSF	46.30	35.00	14.86	0.20
<i>Artocarpus anisophyllus</i>	PF	26.10	29.30	14.91	0.44
<i>Artocarpus elasticus</i>	OSF	45.10	41.20	9.78	0.37
<i>Artocarpus integer</i>	AF	41.00	39.30	7.09	0.36
<i>Artocarpus kemando</i>	YSF	38.20	37.60	6.39	0.42
<i>Artocarpus nitidus</i>	OSF	21.00	37.40	9.54	0.98
<i>Artocarpus tamaran</i>	PF	22.50	35.50	15.40	0.79
<i>Baccaurea angulata</i>	AF	57.10	29.10	15.05	0.07
<i>Baccaurea macrocarpa</i>	PF	41.10	37.20	13.40	0.36
<i>Baccaurea maingayi</i>	OSF	59.80	37.60	14.82	0.12
<i>Baccaurea motleyana</i>	AF	25.60	31.10	16.02	0.55
<i>Baccaurea polyneura</i>	AF	16.10	28.80	14.74	0.79
<i>Baccaurea pubera</i>	PF	44.70	34.20	18.05	0.18
<i>Baccaurea</i> sp.	YSF	28.10	35.90	15.57	0.62
<i>Barringtonia</i> sp.	YSF	31.20	29.70	16.79	0.33
<i>Bellucia pentamera</i>	AF	39.70	35.30	14.93	0.33
<i>Bhesa paniculata</i>	YSF	25.00	28.70	10.04	0.66

Appendix 7 continued

Species	Forest Types	Observed Indicator Value	Indicator Value for Randomized Group		Significance Value (p < 0.05)
			Mean	SD	
<i>Breynia racemosa</i>	YSF	87.20	36.70	17.75	0.01
<i>Breynia</i> sp.	OSF	14.30	29.40	15.56	0.91
<i>Calophyllum canum</i>	PF	50.00	28.60	9.79	0.14
<i>Calophyllum floribundum</i>	PF	50.00	28.60	9.79	0.14
<i>Calophyllum</i> sp.	PF	41.10	31.40	16.62	0.21
<i>Calophyllum woodii</i>	PF	47.50	37.10	14.73	0.24
<i>Campnosperma auriculatum</i>	OSF	36.80	37.00	10.43	0.49
<i>Campnosperma coriaceum</i>	YSF	27.30	34.10	16.25	0.59
<i>Canarium</i> sp. 1	PF	23.50	30.80	15.56	0.59
<i>Canarium</i> sp. 2	PF	33.00	28.10	15.29	0.35
<i>Canthium umbelligerum</i>	OSF	29.40	32.90	16.96	0.51
<i>Cantleya corniculata</i>	PF	60.30	34.80	14.77	0.08
<i>Cassia</i> sp.	AF	33.30	28.50	9.96	0.36
<i>Castanopsis motleyana</i>	AF	38.00	32.40	16.59	0.27
<i>Citrus aurantiifolia</i>	AF	33.30	28.40	9.85	0.36
<i>Cleisanthus</i> sp.	OSF	20.00	28.40	9.90	1.00
<i>Cleistanthus</i> sp.	PF	33.40	35.70	13.70	0.48
<i>Clerodendrum</i> sp.	PF	50.00	28.60	9.79	0.14
<i>Commersonia bartramia</i>	YSF	74.20	42.60	18.59	0.06
<i>Cratoxylum arborescens</i>	OSF	53.90	31.60	15.83	0.09
<i>Cratoxylum formosum</i>	YSF	41.50	42.10	11.33	0.48
<i>Cratoxylum glaucum</i>	AF	25.50	29.00	15.58	0.50
<i>Croton</i> sp.	OSF	20.00	28.50	10.17	1.00
<i>Dacryodes rostrata</i>	AF	33.30	28.50	9.96	0.36
<i>Dacryodes</i> sp. 1	OSF	20.00	28.40	9.90	1.00
<i>Dacryodes</i> sp. 2	AF	33.30	28.50	9.96	0.36
<i>Decussocarpus motleyi</i>	AF	33.30	28.50	9.96	0.36
<i>Dialium indum</i>	PF	40.30	31.80	17.50	0.23
<i>Dillenia borneensis</i>	PF	30.40	31.60	16.50	0.35
<i>Dillenia excelsa</i>	AF	27.10	36.90	9.49	0.88
<i>Dillenia suffruticosa</i>	AF	44.80	32.20	15.67	0.17
<i>Diospyros buxifolia</i>	AF	33.30	28.50	9.96	0.36
<i>Diospyros foxworthyi</i>	AF	33.70	35.10	12.74	0.47
<i>Diospyros piscicapa</i>	OSF	13.80	32.10	16.10	0.96
<i>Dipterocarpus cuspidatus</i>	PF	33.00	28.10	15.29	0.35
<i>Dipterocarpus fagineus</i>	PF	50.00	28.60	9.79	0.14

