SEED DENSITY, SEED GERMINATION PERFORMANCE ON VARIOUS SUBSTRATES AND THE EFFECTS OF IBA (INDOLE-3-BUTYRIC ACID) ON STEM CUTTING OF *Eucalyptus pellita*

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SEED DENSITY, SEED GERMINATION PERFORMANCE ON VARIOUS SUBSTRATES AND THE EFFECTS OF IBA (INDOLE-3-BUTYRIC ACID) ON STEM CUTTING OF *Eucalyptus pellita*

by

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LIST OF SYMBOLS

%	Percentage
α	Alpha
<	Less that
>	More that
=	Equal to
cm	Centimetre
sin	Sine
√	Square root

LIST OF ABBREVIATION

ANOVA	Analysis of variances
BILT	Ballarpur Industries Limited
BTTL	BILT Tree Tech Ltd.
CRD	Complete Randomised Design
IAA	Indole-3-acetic acid
IBA	Indole-3-Butyric Acid
HSD	Honest Significant Difference
ISTA	International Seed Testing Association
LVL	laminated-veneer-lumber
PPM	Parts per million
R&D	Research and Development
SFI	Sabah Forest Industries Sdn. Bhd.
USDA	United States Department of Agriculture

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UJIAN BERAT BIJI BENIH, KEBOLEHUPAYAAN PERTUMBUHAN BIJI BENIH DAN KESAN *IBA (INDOLE-3-BUTYRIC ACID)* KE ATAS KERATAN BATANG *Eucalyptus pellita*

ABSTRAK

Objektif utama kajian ini adalah untuk memperkenal teknik penghasilan biji benih yang boleh dipraktikkan oleh komuniti setempat untuk menyokong industri berasaskan spesies *Eucalyptus* di Malaysia. *Eucalyptus* spp. termasuklah *E. pellita* adalah faktor utama kepada beberapa industri seperti industri penghasilan kertas dan perabot sama ada di dalam negara mahupun di peringkat antarabangsa. Namun, faktor kualiti kayu dan sumber bekalan dalam negara yang tidak cukup serta kawasan yang terhad untuk penanaman spesies ini menyebabkan Malaysia mengimport kayu dan pulpa dari negara jiran dengan kos yang tinggi. Oleh yang demikian, Malaysia perlu mengambil inisiatif dengan mempromosi kayu *Eucalyptus* yang ditanam di dalam negara. Kajian pertama di dalam tesis ini adalah berkaitan penilaian ke atas teknik penghasilan biji benih *E. pellita* di tiga tempat di Malaysia (SFI Sdn. Bhd., Samling Group Sarawak dan Hok Lai Timber Sdn Bhd/ Jabatan Perhutanan Perak). Hasil tinjauan mendapati, hanya SFI dan Samling Group Sarawak didapati menghasilkan anak pokok *E. pellita* menggunakan teknik percambahan menggunakan biji benih tempatan dan teknik keratan batang. Manakala Hok Lai Timber telah mengguna teknik percambahan biji benih *hibrid Eucalyptus* menggunakan biji benih yang diimport untuk menghasilkan anak pokok untuk tujuan di peringkat kajian. Kajian juga merangkumi tiga lagi objektif kajian ialah untuk menguji percambahan biji benih *E. pellita* menggunakan lima berat bijih benih berbeza di media sabut kelapa, menguji

percambahan biji benih meggunakan lima substrat berbeza dan objektif terakhir adalah menguji keberkesanan formulasi hormon pengakaran campuran ke atas keratan batang *E. pellita* menggunakan lima sukatan IBA (Indole-3-Butyric Acid) yang berbeza. Kesemua ujikaji di atas adalah menggunakan *Complete Randomised Design (CRD)* sebagai rekabentuk eksperimen dan Analisis Varians Satu Hala sebagai alat penganalisis ujikaji. Keputusan analisis dari ujikaji menggunakan berat biji benih menunjukkan keputusan yang tidak signifikan atau tiada perubahan ketara. Ini dapat disahkan bahawa berat biji benih *E. pellita* tidak mempengaruhi jumlah percambahan dan aplikasi berat spesifik semasa penanam biji benih adalah tidak diperlukan. Ujikaji Substrat ke atas percambahan biji benih *E. pellita* menunjukkan Hampas Padi tidak boleh digunakan sebagai substrat kerana tiada sebarang percambahan direkodkan manakala analisis ke atas empat lagi substrat menunjukkan keputusan tidak signifikan. Ujikaji yang terakhir menunjukkan analisis ANOVA yang tidak menunjukkan perubahan ketara seterusnya mengesahkan IBA tidak memberi kesan yang ketara terhadap pertumbuhan akar keratan batang *E. pellita*. Keratan batang *E. pellita* boleh berakar dengan atau tanpa IBA atau hormon pengakaran di dalam ekperimen ini. Kesimpulan utama kajian ini ialah penghasilan anak pokok menggunakan biji benih dan keratan batang *E. pellita* adalah sesuai dipraktikkan oleh komuniti setempat memandangkan teknik tersebut adalah mudah dan biasa digunakan di industri berasaskan *Eucalyptus* pada masa kini di Malaysia.