Appendix 7 continued

Species	Forest Types	Observed Indicator Value	Indicator Value for Randomized Group		Significance Value (p < 0.05)
			Mean	SD	
<i>Dipterocarpus kunstleri</i>	OSF	20.00	28.40	9.90	1.00
<i>Dipterocarpus oblongifolius</i>	PF	83.80	31.80	15.82	0.00
<i>Dipterocarpus obtusifolius</i>	PF	50.00	28.60	9.79	0.14
<i>Dipterocarpus sarawakensis</i>	PF	96.20	40.90	19.45	0.01
<i>Dryobalanops beccarii</i>	OSF	37.90	36.70	14.38	0.37
<i>Durio zibethinus</i>	AF	80.30	36.50	16.09	0.02
<i>Dyera costulata</i>	OSF	20.00	28.80	10.31	1.00
<i>Elaeocarpus nitidus</i>	OSF	17.00	32.10	15.00	0.89
<i>Elaeocarpus sphaeroblastus</i>	AF	33.30	29.00	10.21	0.38
<i>Elateriospermum tapos</i>	YSF	23.90	37.20	15.86	0.80
<i>Endospermum diadenum</i>	YSF	71.50	41.60	12.70	0.02
<i>Euodia glabra</i>	PF	28.70	33.20	15.78	0.54
<i>Eurya acuminata</i>	YSF	29.90	36.60	10.85	0.69
<i>Eurycoma longifolia</i>	AF	33.30	29.00	10.21	0.38
<i>Eusideroxylon zwageri</i>	PF	50.00	28.70	10.43	0.16
<i>Euthemis minor</i>	YSF	16.70	28.50	15.36	0.82
<i>Fagraea racemosa</i>	OSF	20.00	28.40	9.90	1.00
<i>Ficus aurata</i>	OSF	12.30	28.70	15.48	1.00
<i>Ficus brunneoaurata</i>	YSF	33.80	33.10	16.95	0.44
<i>Ficus gecharis</i>	OSF	23.10	30.30	15.76	0.75
<i>Ficus grossularioides</i>	YSF	25.00	28.10	9.71	0.64
<i>Ficus racemosa</i>	YSF	25.00	28.20	10.00	0.62
<i>Ficus</i> sp. 1	PF	30.50	32.00	16.60	0.43
<i>Ficus</i> sp. 2	AF	33.30	28.50	9.96	0.36
<i>Flacourtia jangomas</i>	OSF	20.00	28.80	10.31	1.00
<i>Flacourtia rukam</i>	AF	43.20	30.00	16.21	0.15
<i>Fordia splendidissima</i>	PF	50.00	28.60	9.79	0.14
<i>Garcinia mangostana</i>	AF	66.70	28.30	14.90	0.04
<i>Garcinia nitida</i>	YSF	32.90	34.00	12.71	0.48
<i>Garcinia parvifolia</i>	AF	19.70	34.20	14.64	0.86
<i>Garcinia</i> sp.	PF	39.20	32.30	17.74	0.31
<i>Gironniera nervosa</i>	YSF	39.90	31.10	16.45	0.20
<i>Glochidion macrostigma</i>	AF	33.30	28.50	9.96	0.36
<i>Glochidion</i> sp. 1	YSF	15.60	34.60	17.38	0.88
<i>Glochidion</i> sp. 2	YSF	25.00	28.70	10.04	0.66
<i>Glochidion</i> sp. 3	YSF	16.30	28.40	15.54	0.82
<i>Gluta wallichii</i>	PF	66.90	42.20	16.12	0.14

Appendix 7 continued

Species	Forest Types	Observed Indicator Value	Indicator Value for Randomized Group		Significance Value (p < 0.05)
			Mean	SD	
<i>Gnetum gnemon</i>	AF	34.10	35.40	8.85	0.55
<i>Goniothalamus uvarioides</i>	OSF	24.90	31.90	15.52	0.56
<i>Goniothalamus velutinus</i>	AF	33.30	28.50	9.96	0.36
<i>Gonystylus</i> sp.	AF	33.30	28.50	9.96	0.36
<i>Gymnacranthera</i> sp. 1	PF	24.30	36.50	17.15	0.72
<i>Gymnacranthera</i> sp. 2	PF	50.00	28.60	9.79	0.14
<i>Gymnacranthera</i> sp. 3	PF	50.00	28.60	9.79	0.14
<i>Hevea brasiliensis</i>	YSF	30.00	39.30	11.02	0.78
<i>Homalanthus populneus</i>	AF	46.00	35.40	13.01	0.22
<i>Hopea ferruginea</i>	PF	31.00	31.50	16.04	0.37
<i>Horsfieldia</i> sp.	YSF	22.00	32.30	16.98	0.76
<i>Ilex hypoglauca</i>	AF	47.00	33.30	15.52	0.19
<i>Ixonanthes beccarii</i>	OSF	44.50	39.80	16.43	0.29
<i>Ixonanthes</i> sp.	AF	16.60	29.30	14.93	0.81
<i>Ixora</i> sp.	YSF	26.90	33.20	15.73	0.56
<i>Kibara coriacea</i>	PF	20.30	29.40	15.73	0.68
<i>Kibessia coriacea</i>	YSF	50.00	29.90	15.74	0.14
<i>Knema latifolia</i>	OSF	47.20	34.70	13.10	0.18
<i>Knema</i> sp. 1	OSF	20.00	28.70	10.16	1.00
<i>Knema</i> sp. 2	OSF	20.00	28.50	10.17	1.00
<i>Knema</i> sp. 3	YSF	25.00	28.10	9.83	0.63
<i>Koompassia excelsa</i>	PF	50.00	28.60	9.79	0.14
<i>Koompassia malaccensis</i>	PF	50.00	28.60	9.79	0.14
<i>Lansium domesticum</i>	AF	56.50	31.30	16.90	0.11
<i>Lansium parasiticum</i>	YSF	25.00	28.20	10.00	0.62
<i>Leea indica</i>	YSF	45.60	29.80	16.48	0.14
<i>Leucosyke</i> sp.	YSF	25.00	28.20	10.00	0.62
<i>Lindera</i> sp.	AF	33.30	28.40	9.85	0.36
<i>Lithocarpus echinifer</i>	YSF	23.80	39.70	10.03	0.97
<i>Lithocarpus ewyckii</i>	PF	82.70	31.80	16.65	0.01
<i>Lithocarpus</i> sp.	YSF	25.00	28.20	10.00	0.62
<i>Lithocarpus turbinatus</i>	PF	50.00	28.60	9.79	0.14
<i>Litsea cordata</i>	YSF	25.00	28.20	10.00	0.62
<i>Litsea garciae</i>	AF	33.30	28.40	9.85	0.36
<i>Litsea gracilipes</i>	AF	33.30	28.50	9.96	0.36
<i>Litsea grandis</i>	YSF	25.00	28.70	10.04	0.66
<i>Litsea lancifolia</i>	PF	49.60	43.30	12.41	0.30

Appendix 7 continued

Species	Forest Types	Observed Indicator Value	Indicator Value for Randomized Group		Significance Value (p < 0.05)
			Mean	SD	
<i>Litsea nidularis</i>	YSF	25.00	28.20	10.00	0.62
<i>Litsea resinosa</i>	PF	50.00	28.60	9.79	0.14
<i>Litsea</i> sp. 1	PF	26.90	29.00	15.80	0.47
<i>Litsea</i> sp. 2	PF	50.00	28.60	9.79	0.14
<i>Litsea</i> sp. 3	YSF	25.00	28.70	10.04	0.66
<i>Litsea</i> sp. 4	YSF	25.00	28.20	10.00	0.62
<i>Litsea</i> sp. 5	AF	16.80	28.80	14.63	0.79
<i>Macaranga caladiifolia</i>	AF	66.40	39.40	12.97	0.04
<i>Macaranga gigantea</i>	AF	17.00	29.20	14.96	0.80
<i>Macaranga</i> sp.	PF	50.00	28.60	9.79	0.14
<i>Mallotus repandus</i>	YSF	20.30	33.70	16.13	0.74
<i>Mallotus</i> sp.	AF	12.60	29.80	16.16	1.00
<i>Mangifera graffithii</i>	AF	33.30	29.00	10.21	0.38
<i>Mangifera griffithii</i>	OSF	20.00	28.80	10.31	1.00
<i>Mangifera pajang</i>	AF	33.30	29.00	10.21	0.38
<i>Mangifera</i> sp. 1	AF	20.10	30.80	16.77	0.69
<i>Mangifera</i> sp. 2	AF	33.30	29.00	10.21	0.38
<i>Mangifera</i> sp. 3	AF	33.30	29.00	10.21	0.38
<i>Mangifera torquenda</i>	AF	23.80	28.30	15.04	0.56
<i>Melastoma polyanthum</i>	YSF	25.00	28.10	9.71	0.64
<i>Memecylon</i> sp. 1	OSF	39.30	38.70	17.54	0.41
<i>Memecylon</i> sp. 2	PF	40.10	31.70	17.73	0.21
<i>Mesua ferrea</i>	PF	50.00	28.60	9.79	0.14
<i>Mesua</i> sp.	OSF	22.30	30.00	16.71	0.67
<i>Microcos</i> sp.	YSF	25.00	28.20	10.00	0.62
<i>Myristica</i> sp.	PF	50.00	28.60	9.79	0.14
<i>Nauclea</i> sp.	OSF	37.80	32.00	15.29	0.26
<i>Nephelium cuspidatum</i>	PF	23.80	29.20	16.01	0.58
<i>Nephelium lappaceum</i>	AF	22.60	28.50	14.55	0.57
<i>Nephelium maingayi</i>	AF	14.40	29.70	14.92	0.91
<i>Nephelium ramboutan-ake</i>	AF	55.90	33.20	16.69	0.10
<i>Norrisia major</i>	OSF	51.50	36.70	14.21	0.18
<i>Ochanostachys amentacea</i>	OSF	34.80	33.40	15.68	0.37
<i>Octomeles sumatrana</i>	OSF	20.00	28.80	10.31	1.00
<i>Ormosia bancana</i>	OSF	20.00	28.70	10.35	1.00
<i>Palaquium gutta</i>	PF	38.20	38.00	11.90	0.45
<i>Palaquium obovatum</i>	AF	51.30	30.30	16.15	0.12

Appendix 7 continued

Species	Forest Types	Observed Indicator Value	Indicator Value for Randomized Group		Significance Value (p < 0.05)
			Mean	SD	
<i>Palaquium</i> sp. 1	OSF	20.00	28.40	9.90	1.00
<i>Palaquium</i> sp. 2	YSF	25.00	28.70	10.04	0.66
<i>Pangium edule</i>	OSF	20.00	28.70	10.35	1.00
<i>Parastemon urophyllus</i>	PF	37.90	32.20	17.44	0.25
<i>Parkia speciosa</i>	AF	66.70	30.60	14.75	0.04
<i>Pellacalyx lobbii</i>	AF	34.20	33.60	15.82	0.38
<i>Pentaspadon motleyi</i>	YSF	25.50	37.60	12.64	0.81
<i>Pentaspadon</i> sp.	AF	33.30	28.50	9.96	0.36
<i>Pimelodendron griffithianum</i>	YSF	17.40	29.50	15.01	0.81
<i>Pimelodendron</i> sp.	YSF	40.30	37.60	13.16	0.31
<i>Ploiarium alternifolium</i>	AF	15.90	28.30	15.17	0.81
<i>Polyalthia cauliflora</i>	YSF	25.00	28.20	10.00	0.62
<i>Polyalthia</i> sp.	OSF	37.80	35.20	17.25	0.33
<i>Pometia pinnata</i>	OSF	19.90	36.20	16.01	0.90
<i>Psychotria viridiflora</i>	YSF	27.80	30.80	15.41	0.43
<i>Pterospermum</i> sp.	YSF	25.00	28.20	10.00	0.62
<i>Santiria</i> sp.	YSF	25.00	28.20	10.00	0.62
<i>Sarcotheca</i> sp.	YSF	25.00	28.20	10.00	0.62
<i>Saurauia acuminata</i>	OSF	13.50	32.90	15.50	0.98
<i>Rubroshorea beccariana</i>	AF	29.90	35.80	18.11	0.55
<i>Rubroshorea bullata</i>	OSF	20.00	28.50	10.17	1.00
<i>Rubroshorea coriacea</i>	PF	18.70	30.20	15.15	0.77
<i>Rubroshorea curtisii</i>	OSF	20.00	28.70	10.16	1.00
<i>Rubroshorea macrophylla</i>	AF	44.00	39.20	17.06	0.34
<i>Rubroshorea macroptera</i>	OSF	15.10	30.30	15.29	1.00
<i>Rubroshorea palembanica</i>	YSF	25.00	28.20	10.00	0.62
<i>Rubroshorea stenoptera</i>	YSF	25.00	28.20	10.00	0.62
<i>Shorea ladiana</i>	PF	44.70	30.20	16.46	0.17
<i>Stemonurus</i> sp.	YSF	28.30	30.80	16.04	0.53
<i>Sterculia</i> sp.	OSF	20.00	28.70	10.16	1.00
<i>Strombosia ceylanica</i>	YSF	25.00	28.20	10.00	0.62
<i>Symplocos</i> sp.	AF	33.30	29.00	10.21	0.38
<i>Syzygium arcuatinervium</i>	YSF	25.00	28.20	10.00	0.62
<i>Syzygium jambos</i>	YSF	25.00	28.70	10.04	0.66
<i>Syzygium kunstleri</i>	PF	42.30	40.40	10.41	0.39
<i>Syzygium leucoxydon</i>	OSF	41.40	39.40	9.39	0.44
<i>Syzygium monticola</i>	PF	31.10	36.00	15.66	0.51