SEED DENSITY, SEED GERMINATION PERFORMANCE ON VARIOUS SUBSTRATES AND THE EFFECTS OF IBA (INDOLE-3-BUTYRIC ACID) ON STEM CUTTING OF *Eucalyptus pellita*

ABSTRACT

The main objective of this research is to propose a seedling production technique to be applied by the local community to support the *Eucalyptus pellita*-based industry in Malaysia. *Eucalyptus* spp. which includes *E. pellita* is a key plant to several industries such as the paper and furniture industries, both for local and global use. However, issues related to wood quality and limited supply of *Eucalyptus* wood and limited industrial plantation land to plant *Eucalyptus* are forcing industries in Malaysia to import wood and pulp supply from neighbouring countries which can be very costly. To overcome these problems, one of the key initiatives taken by the Malaysian government is to promote the plantation of more locally grown *Eucalyptus* trees. The study was first carried out to assess the seedling production technique of *E. pellita* by using the seed planting and stem cutting techniques in Malaysia carried out at three different locations (SFI Sdn. Bhd., Samling Group Sarawak and Hok Lai Timber Sdn Bhd/ Perak Forestry Department). The investigation showed that SFI and Samling used local seeds and stem cuttings of *E. pellita* for seedling production while Hok Lai Timber in Perak used imported *Eucalyptus hybrid* seeds to produce seedlings for the trial. The study was also carried out to meet three other objectives which are to test seed germination of *E. pellita* by using five different seed densities in cocopeat media, to assess seed germination performance in five different types of substrates, and to assess the effectiveness of the formulated rooting hormone mix on *E. pellita* stem cuttings by using

different levels of IBA (Indole-3-Butyric Acid) measurement. All three tests stated above used the Complete Randomised Design (CRD) as the experimental design and One-Way ANOVA as the analysis tool. Analysis of results generated from seed density tests showed an insignificant result. This confirms that seed density does not affect germination result, and that specific seed density application is not required during seed sowing. The substrate tests for seed germination showed that rice husk substrate was unusable since no germination took place while the other substrates showed no significant result. The third test displayed an insignificant ANOVA result which confirms that IBA did not have any significant effect on root growth of *E. pellita* stem cuttings. The stem cuttings can grow root with or without IBA or rooting hormone formula. The main conclusion of this study is that both *E. pellita* seed planting and stem cutting techniques are suitable to be practised by the local community as these techniques are easy and common in the current Malaysia industries.

CHAPTER 1

INTRODUCTION

The genus *Eucalyptus* is classified as flowering trees in the myrtle family, Myrtaceae (Govaerts et al. 2008; USDA, n.d). One particular species of this genus, namely *Eucalyptus pellita* is a well-known flowering tree for forest plantation (Orwa et al., 2009; World Agroforestry Centre, 2019). *Eucalyptus* species originate from Australia and nearby island (Liu & Li, 2010; Stanturf et al., 2013) and have been cultivated throughout the tropics and subtropics regions (Eucalyptus L'Her, 2009; Liu & Li, 2010; Stanturf et al., 2013; Sunset Western Garden Book, 1995). Similar to other families of the *Eucalyptus* species, *E. pellita* is native to Australia and Papua New Guinea (Harwood, 1998; World Agroforestry Centre, 2019). *E. pellita* is mostly planted in tropical areas (Burley & Barnes, 1989) and is one of the most planted Eucalypt species worldwide (Harwood, 2011). *E. pellita* is suitable to grow in a warm, humid and high rainfall area (Bristow, 2011; Hardwood, 1998). It prefers moist sites with soil conditions that vary from shallow sands on sandstone ridges to shallow sandy podsols (Queensland) and deep forest loams soil condition (Bristow, 2011; Hardwood, 1998).

E. pellita produces about 764 - 960 kg-1 m-3 basic stand density from natural stands, medium or tall sized tree, has a straight trunk to about half the tree height, and a large heavily branched crown and beautiful dark-red timber that can be used for flooring and appearance grade uses (Bootle, 1983; Boland et al., 1992; Brooker and Kleinig, 1994). The leaves of *E. pellita* is alternate, petiolate, usually tapered to a long, fine point, broad-lanceolate to lanceolate, 10-15 x 2-4 cm, strong green colour. The fruits is shortly

pedicellate, hemispherical to obconical, often slightly ribbed, 7-14 x 7-17 mm, disc broad, more or less level with valves usually 4. The Inflorescence flower is simple, axillary, usually 7 flowered with broad peduncles, flattened, 1-2.5 cm long. The flower pedicles occasionally absent, but usually stout, angular, 1-9 mm long obconical hypanthia buds, usually with ribs continuing from the angular pedicles, 9-21 x 6-12 mm and the operculum shape is very variable, generally rostrate and about 1-1.5 times the length of the hypanthium (Orwa et al., 2009).

Economically, *Eucalyptus* species is important in pulp and paper industries. It is used as charcoal and fuelwood for domestic use apart from being used as solid wood for some products (Maile & Nieuwenhuis, 1996; McNabb, K. 2002). Nowadays, *Eucalyptus* spp. is not only used for pulp and paper making, but also for the production of pesticides (Batisha et al., 2008). It is also used as a condiment or spice and in medicines as antimicrobial/insecticidal agents to repel insect or protect stored products (Bakkali et al., 2008, Dorman & Deans, 2000; Isman & Machial, 2006). Nowadays, *E. pellita* is not only popular as furniture, particleboard, flooring, tool handles, boat building, and in pulp and paper industries (Yusoff et al., 2013) but also in other industries such as plywood production, solid wood processing, and laminated-veneer-lumber (LVL) production (Hii et al., 2017).

In order to provide an ample supply of seedlings for commercial plantations, suitable techniques to produce healthy and good quality seedlings must be applied. However, currently, the industries involved in commercial forest plantation are facing significant problems due to insufficient seedling supply and lack of suitable germination techniques to produce good quality *E. pellita* seedlings. This situation would create a significant gap

in the whole process of the forest plantation industry and would affect the subsequent industries linking to timber products.

Thus, ensuring a stable supply of seedlings is crucial, and one of the sources of seedling production is through successful seed germination. Germination is defined as the emergence and development from the seed embryo of those essential structures which are indicative of the seed's capacity to produce a normal plant under favourable conditions (Justice, 1972; ISTA, 1976; Shepherd, 2012). Germinations of *Eucalyptus sp.* seeds are usually conducted in a laboratory using petri dishes filled with moist substrate as practised by the Australian Tree Seed Centre (Gunn, 2001). Several studies (Gasparin et al., 2013; Mamani et al., 2018; Yerima et al., 2015) have been conducted on seed germinations using various substrates other than the moist paper substrate, and findings showed that seeds of each plant species presented a variable degree of performance when subjected to different substrates (Mondo et al., 2008). Seed germination test is a compulsory step before the seed can be used in plantation activity in proper plantation practices (de Melo et al., 2015). Seeds need to be tested for germination to determine their performance as this is also required for labelling and marketing purposes and to determine if a seed lot has been properly labelled when it is sold or offered for sale (Elias et al., 2012). Of all the quality measurements of seed lots, seed germination is the most important stage (Bonner, 1974; Wilan, 1987).

This study intended to explore the possible variations of seed germination performance of *E. pellita* so that in a long run, a stable supply of seedlings and saplings for the industry can be created. In addition, it provides an additional source of income for small nursery owners. The specific research questions to be addressed in this study are:

i. To evaluate seed density and seed germination performance on various substrates, and

ii. To evaluate the effects of IBA (indole-3-butyric acid) on stem cutting of *Eucalyptus pellita*.

1.1 Objectives

The general objective of this study was to propose the most suitable seedling production technique to be applied by the local community to support the *E. pellita*-based industries by introducing the seed germination and stem cutting techniques. The specific objectives of this study are:

i. To assess the seedling production technique of *E. pellita* in Malaysia,

ii. To test seed germination of *E. pellita* by using five different densities~~,~~

iii. To assess seed germination performance in five different types of substrates, and

iv. To assess the effectiveness of the formulated rooting hormone mix on *E. pellita* stem cutting root growth by using different levels of IBA (Indole-3-Butyric Acid).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction of *E. pellita* and Its Uses

Similar to other families of the *Eucalyptus species*, *E. pellita* is a native origin to Australia and Papua New Guinea (Harwood, 1998; World Agroforestry Centre, 2019). *E. pellita* is mostly planted in tropical areas (Burley & Barnes, 1989) and is one of the most planted Eucalypt species worldwide (Harwood, 2011). *E. pellita* grows suitably in warm, humid and high rainfall area (Bristow, 2011; Hardwood, 1998). It prefers moist sites with soils conditions that vary from shallow sands on sandstone ridges to shallow sandy podsols (Queensland) and deep forest loam soil condition (Bristow, 2011; Hardwood, 1998). Compared to other eucalypts investigated in these warm humid regions, *E. pellita* is easily propagated (Harwood, 1998) and has fast early growth in plantations (Sun et al., 1996; Harwood et al., 1997a; Annandale & Keenan, 2000; Bristow et al., 2005b; Bristow et al., 2006b). It also receives relatively minor damage from pests and diseases. *E. pellita* produces a valuable dark-red timber with a basic density from natural stands about 764 - 960 kg^{-1} m^{-3} that can be used for flooring and appearance grade uses (Bootle, 1983; Boland et al., 1992; Brooker & Kleinig, 1994).

Eucalyptus spp. is important in pulp and paper industries, and it is also used as charcoal and fuelwood for domestic use as well as raw materials for some solid wood products (Maile & Nieuwenhuis, 1996; McNabb, 2002). Nowadays, *Eucalyptus sp*. is used not only in pulp and paper making but also in the making of pesticides (Batisha et al., 2008); it is also used as a condiment or spice and in medicines, as antimicrobial/insecticidal agents

to repel insect or protect stored products (Bakkali et al., 2008, Dorman & Deans, 2000; Isman & Machial, 2006). *E. pellita* nowadays is not just popular for furniture, particleboard, flooring, tool handles, boat building, pulp and paper industries (Yusoff et al., 2013) but also in other industries such as plywood production, solid wood processing and laminated-veneer-lumber (LVL) production (Hii et al., 2017).

2.2 *Eucalyptus species* planting history, locally and globally

Tree improvement programmes in several places in Australia and South America involve *E. pellita* as one of the targets for hybridization activities (Yeni Widyana et al., 2011) since the species has good capability to breed with other species to form the combination of selected traits (Eldridge, 1993). The development of techniques for clonal (asexual) propagation of plants means that plantations in countries such as Brazil and India now consist largely of clonal plantations since seed sowing has been largely abandoned in these countries (Eldridge et al., 1994; Lal, 2010).