Appendix 7 continued

Species	Forest Types	Observed Indicator Value	Indicator Value for Randomized Group		Significance Value (p < 0.05)
			Mean	SD	
<i>Syzygium polyanthum</i>	YSF	25.00	28.20	10.00	0.62
<i>Syzygium sarawakensis</i>	YSF	25.00	28.20	10.00	0.62
<i>Syzygium</i> sp. 1	AF	33.30	29.00	10.21	0.38
<i>Syzygium</i> sp. 2	OSF	20.00	28.80	10.31	1.00
<i>Syzygium</i> sp. 3	OSF	20.00	28.40	9.90	1.00
<i>Syzygium</i> sp. 4	AF	33.30	28.40	9.85	0.36
<i>Syzygium</i> sp. 5	PF	50.00	28.60	9.79	0.14
<i>Syzygium</i> sp. 6	YSF	25.00	28.20	10.00	0.62
<i>Syzygium</i> sp. 7	PF	20.30	29.20	16.18	0.63
<i>Syzygium</i> sp. 8	AF	27.40	34.00	18.02	0.61
<i>Syzygium</i> sp. 9	AF	19.20	30.30	16.51	0.77
<i>Syzygium</i> sp. 10	YSF	19.00	29.40	15.77	0.75
<i>Syzygium</i> sp. 11	OSF	20.00	28.70	10.16	1.00
<i>Syzygium</i> sp. 12	YSF	25.00	28.70	10.04	0.66
<i>Syzygium</i> sp. 13	YSF	14.90	28.60	15.02	0.89
<i>Syzygium</i> sp. 14	YSF	25.00	28.70	10.04	0.66
<i>Syzygium</i> sp. 15	OSF	20.00	28.80	10.31	1.00
<i>Talauma</i> sp.	YSF	50.00	28.40	14.44	0.09
<i>Theobroma cacao</i>	AF	33.30	29.00	10.21	0.38
<i>Timonius lasianthoides</i>	YSF	49.10	39.40	13.31	0.24
<i>Timonius</i> sp.	OSF	20.00	28.40	9.90	1.00
<i>Trema occidentalis</i>	YSF	25.00	28.10	9.71	0.64
<i>Tristaniopsis whiteana</i>	OSF	15.70	32.80	17.18	0.91
<i>Turpinia sphaerocarpa</i>	AF	34.60	32.80	15.94	0.35
<i>Upuna borneensis</i>	OSF	20.00	28.50	10.17	1.00
<i>Urophyllum</i> sp.	AF	35.60	34.50	15.01	0.37
<i>Vatica</i> sp.	PF	50.00	28.70	10.43	0.16
<i>Vernonia arborea</i>	YSF	24.10	36.60	16.02	0.77
<i>Vitex pubescens</i>	YSF	43.40	34.10	14.61	0.22
<i>Whiteodendron moultonianum</i>	AF	33.30	28.50	9.96	0.36
<i>Xanthophyllum amoenum</i>	PF	31.20	32.60	17.41	0.38
<i>Xanthophyllum</i> sp. 1	PF	27.30	28.40	15.79	0.43
<i>Xanthophyllum</i> sp. 2	AF	33.30	28.40	9.85	0.36
<i>Xylopia ferruginea</i>	AF	31.20	34.40	14.86	0.50
Unknown 1	AF	33.30	29.00	10.21	0.38
Unknown 2	AF	33.30	29.00	10.21	0.38
Unknown 3	AF	21.10	29.60	15.58	0.58

Appendix 7 continued

Species	Forest Types	Observed Indicator Value	Indicator Value for Randomized Group		Significance Value (p < 0.05)
			Mean	SD	
<i>Unknown 4</i>	OSF	23.20	30.20	16.85	0.60
<i>Unknown 5</i>	AF	33.30	29.00	10.21	0.38
<i>Unknown 6</i>	OSF	20.00	28.40	9.90	1.00
<i>Unknown 7</i>	PF	50.00	28.70	10.43	0.16
<i>Unknown 8</i>	OSF	20.00	28.40	9.90	1.00
Average		33.94	31.43	12.95	0.50

* Proportion of randomized trials with indicator value equal to or exceeding the observed indicator value.

$p = (1 + \text{number of runs} \geq \text{observed}) / (1 + \text{number of randomized runs})$

PF – Primary forest, OSF – Old secondary forest, YSF – Young secondary forest, AF – Agroforest

Appendix 8: Potential Tree Species Estimated to Successfully Survive at Each Forest Type (Based on Standing Biomass)