The planting of *Eucalyptus* spp. in Peninsular Malaysia started in 1893 with seeds from Queensland (FAO, 1979). The first species planted was *Eucalyptus robusta*. In subsequent years, various species were planted as ornamentals by the British colonizers at hill stations in the early 1920's (Freezaillah et al., 1966). The earliest recorded introduction of *Eucalyptus spp.* by the Forestry Department was in 1927 when seeds of *Eucalyptus deglupta* were obtained from New Guinea (Freezaillah et al., 1966). Plantations of various *Eucalyptus* were established at the Forest Reserves in Cameron Highlands between 1931 and 1941 for timber and fuelwood production (Freezaillah et al., 1966). The Eucalyptus planting and research initiative is not come to an end in Peninsular

Malaysia after several research was failed previously. The Forest research institute of Malaysia (FRIM) was initiative more research on the Eucalyptus species including *E.pellita*. Recent project Collaboration between FRIM and Plus Intervest Sdn Bhd started from 2016 and then with Malaysian Panel-Products Manufacturers' Association (MPMA) from 2019 which aims to produce tissue culture plants of *Eucalyptus sp*. and high value commercial species for plantations including producing tissue culture protocols for *Eucalyptus hybrid* and *E. pellita* for production of planting materials of the community plantation programme not only by the timber industry but also by the plantation industry and local communities (Forest Research Institute Malaysia, 2020). The collaboration is important since it aim to reduce the dependence on resources from the natural forest. Another field research also was conducted at Hulu Sedili Forest Reserve, Kota Tinggi, Johor by Ahmad, Z.Y et al (2020), to compare the early growth performance of plantation–grown *Eucalyptus hybrid* and *E. pellita* where in 18 months, the *E. hybrid*, originating from Southern China outperformed *E. pellita* in both diameter and height growth (Ahmad, Z.Y et al.,2020).

In Sabah, Sabah Softwoods Sdn. Bhd. introduced *Eucalyptus deglupta*, together with other species in 1974 (Tan, 1987). This afforestation project covered an area of 61,000 ha of logged over forest in Tawau Residency for pulpwood and timber production. However, the growth rate of *Eucalyptus deglupta* appeared to be generally much lower in comparison to *Gmelina arborea*, *Paraserianthes falcataria* and *Acacia mangium*. Consequently, further planting of *E. deglupta* was stopped in 1982. In 1979, the Forestry Department tested Eucalyptus as a plantation species on about 0.4 ha of land in Sarawak (Kendawang, 1992). Currently, plantations in Sabah, Sarawak and Peninsular Malaysia

have started to actively plant *Eucalyptus* sp. due to demands in pulp, paper and other products.

2.3 Seed handling and germination test for *Eucalyptus species* seeds

Seed handling encompasses several procedures beginning with the selection of the best quality seed source, followed by the collection, processing, storage, and pre-treatment process prior to germination (Schmidt, 2000). *Eucalyptus* sp. seed germination is usually conducted in a laboratory using petri dishes filled with a moist substrate as practiced by the Australian Tree Seed Centre (Gunn, 2001). Seed germination test is a compulsory step before the seed can be used in a plantation activity in proper plantation practices (de Melo et al., 2015). Seeds need to be tested for germination to determine their performance, and this is also needed for labelling and marketing purposes and to determine if a seed lot has been properly labelled when sold or offered for sale (Elias et al., 2012).

Of all the quality measurements of seed lots, seed germination test is the most important stage (Bonner, 1974; Wilan, 1985). Germination is defined as the emergence and development from the seed embryo of those essential structures which are indicative of the seed's capacity to produce a normal plant under favourable conditions (Justice, 1972; ISTA, 1976; Shepherd, 2012). Seed germination test on selected substrates is not only useful for germination purposes, but also useful for nursery mortality expectation assessment. A quick review on the existing literature shows that several research such as by Gasparin et al. (2013), Mamani et al. (2018), and Yerima et al. (2015) had been carried out on seed germination using various substrates other than the moist paper substrate to obtain various

objectives. Seeds of each plant species presented discriminated performance when subjected to different substrates (Mondo et al., 2008).

2.4 Stem Cutting of *Eucalyptus species*

In the Eucalypt plantation industry, the three popular methods in seedling production in a nursery are seed germination, stem cutting (macro-propagation) and tissue culture (micro-propagation). Large scale industries prefer either the tissue culture technique or the stem cutting technique, also known as vegetative propagation, rather than the seed germinate technique. Of these two techniques, the stem cutting method is the most widely used technique in Eucalypt propagation as this technique is easier to handle compared to the micro propagation technique (Sulichantini et. al., 2014).

Vegetative propagation of eucalyptus is preferred because it conserves valuable germplasm and offers predictability in commercial plantations (Jain & Nakhooda, 2016). In contrast, establishing a eucalypt plantation through the seed germination technique is risky since there is a huge possibility of unsuitable provenance and undesirable genetics (Eldridge et al., 1994) which may lead to slow growth rate and poor timber (Jain & Nakhooda, 2016). In addition, irregular flowering and high abortion rates have been observed in this technique (Eldridge et al., 1994; Gardner et al., 2016) which lead to unreliable and often limited seed supply (Hung & Trueman, 2011). Unlike vegetative propagation, propagation by seed is a relatively slower process for plantation practices as the trees need to reach maturity before they are able to produce seeds (Jain & Nakhooda, 2016).

CHAPTER 3

SEEDLING PRODUCTION TECHNIQUE OF *E. PELLITA* IN MALAYSIA

3.1 Introduction

Established methods are available for seed management, raising seedlings, nursery management, establishment techniques, management of coppice crops, farm plantation, and even several possible breeding strategies for *Eucalyptus* trees including *E. pellita* (FAO, 1981). Cutting and tissue cultures are the two types of breeding strategies, and these techniques take an important role in eucalypt plantations (Haizhong, 1983). Tree breeding and management measures are viewed as the two important measures to solve the problem of low yield in China (Jiayu & Siming, 1996). In India, the atmosphere for eucalypt planting was congenial as foresters, scientists, and workers contributed to the concept that eucalypt is a suitable species to be planted in degraded forests, barren lands, and marginal private lands (Palanna, 1996).

3.1.1 Objective

The objective of this investigation was to assess the seedling production technique of *E. pellita* in Malaysia in three locations—Peninsular Malaysia, Sabah and Sarawak.

3.2 Materials and Methods

3.2.1 Area Selection

The three selected places for the study are located in Peninsular Malaysia, Sabah and Sarawak. The selection of these places was determined based on the following criteria:

i. The location is a legitimate *E. pellita* or any *Eucalyptus* species plantation.

ii. The location is producing *E. pellita* or any *Eucalyptus* species seedlings.

iii. The management is able to disclose the method used to produce seedlings for their plantation.

iv. The plantation is industrial based.

The previous experience working at a plantation also influenced the selection of the places. Based on the visits to potential plantations, the three locations were selected as they were the most active plantations for *E. pellita* and *E.* species. Below are the details of the selected sites.

Sabah - Sabah Forest Industries Sdn. Bhd. (Visited on 7 March 2017)

Sabah Forest Industries (SFI) is one of Malaysia's largest timber growers and wood processors. It is located in Sipitang, Sabah, West Malaysia (Figure 3.1). It manages a forest estate of about 288,000 hectares, pulp and paper manufacturing facilities, and an integrated timber complex consisting of a saw mill and a veneer and plywood factory (Wooff, 2012). Wood for SFI's manufacturing processes comes mainly from woods harvested from the forests which it manages. These consist of two areas of government owned forest reserve for which SFI holds licences that are valid until 2095 and two parcels of land (Wooff, 2012). During the research visit, the main nursery of SFI (N 5° 1' 55.1064", E 115° 31' 41.7072") and compartment L41 in Mendulong area (4º 54' 56.5" N; 115º 42'. 27.6" E) of Sabah Forest Industries were selected for the one-day assessment of the nursery, R&D nursery, and Eucalyptus plantation area at SFI plantation.

According to the World Weather Report (2021), temperature in Sipitang, where the main nursery and SFI office are located, ranged between 22° C and 33° C (2010-2020) and rainfall ranging between 48.08 mm and 910.4 mm per day (2010-2020). The altitude of Sipitang is 6 metres. Meanwhile, the annual rainfall for one of SFI sections known as the Mendulong Station or L41 is approximately 3,757 mm (SFI, 2015). This is where the R&D nursery, office and some plantations are located. According to Kee et al. (2017), the maximum and minimum temperatures for Mendulong (compartment L41) range between 17° C and 30° C, and the elevation of the compartment is approximately 415 m above the sea level (altitude). The L41 area covers 183,316 ha of plantation, and until 2016, most of the plantation was planted with the *Acacia mangium* species of about 661.29 ha (Kee et al., 2017). According to SFI 2011 report, clonal trials of *E. hybrid* existed around the Mendulong area (see Figure 3.2). The clonal trials were planted at compartment P29 (1100 m altitude), compartment L14 (300 m altitude), compartment P14 (800 m altitude) and compartment P28 (1100 m altitude). All of the clonal trials successfully reached 6 to 15 months in 2011. The report also mentioned that *Eucalyptus* clones could be successfully planted on the ground at any height at sea level.