Species	Forest Types	Observed Indicator Value	Indicator Value for Randomized Group		Significance Value (p < 0.05)
			Mean	SD	
<i>Actinodaphne</i> sp.	YSF	25.00	28.30	10.10	0.63
<i>Adinandra borneensis</i>	YSF	19.20	33.80	17.33	0.78
<i>Adinandra dumosa</i>	OSF	18.60	37.90	15.76	0.94
<i>Aetoxylon sympetalum</i>	PF	47.10	30.70	14.96	0.15
<i>Aglaia</i> sp.	YSF	25.00	28.30	10.10	0.63
<i>Alangium javanicum</i>	AF	56.30	32.70	17.01	0.11
<i>Allantospermum borneense</i>	PF	76.30	31.00	15.93	0.03
<i>Alseodaphne</i> sp. 1	YSF	25.00	28.80	10.09	0.66
<i>Alseodaphne</i> sp. 2	YSF	25.00	28.30	10.10	0.63
<i>Alstonia scholaris</i>	AF	31.30	35.10	12.91	0.54
<i>Alstonia spatulata</i>	YSF	55.00	43.20	12.30	0.24
<i>Anisophyllea disticha</i>	PF	48.50	34.90	13.18	0.15
<i>Anisophyllea</i> sp. 1	OSF	20.00	28.70	10.13	1.00
<i>Anisophyllea</i> sp. 2	PF	32.30	31.10	15.64	0.32
<i>Aporosa benthamiana</i>	PF	88.60	29.20	15.35	0.01
<i>Aporosa</i> sp. 1	AF	12.30	34.10	15.60	0.98
<i>Aporosa</i> sp. 2	AF	33.30	28.30	9.96	0.36
<i>Archidendron borneense</i>	YSF	56.10	35.70	14.05	0.11
<i>Archidendron jiringa</i>	AF	77.80	38.70	13.67	0.00
<i>Ardisia javanica</i>	YSF	46.30	34.70	14.79	0.17
<i>Artocarpus anisophyllus</i>	PF	26.10	30.50	15.35	0.47
<i>Artocarpus elasticus</i>	OSF	45.10	40.70	9.84	0.35
<i>Artocarpus integer</i>	AF	41.00	39.30	7.27	0.42
<i>Artocarpus kemando</i>	YSF	38.20	37.40	6.45	0.40
<i>Artocarpus nitidus</i>	OSF	21.00	37.40	9.98	0.98
<i>Artocarpus tamaran</i>	PF	22.50	35.20	15.50	0.76
<i>Baccaurea angulata</i>	AF	57.10	30.50	16.60	0.11
<i>Baccaurea macrocarpa</i>	PF	41.10	37.40	13.05	0.35
<i>Baccaurea maingayi</i>	OSF	59.80	37.10	14.27	0.11
<i>Baccaurea motleyana</i>	AF	25.60	30.10	15.19	0.53
<i>Baccaurea polyneura</i>	AF	16.10	28.70	15.42	0.77
<i>Baccaurea pubera</i>	PF	44.70	33.40	17.50	0.16
<i>Baccaurea</i> sp.	YSF	28.10	34.80	15.26	0.57
<i>Barringtonia</i> sp.	YSF	31.20	29.80	16.01	0.33
<i>Bellucia pentamera</i>	AF	39.70	35.60	15.20	0.34
<i>Bhesa paniculata</i>	YSF	25.00	28.80	10.09	0.66
<i>Breynia racemosa</i>	YSF	87.20	36.10	16.17	0.01

Appendix 8 continued

Species	Forest Types	Observed Indicator Value	Indicator Value for Randomized Group		Significance Value (p < 0.05)
			Mean	SD	
<i>Breynia</i> sp.	OSF	14.30	29.30	16.37	0.91
<i>Calophyllum canum</i>	PF	50.00	28.30	9.86	0.13
<i>Calophyllum floribundum</i>	PF	50.00	28.30	9.86	0.13
<i>Calophyllum</i> sp.	PF	41.10	31.40	16.88	0.20
<i>Calophyllum woodii</i>	PF	47.50	36.20	14.56	0.21
<i>Campnosperma auriculatum</i>	OSF	36.80	36.70	10.48	0.48
<i>Campnosperma coriaceum</i>	YSF	27.30	34.60	16.99	0.59
<i>Canarium</i> sp. 1	PF	23.50	30.30	15.46	0.56
<i>Canarium</i> sp. 2	PF	33.00	28.20	15.25	0.36
<i>Canthium umbelligerum</i>	OSF	29.40	33.40	17.22	0.53
<i>Cantleya corniculata</i>	PF	60.30	34.70	14.67	0.08
<i>Cassia</i> sp.	AF	33.30	29.00	10.35	0.37
<i>Castanopsis motleyana</i>	AF	38.00	31.40	15.49	0.24
<i>Citrus aurantiifolia</i>	AF	33.30	28.30	10.06	0.34
<i>Cleisanthus</i> sp.	OSF	20.00	28.20	9.70	1.00
<i>Cleistanthus</i> sp.	PF	33.40	35.60	13.78	0.48
<i>Clerodendrum</i> sp.	PF	50.00	28.30	9.86	0.13
<i>Commersonia bartramia</i>	YSF	74.20	42.80	18.71	0.06
<i>Cratoxylum arborescens</i>	OSF	53.90	31.00	15.94	0.10
<i>Cratoxylum formosum</i>	YSF	41.50	41.20	11.10	0.44
<i>Cratoxylum glaucum</i>	AF	25.50	28.00	15.36	0.46
<i>Croton</i> sp.	OSF	20.00	29.00	10.28	1.00
<i>Dacryodes rostrata</i>	AF	33.30	29.00	10.35	0.37
<i>Dacryodes</i> sp. 1	OSF	20.00	28.20	9.70	1.00
<i>Dacryodes</i> sp. 2	AF	33.30	29.00	10.35	0.37
<i>Decussocarpus motleyi</i>	AF	33.30	29.00	10.35	0.37
<i>Dialium indum</i>	PF	40.30	31.40	16.62	0.23
<i>Dillenia borneensis</i>	PF	30.40	31.30	15.55	0.37
<i>Dillenia excelsa</i>	AF	27.10	37.00	9.82	0.87
<i>Dillenia suffruticosa</i>	AF	44.80	32.30	16.62	0.17
<i>Diospyros buxifolia</i>	AF	33.30	29.00	10.35	0.37
<i>Diospyros foxworthyi</i>	AF	33.70	34.70	12.88	0.47
<i>Diospyros piscicapa</i>	OSF	13.80	30.10	15.03	0.96
<i>Dipterocarpus cuspidatus</i>	PF	33.00	28.20	15.25	0.36
<i>Dipterocarpus fagineus</i>	PF	50.00	28.30	9.86	0.13
<i>Dipterocarpus kunstleri</i>	OSF	20.00	28.20	9.70	1.00
<i>Dipterocarpus oblongifolius</i>	PF	83.80	31.70	15.75	0.00