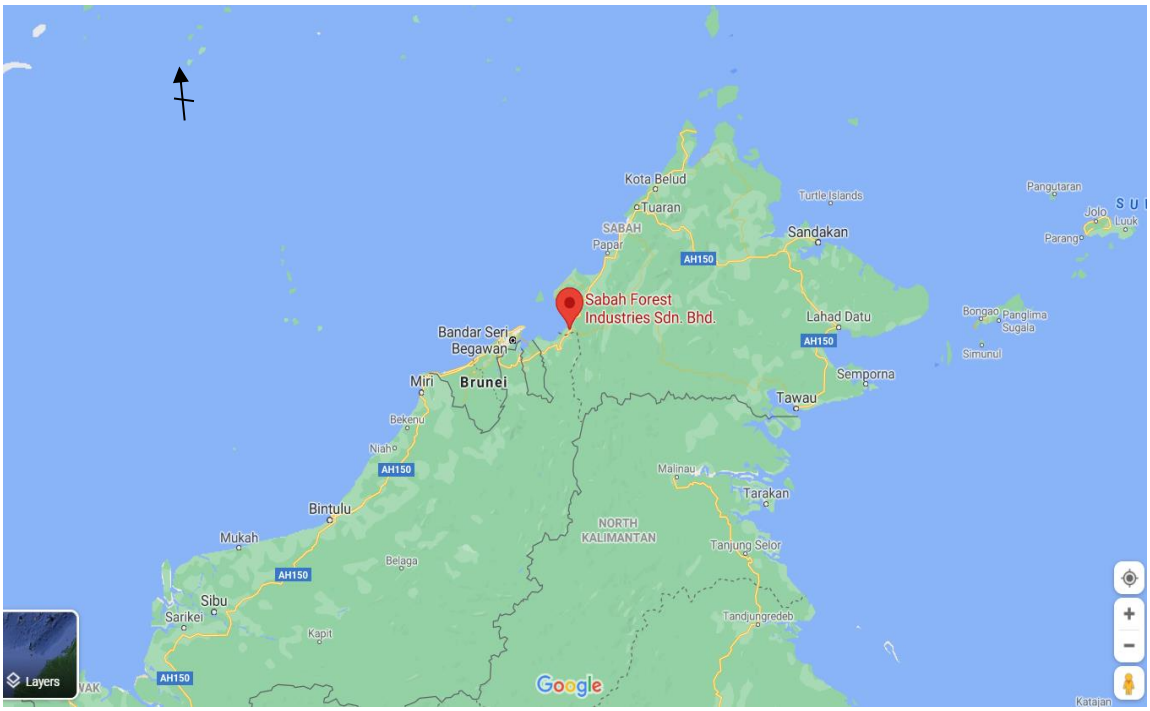

Figure 3.1 Sabah Forest Industries Sdn. Bhd. main office and nursery in Sipitang, Sabah, Malaysia viewed using Google Maps

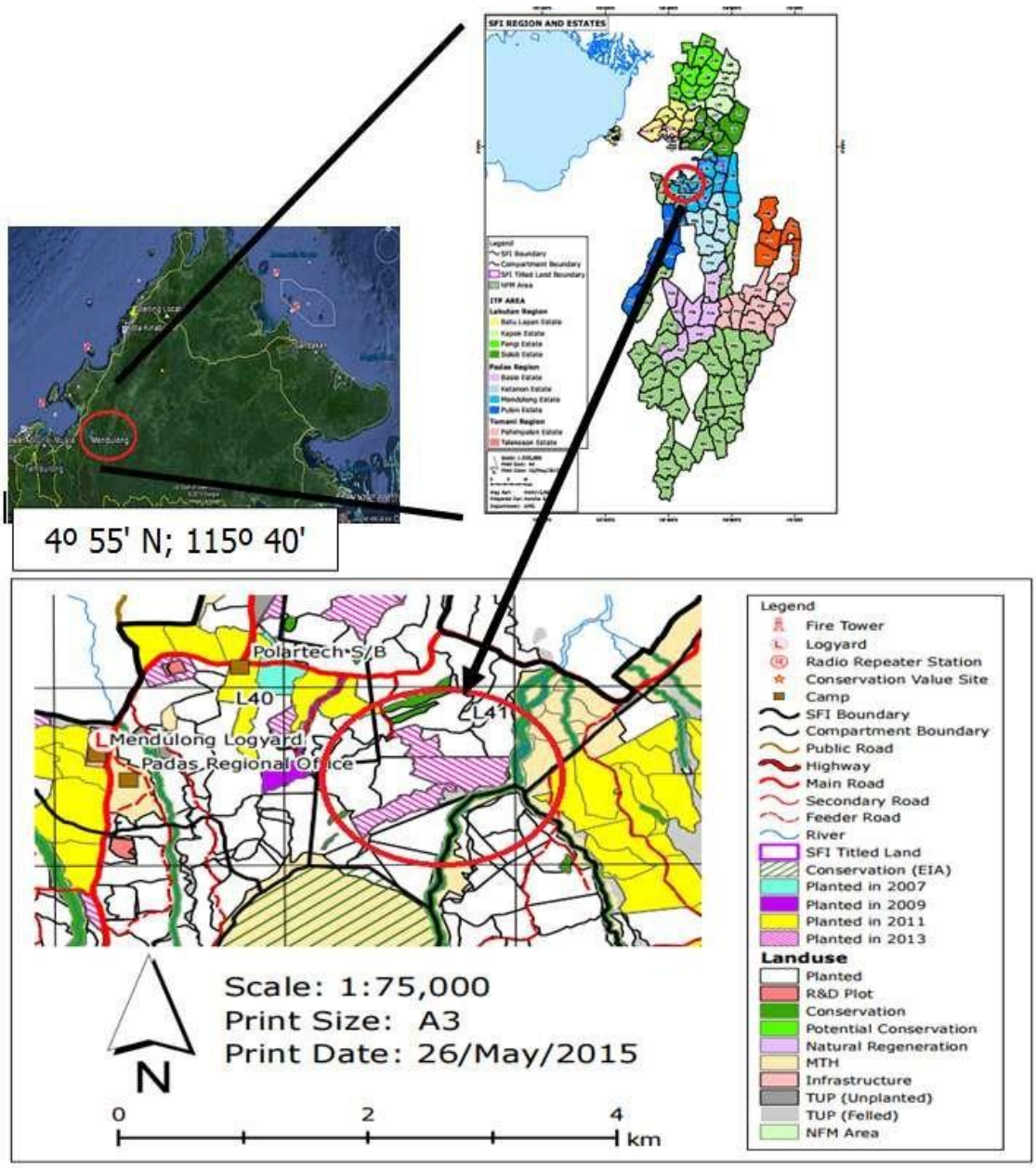

Figure 3.2 Mendulong estate location map in 2015 (Kee et al., 2017)

The research visit was conducted on 7 March 2017, and the plantation nursery and Eucalypt plantation at Mendulong station and SFI main nursery were visited. Figures 3.3 to 3.6 display the photographs taken during the visit to the nursery site and field planting of *E. pellita*.