Appendix 8 continued

Species	Forest Types	Observed Indicator Value	Indicator Value for Randomized Group		Significance Value (p < 0.05)
			Mean	SD	
<i>Dipterocarpus obtusifolius</i>	PF	50.00	28.30	9.86	0.13
<i>Dipterocarpus sarawakensis</i>	PF	96.20	40.10	18.34	0.01
<i>Dryobalanops beccarii</i>	OSF	37.90	37.10	14.36	0.39
<i>Durio zibethinus</i>	AF	80.30	36.70	16.45	0.01
<i>Dyera costulata</i>	OSF	20.00	28.40	9.79	1.00
<i>Elaeocarpus nitidus</i>	OSF	17.00	32.50	15.25	0.89
<i>Elaeocarpus sphaeroblastus</i>	AF	33.30	28.30	9.96	0.36
<i>Elateriospermum tapos</i>	YSF	23.90	36.40	15.79	0.79
<i>Endospermum diadenum</i>	YSF	71.50	41.00	12.02	0.01
<i>Euodia glabra</i>	PF	28.70	33.70	15.85	0.54
<i>Eurya acuminata</i>	YSF	29.90	37.60	10.89	0.73
<i>Eurycoma longifolia</i>	AF	33.30	28.30	9.96	0.36
<i>Eusideroxylon zwageri</i>	PF	50.00	28.60	10.33	0.15
<i>Euthemis minor</i>	YSF	16.70	28.70	16.26	0.82
<i>Fagraea racemosa</i>	OSF	20.00	28.20	9.70	1.00
<i>Ficus aurata</i>	OSF	12.30	28.60	15.12	1.00
<i>Ficus brunneoaurata</i>	YSF	33.80	32.80	16.99	0.43
<i>Ficus geocharis</i>	OSF	23.10	29.20	14.62	0.73
<i>Ficus grossularioides</i>	YSF	25.00	28.70	10.13	0.64
<i>Ficus racemosa</i>	YSF	25.00	28.30	10.10	0.63
<i>Ficus</i> sp. 1	PF	30.50	31.20	16.27	0.41
<i>Ficus</i> sp. 2	AF	33.30	29.00	10.35	0.37
<i>Flacourtia jangomas</i>	OSF	20.00	28.40	9.79	1.00
<i>Flacourtia rukam</i>	AF	43.20	30.00	16.04	0.15
<i>Fordia splendidissima</i>	PF	50.00	28.30	9.86	0.13
<i>Garcinia mangostana</i>	AF	66.70	29.40	16.28	0.06
<i>Garcinia nitida</i>	YSF	32.90	34.30	12.55	0.51
<i>Garcinia parvifolia</i>	AF	19.70	33.40	14.18	0.85
<i>Garcinia</i> sp.	PF	39.20	31.50	16.71	0.30
<i>Gironniera nervosa</i>	YSF	39.90	31.20	17.19	0.20
<i>Glochidion macrostigma</i>	AF	33.30	29.00	10.35	0.37
<i>Glochidion</i> sp. 1	YSF	15.60	33.60	17.39	0.87
<i>Glochidion</i> sp. 2	YSF	25.00	28.80	10.09	0.66
<i>Glochidion</i> sp. 3	YSF	16.30	28.30	16.13	0.82
<i>Gluta wallichii</i>	PF	66.90	41.30	16.09	0.13
<i>Gnetum gnemon</i>	AF	34.10	35.30	8.90	0.54
<i>Goniothalamus uvarioides</i>	OSF	24.90	32.30	15.07	0.57

Appendix 8 continued

Species	Forest Types	Observed Indicator Value	Indicator Value for Randomized Group		Significance Value (p < 0.05)
			Mean	SD	
<i>Goniothalamus velutinus</i>	AF	33.30	29.00	10.35	0.37
<i>Gonystylus</i> sp.	AF	33.30	29.00	10.35	0.37
<i>Gymnacranthera</i> sp. 1	PF	24.30	35.60	16.80	0.71
<i>Gymnacranthera</i> sp. 2	PF	50.00	28.30	9.86	0.13
<i>Gymnacranthera</i> sp. 3	PF	50.00	28.30	9.86	0.13
<i>Hevea brasiliensis</i>	YSF	30.00	39.20	11.13	0.77
<i>Homalanthus populneus</i>	AF	46.00	34.80	13.04	0.20
<i>Hopea ferruginea</i>	PF	31.00	30.80	15.53	0.36
<i>Horsfieldia</i> sp.	YSF	22.00	32.20	15.76	0.79
<i>Ilex hypoglauca</i>	AF	47.00	33.40	15.78	0.19
<i>Ixonanthes beccarii</i>	OSF	44.50	39.60	16.21	0.29
<i>Ixonanthes</i> sp.	AF	16.60	28.80	14.45	0.80
<i>Ixora</i> sp.	YSF	26.90	33.60	16.02	0.57
<i>Kibara coriacea</i>	PF	20.30	29.40	15.50	0.68
<i>Kibessia coriacea</i>	YSF	50.00	30.10	16.12	0.14
<i>Knema latifolia</i>	OSF	47.20	35.10	13.39	0.19
<i>Knema</i> sp. 1	OSF	20.00	28.30	9.90	1.00
<i>Knema</i> sp. 2	OSF	20.00	29.00	10.28	1.00
<i>Knema</i> sp. 3	YSF	25.00	28.70	10.05	0.66
<i>Koompassia excelsa</i>	PF	50.00	28.30	9.86	0.13
<i>Koompassia malaccensis</i>	PF	50.00	28.30	9.86	0.13
<i>Lansium domesticum</i>	AF	56.50	31.70	17.27	0.11
<i>Lansium parasiticum</i>	YSF	25.00	28.30	10.10	0.63
<i>Leea indica</i>	YSF	45.60	30.80	16.22	0.15
<i>Leucosyke</i> sp.	YSF	25.00	28.30	10.10	0.63
<i>Lindera</i> sp.	AF	33.30	28.30	10.06	0.34
<i>Lithocarpus echinifer</i>	YSF	23.80	40.50	10.42	0.97
<i>Lithocarpus ewyckii</i>	PF	82.70	30.80	15.92	0.01
<i>Lithocarpus</i> sp.	YSF	25.00	28.30	10.10	0.63
<i>Lithocarpus turbinatus</i>	PF	50.00	28.30	9.86	0.13
<i>Litsea cordata</i>	YSF	25.00	28.30	10.10	0.63
<i>Litsea garciae</i>	AF	33.30	28.30	10.06	0.34
<i>Litsea gracilipes</i>	AF	33.30	29.00	10.35	0.37
<i>Litsea grandis</i>	YSF	25.00	28.80	10.09	0.66
<i>Litsea lancifolia</i>	PF	49.60	43.70	12.03	0.29
<i>Litsea nidularis</i>	YSF	25.00	28.30	10.10	0.63
<i>Litsea resinosa</i>	PF	50.00	28.30	9.86	0.13

Appendix 8 continued

Species	Forest Types	Observed Indicator Value	Indicator Value for Randomized Group		Significance Value (p < 0.05)
			Mean	SD	
<i>Litsea</i> sp. 1	PF	26.90	28.50	14.97	0.47
<i>Litsea</i> sp. 2	PF	50.00	28.30	9.86	0.13
<i>Litsea</i> sp. 3	YSF	25.00	28.80	10.09	0.66
<i>Litsea</i> sp. 4	YSF	25.00	28.30	10.10	0.63
<i>Litsea</i> sp. 5	AF	16.80	28.70	15.32	0.77
<i>Macaranga caladiifolia</i>	AF	66.40	39.60	13.08	0.04
<i>Macaranga gigantea</i>	AF	17.00	29.10	14.57	0.79
<i>Macaranga</i> sp.	PF	50.00	28.30	9.86	0.13
<i>Mallotus repandus</i>	YSF	20.30	34.80	18.06	0.74
<i>Mallotus</i> sp.	AF	12.60	29.00	15.16	1.00
<i>Mangifera graffithii</i>	AF	33.30	28.30	9.96	0.36
<i>Mangifera griffithii</i>	OSF	20.00	28.40	9.79	1.00
<i>Mangifera pajang</i>	AF	33.30	28.30	9.96	0.36
<i>Mangifera</i> sp. 1	AF	20.10	29.80	15.30	0.70
<i>Mangifera</i> sp. 2	AF	33.30	28.30	9.96	0.36
<i>Mangifera</i> sp. 3	AF	33.30	28.30	9.96	0.36
<i>Mangifera torquenda</i>	AF	23.80	29.40	15.66	0.58
<i>Melastoma polyanthum</i>	YSF	25.00	28.70	10.13	0.64
<i>Memecylon</i> sp. 1	OSF	39.30	37.90	16.80	0.38
<i>Memecylon</i> sp. 2	PF	40.10	31.00	17.16	0.20
<i>Mesua ferrea</i>	PF	50.00	28.30	9.86	0.13
<i>Mesua</i> sp.	OSF	22.30	30.00	15.96	0.66
<i>Microcos</i> sp.	YSF	25.00	28.30	10.10	0.63
<i>Myristica</i> sp.	PF	50.00	28.30	9.86	0.13
<i>Nauclea</i> sp.	OSF	37.80	32.30	14.73	0.27
<i>Nephelium cuspidatum</i>	PF	23.80	28.40	15.08	0.58
<i>Nephelium lappaceum</i>	AF	22.60	28.70	14.45	0.58
<i>Nephelium maingayi</i>	AF	14.40	30.40	16.08	0.92
<i>Nephelium ramboutan-ake</i>	AF	55.90	33.40	17.15	0.11
<i>Norrisia major</i>	OSF	51.50	35.60	13.88	0.14
<i>Ochanostachys amentacea</i>	OSF	34.80	32.10	15.15	0.34
<i>Octomeles sumatrana</i>	OSF	20.00	28.40	9.79	1.00
<i>Ormosia bancana</i>	OSF	20.00	28.70	10.13	1.00
<i>Palaquium gutta</i>	PF	38.20	37.50	11.37	0.44
<i>Palaquium obovatum</i>	AF	51.30	29.80	16.35	0.11
<i>Palaquium</i> sp. 1	OSF	20.00	28.20	9.70	1.00
<i>Palaquium</i> sp. 2	YSF	25.00	28.80	10.09	0.66

Appendix 8 continued

Species	Forest Types	Observed Indicator Value	Indicator Value for Randomized Group		Significance Value (p < 0.05)
			Mean	SD	
<i>Pangium edule</i>	OSF	20.00	28.70	10.13	1.00
<i>Parastemon urophyllus</i>	PF	37.90	31.20	17.00	0.23
<i>Parkia speciosa</i>	AF	66.70	31.60	16.01	0.06
<i>Pellacalyx lobbii</i>	AF	34.20	31.90	15.22	0.33
<i>Pentaspadon motleyi</i>	YSF	25.50	36.10	12.40	0.77
<i>Pentaspadon</i> sp.	AF	33.30	29.00	10.35	0.37
<i>Pimelodendron griffithianum</i>	YSF	17.40	29.20	15.74	0.80
<i>Pimelodendron</i> sp.	YSF	40.30	37.10	13.17	0.31
<i>Ploiarium alternifolium</i>	AF	15.90	29.30	15.90	0.82
<i>Polyalthia cauliflora</i>	YSF	25.00	28.30	10.10	0.63
<i>Polyalthia</i> sp.	OSF	37.80	34.70	16.12	0.32
<i>Pometia pinnata</i>	OSF	19.90	36.60	16.18	0.89
<i>Psychotria viridiflora</i>	YSF	27.80	30.50	16.22	0.40
<i>Pterospermum</i> sp.	YSF	25.00	28.30	10.10	0.63
<i>Santiria</i> sp.	YSF	25.00	28.30	10.10	0.63
<i>Sarcotheca</i> sp.	YSF	25.00	28.30	10.10	0.63
<i>Saurauia acuminata</i>	OSF	13.50	31.80	15.08	0.98
<i>Rubroshorea beccariana</i>	AF	29.90	34.80	17.04	0.56
<i>Rubroshorea bullata</i>	OSF	20.00	29.00	10.28	1.00
<i>Rubroshorea coriacea</i>	PF	18.70	30.20	15.97	0.78
<i>Rubroshorea curtisii</i>	OSF	20.00	28.30	9.90	1.00
<i>Rubroshorea macrophylla</i>	AF	44.00	39.00	17.85	0.30
<i>Rubroshorea macroptera</i>	OSF	15.10	30.80	16.34	1.00
<i>Rubroshorea palembanica</i>	YSF	25.00	28.30	10.10	0.63
<i>Rubroshorea stenoptera</i>	YSF	25.00	28.30	10.10	0.63
<i>Shorea ladiana</i>	PF	44.70	29.30	15.69	0.16
<i>Stemonurus</i> sp.	YSF	28.30	31.00	16.11	0.53
<i>Sterculia</i> sp.	OSF	20.00	28.30	9.90	1.00
<i>Strombosia ceylanica</i>	YSF	25.00	28.30	10.10	0.63
<i>Symplocos</i> sp.	AF	33.30	28.30	9.96	0.36
<i>Syzygium arcuatinervium</i>	YSF	25.00	28.30	10.10	0.63
<i>Syzygium jambos</i>	YSF	25.00	28.80	10.09	0.66
<i>Syzygium kunstleri</i>	PF	42.30	40.40	10.28	0.40
<i>Syzygium leucoxylon</i>	OSF	41.40	39.20	9.22	0.43
<i>Syzygium monticola</i>	PF	31.10	36.00	15.44	0.52
<i>Syzygium polyanthum</i>	YSF	25.00	28.30	10.10	0.63
<i>Syzygium sarawakensis</i>	YSF	25.00	28.30	10.10	0.63