Figure 3.3 4-week old *E. pellita* seedlings (produced using seed germination technique) at SFI nursery plantation which are ready to be transferred to the ground

Figure 3.4 5-10-week old *E. pellita* seedlings (produced using the stem cutting technique) at SFI R&D nursery plantation which are ready to be transferred to the ground

Figure 3.5 2-year old *E. pellita* at L41, around Mendulong station (produced using seed germination technique)

Figure 3.6 3-year old *E. pellita* at L41, around Mendulong station (produced using the stem cutting technique)

Sarawak - Samling Plantation Sdn. Bhd. (Visited on 21 February 2017)

Over the past 12 years, Samling has developed its own in-house expertise to manage Industrial Tree Plantation (ITPs) in Sarawak according to international best practices. Samling forest plantation is located in Bintulu, Sarawak, Malaysia where Samling operates as Segan Licensed Planted Forest (SEGAN) for ITPs, operating under a government licence (LPF/0014) held by Syarikat Samling Timber Sdn. Bhd. (SST) forestry and forest products manufacturing company. SEGAN was successfully audited for compliance with MTCS by SIRIM QAS International Sdn. Bhd. in December 2013 with SIRIM's Certificate for Forest Management (Forest Plantation) No. FPMC 0002 issued on 18 July 2014. Samling Reforestation (Bintulu) Sdn. Bhd. (SRB) is the contracting company engaged to undertake all reforestation work in SEGAN. SST and SRB are both members of the Samling Group with its headquarter in Miri, the largest city in the north of Sarawak, East Malaysia as shown in Figure 3.7. SRB and SST are jointly referred to here as Samling (Samling, 2018). Currently, 20,000 hectares have been planted with *Acacia mangium, Acacia hybrid, E. pellita, Gmelina arborea* and *Paraserianthes falcataria* (Samling, 2020).

In SEGAN Nursery where the assessment was conducted, species such *Eucalyptus* , *Acacia* and Dipterocarp (a local species) were planted and raised for reforestation planting programmes. The average annual rainfall recorded over the last 12 years at Segan nursery was 4,150mm (Samling, 2018). Rainfall ranged from as low as 2,948mm (2005) to as high as 4,943mm (2003) with an average rainy days of 16.6 rain days a month and 183 days a year which might affect operational costs (Samling, 2018). Figures 3.9 to 3.12 display the photographs taken at the site visit, SEGAN Samling Reforestation Bintulu.

Figure 3.7 SEGAN station, Samling Reforestation Sdn. Bhd., Bintulu office location viewed on Google Map

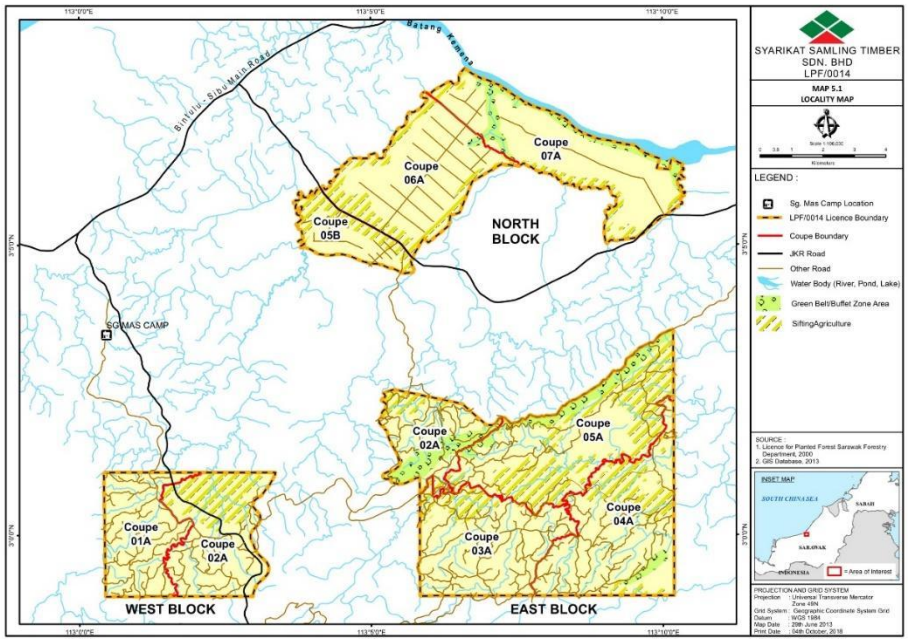

Figure 3.8 Locality map of SEGAN Industrial Tree Plantation in Bintulu (Samling, 2018)

Figure 3.9 Green house at Samling SEGAN plantation nursery where various species germination including *E. pellita* took place before the seedlings were placed under direct sunlight.

Figure 3.10 Mother plant of various species of Eucalypt including *E. pellita* and *E. hybrid* for stem cutting production

Figure 3.11 Plantation nursery for plants being moved from the greenhouse into direct sunlight, ready to be planted on the ground. Various species were placed here before being planted onto the ground.