Appendix 8 continued

Species	Forest Types	Observed Indicator Value	Indicator Value for Randomized Group		Significance Value (p < 0.05)
			Mean	SD	
<i>Syzygium</i> sp. 1	AF	33.30	28.30	9.96	0.36
<i>Syzygium</i> sp. 2	OSF	20.00	28.40	9.79	1.00
<i>Syzygium</i> sp. 3	OSF	20.00	28.20	9.70	1.00
<i>Syzygium</i> sp. 4	AF	33.30	28.30	10.06	0.34
<i>Syzygium</i> sp. 5	PF	50.00	28.30	9.86	0.13
<i>Syzygium</i> sp. 6	YSF	25.00	28.30	10.10	0.63
<i>Syzygium</i> sp. 7	PF	20.30	28.70	15.34	0.63
<i>Syzygium</i> sp. 8	AF	27.40	34.30	17.27	0.61
<i>Syzygium</i> sp. 9	AF	19.20	30.50	15.48	0.79
<i>Syzygium</i> sp. 10	YSF	19.00	28.50	14.49	0.74
<i>Syzygium</i> sp. 11	OSF	20.00	28.30	9.90	1.00
<i>Syzygium</i> sp. 12	YSF	25.00	28.80	10.09	0.66
<i>Syzygium</i> sp. 13	YSF	14.90	28.80	15.97	0.89
<i>Syzygium</i> sp. 14	YSF	25.00	28.80	10.09	0.66
<i>Syzygium</i> sp. 15	OSF	20.00	28.40	9.79	1.00
<i>Talauma</i> sp.	YSF	50.00	29.00	15.04	0.10
<i>Theobroma cacao</i>	AF	33.30	28.30	9.96	0.36
<i>Timonius lasianthoides</i>	YSF	49.10	39.60	13.08	0.26
<i>Timonius</i> sp.	OSF	20.00	28.20	9.70	1.00
<i>Trema occidentalis</i>	YSF	25.00	28.70	10.13	0.64
<i>Tristaniaopsis whiteana</i>	OSF	15.70	32.90	16.29	0.92
<i>Turpinia sphaerocarpa</i>	AF	34.60	32.40	14.79	0.35
<i>Upuna borneensis</i>	OSF	20.00	29.00	10.28	1.00
<i>Urophyllum</i> sp.	AF	35.60	34.50	14.79	0.37
<i>Vatica</i> sp.	PF	50.00	28.60	10.33	0.15
<i>Vernonia arborea</i>	YSF	24.10	36.00	15.36	0.78
<i>Vitex pubescens</i>	YSF	43.40	33.90	14.41	0.23
<i>Whiteodendron moultonianum</i>	AF	33.30	29.00	10.35	0.37
<i>Xanthophyllum amoenum</i>	PF	31.20	31.90	16.63	0.39
<i>Xanthophyllum</i> sp. 1	PF	27.30	28.40	15.38	0.43
<i>Xanthophyllum</i> sp. 2	AF	33.30	28.30	10.06	0.34
<i>Xylopia ferruginea</i>	AF	31.20	34.50	14.72	0.49
Unknown 1	AF	33.30	28.30	9.96	0.36
Unknown 2	AF	33.30	28.30	9.96	0.36
Unknown 3	AF	21.10	28.50	14.68	0.55
Unknown 4	OSF	23.20	30.10	16.11	0.60

Appendix 8 continued

Species	Forest Types	Observed Indicator Value	Indicator Value for Randomized Group		Significance Value (p < 0.05)
			Mean	SD	
<i>Unknown 5</i>	AF	33.30	28.30	9.96	0.36
<i>Unknown 6</i>	OSF	20.00	28.20	9.70	1.00
<i>Unknown 7</i>	PF	50.00	28.60	10.33	0.15
<i>Unknown 8</i>	OSF	20.00	28.20	9.70	1.00
Averages		33.94	31.28	12.87	0.50

* proportion of randomized trials with indicator value equal to or exceeding the observed indicator value.

$p = (1 + \text{number of runs} \geq \text{observed}) / (1 + \text{number of randomized runs})$

PF – Primary forest, OSF – Old secondary forest, YSF – Young secondary forest, AF – Agroforest

Journal Publications

1. **Nelson, J.**, Noweg, G.T., & Ismail, J. (2022). Potential of *Trichoderma* and AMF mixture with different types of fertiliser for *Durio zibethinus* Murray (Durian) and *Artocarpus heterophyllus* Lam. (Jackfruit) growth. *Borneo Journal of Resource Science and Technology*, 12(1): 73-80. DOI: <https://doi.org/10.33736/bjrst.4495.2022>
2. **Nelson, J.**, Noweg, G.T., Ismail, J., Philip, B., Tuen, A.A., & Judi, S. (2022). The diversity of native tree species from Bung Jagoi community forests, Bau, Sarawak and their potential for reforestation. *International Journal of Environmental Studies*, 80(1):51-67. DOI: 10.1080/00207233.2022.2044696
3. **Nelson, J.** & Noweg, T. (2021). Assessment of forest regeneration following a series of disturbances in two types of primary forest at Bungo Range, Bau, Sarawak. *Journal of Tropical Forest Science* 33(2): 126-136. DOI: <https://doi.org/10.26525/jtfs2021.33.2.126>