Figure 3.12 *Eucalyptus* species plantation at LPF/0014 in Samling plantation (Bintulu) produced using seed germination technique in the greenhouse

Peninsular Malaysia - Perak Forestry Department: Tropical Forest (M) Sdn. Bhd. & Hok Lai Timber Sdn. Bhd. (Visited on 17 March 2017)

Tropical Forest (M) Sdn. Bhd. and Hok Lai Timber Sdn. Bhd. are two local companies operating under Perak Forestry Department. 200 ha of land in Bidor, Perak were given to Tropical Forest (M) Sdn. Bhd. by the Perak Forestry Department to plant *Eucalyptus* species under the permit issued by the department in 2009. The company was established in 1992 and experienced a rapid growth, from a small sawmill to one of the largest plywood, veneer, sawn timber and wood pellet suppliers and exporters in Malaysia (Hok Lai, 2020). The species used for the production of their products are from local species such as Gerutu, Pink Kedondong, Sepetir, Pelong, Nyatoh, Merpauh, Simpoh, Meranti Paasng, Jelutong, Kelempayan, Mersawa, Kasai, Penarahan, and Kedondong. Using exotic species for their products is not a common practice; however, during the visit to Hok Lai office, the representatives mentioned that the *Acacia* species and *Eucalyptus* species were under consideration. This is the reason for the trial to be conducted on the permitted area, namely KPT 63, 72 and 73 in Bidor which is located in Batang Padang District, Perak. Bidor is located on a 41m elevation, and similar to other places in Peninsular Malaysia, climate in Bidor is classified as tropical, and it receives a lot of rain even in the driest month (Climate-Data.org, 2021). The average temperature in Bidor is 26.0 °C with an annual rain of about 2921 mm. Data from World Weather Online (2021) showed that between 2010 and 2021, the lowest temperature in Bidor was recorded at 17°C while the highest temperature was 34°C. The lowest rainfall was 169 mm while the highest was 812 mm.

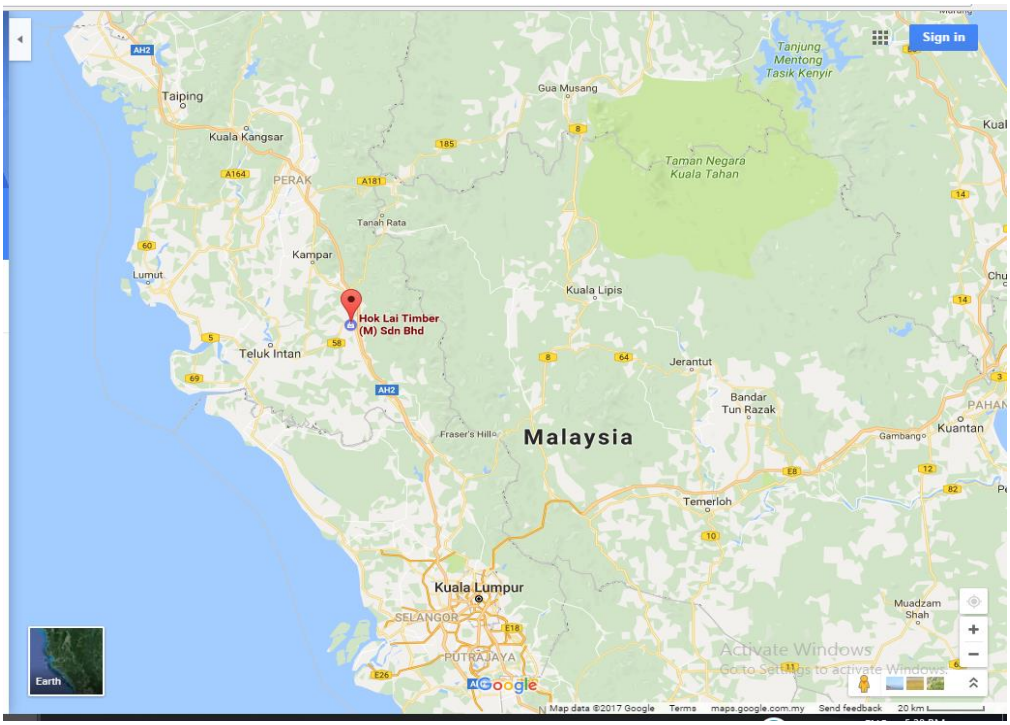

Figure 3.13 South Perak Forestry Department office and Hok Lai Timber Sdn. Bhd.

The purpose of the visit made on 17 March 2017 was to assess the plantation site. Seedlings at the plantation were grown through seed germination using seeds from China. During the visit, representatives from Hok Lai and Perak forestry informed that there was no *Eucalyptus* species or any seed planting activities being carried out at the nursery at that time. However, there was a trial area for *Eucalyptus* species that could be shown to the researchers. According to the rangers from Perak forestry department, Eucalyptus hybrid was planted in 2009, but the species died in 2011. Since then, the species is no longer being planted. The *Eucalyptus* species used for the trial conducted in the permitted area were reported as hybrid from various species; however, they died after a few months of planting

due to unknown reasons. Figure 3.14 and Figure 3.15 display the photographs taken during the site visit at Hok Lai plantation site.

Figure 3.14 Site where *Eucalyptus hybrid* that were supposed to grow died due to an unknown cause

Figure 3.15 *E. hybrid* that still survives around Hok Lai Timber office area

3.3 Findings

Sabah Forest Industries was established in 1982, and it is the biggest pulp and paper company in Malaysia with around 2000 workers including those in the paper mill and account for about 300 workers in the Forestry Department. Sabah Forest Industries Sdn. Bhd. (Sabah) applied the seed germination and stem cutting techniques for seedling production. These methods were not only applied to *E. pellita*, but also to other species such as *E. grandis*, *E. hybrid*, *Acacia Mangium*, and *Acacia hybrid.* Of the two methods, seed germination was the main method in seedling production. The *E. pellita* seeds were collected from SFI local seed orchards, and some were bought in from other companies in