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SEMINAR ON
RECLAMATION, REHABILITATION AND RESTORATION OF DISTURBED SITES: PLANTING OF NATIONAL AND IUCN RED LIST SPECIES

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POSTER

PRINCIPLES OF RESTORING TROPICAL FOREST ECOSYSTEMS AND OPPORTUNITIES FOR CONSERVING ENDEMIC, ENDANGERED AND THREATENED TREE SPECIES

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ABSTRACT

Restoring tropical forest ecosystems involves manipulating natural regeneration to achieve the maximum biomass, structure, biodiversity and ecological functioning that are possible within climatic and edaphic limitations. A nearby remnant of least-disturbed forest should be selected as the "target forest ecosystem" to set restoration goals and to provide a seed source. In the seasonally dry tropics, a regenerant[1] density of 3,086/ha is needed to initiate canopy closure within two years. If regenerants are present at higher densities and they are not suppressed by weeds, protection alone can achieve restoration. However, if herbaceous weeds suppress regenerants, protection must be complemented with weeding and/or fertilizer application (assisted natural regeneration, ANR). Where regenerant density < 3,086/ha, protection and ANR must be complemented with tree planting. Where incoming seed dispersal from remnant forest remains possible, only a few "framework tree species" need be planted i.e. representative species of the target forest type that i) survive and grow well on deforested sites, ii) have dense, spreading crowns to shade out weeds and iii) attract seed-dispersing wildlife. Where such seed dispersal is not possible, all tree species of the target forest ecosystem must be planted (maximum diversity methods). Where top soil is lacking, planting "nurse" trees to improve soil structure and nutrient levels (e.g. *Ficus* & legumes) must precede other restoration procedures.

Re-introduction of endemic, endangered or threatened tree species can be included in all of the above techniques. Focusing only on red listed tree species is not particularly useful, since such lists are incomplete and fail to recognize local rarity. Restorationists should ensure that the rarest tree species in the target forest recolonize restoration sites, usually by tree planting. The greatest barrier to the use of rare species in forest restoration is low seed availability. Partnerships between restorationists and botanical gardens and/or seed banks may be crucial to ensure rare species are represented in restoration projects.

INTRODUCTION

Defining Forest Restoration

Tropical forest ecosystem restoration is "directing and accelerating ecological succession towards an indigenous target forest ecosystem of the maximum biomass, structural complexity, biodiversity and ecological functioning that are self-sustainable within climatic and soil limitations". The definition clearly excludes exotic or domesticated species. It explicitly states four measurable indicators of restoration success. Limits imposed by climate change are implicit. Restoration involves overcoming natural and artificial barriers to succession and driving succession forwards more rapidly than would occur without intervention. The target forest ecosystem should be the nearest remnant of least-disturbed forest, growing under similar topographical and climatic conditions. It is used to set restoration goals, particularly species composition (Elliott *et al.* 2013). Ensuring that the rarest species, in the target forest, re-colonize restoration sites is one of the most difficult aspects of forest ecosystem restoration.

Barriers to succession

In the past, forest ecosystems were subjected to natural disturbances infrequently and they recovered to their former condition within years or decades by natural succession. These days, however, frequent human-caused disturbances block natural succession from repairing the damage within a desirable time-frame. Human-caused barriers to succession require human interventions to overcome them. Such barriers include fire, logging/chopping, soil degradation, livestock, competition with exotic weeds, lack of natural regenerants[1] and seed sources and/or extirpation of seed-dispersing animals, capable of moving seeds to the restoration site.

Rapid site surveys and planning

Surveys of restoration sites, involving all stakeholders, are essential to i) determine which of the above barriers are preventing natural succession and ii) estimate the density of natural regenerants. The number of regenerant individuals and species are counted in 10-m-diameter circular plots, evenly spaced across the site. The same method is used to survey the target forest ecosystem, to quantify restoration goals and detect rare species (for methods see, Elliott *et al.* 2013). Stakeholders then use the site survey results to decide i) what management actions can overcome the barriers identified (e.g. fire patrols, cattle exclusion, weed control etc.) and ii) if regenerants are present at a density high enough to initiate canopy closure by the end of the second year. If not, then complementary tree planting must be planned. In the seasonally dry climate of northern Thailand, we determined that the regenerant density required to meet this guideline was 3,086/ha (an average spacing of 1.8 m between regenerants) from i) replicated, controlled field trials that manipulated tree density and ii) direct measurements of tree crown expansion of many species (Sinhaseni 2008, Elliott *et al.* 2013). Plots with higher densities had delayed biodiversity recovery, whilst those with

[1] Saplings >50 cm tall, larger trees and live tree stumps, capable of coppicing

lower densities remained weedy and suffered from fire intrusion. In equatorial rainforest sites, where trees grow more rapidly, it may be possible to initiate canopy closure in two years with lower regenerant densities, whereas in drier areas, higher densities may be needed (due to the slower growth rates).

Protection

Where natural regeneration remains above the critical threshold and regenerants are not inhibited by herbaceous weeds, protection alone may be sufficient to achieve restoration goals. This situation usually follows selective logging, where standing tree density remains high enough to shade out weeds. Preventing further degradation is essential by i) preventing additional encroachment by outsiders and ii) engaging local communities to prevent fires, exclude livestock and prevent the hunting of seed-dispersing animals, as required.

Assisted natural regeneration (ANR)

Where regenerants persist at densities above the critical threshold, but they are inhibited by weeds, protection must be complemented with “assistance”. This may include i) weeding and ii) fertilizer application. Weeding reduces competition between trees and herbaceous weeds, increases tree survival and accelerates growth. Weed pressing or lodging, using a wooden board to flatten weeds, prevents the soil erosion that is inevitable when using hand tools to dig out weed roots. It effectively uses the biomass of weeds to shade out weeds and suppress weed seed germination. It also adds nutrients to the soil, as the lower layers decompose. Most tree saplings, up to about 1.5 m tall, respond well to fertilizers. Fertilizer accelerates canopy closure and the shading out of weeds. The “assisted” trees may attract seed-dispersing animals, resulting in tree species recruitment, but most trees recolonizing such sites are of a few, common, pioneer species, representing only a small fraction of the species richness of the target forest. Subsequent tree planting or direct seeding is often needed to recolonize ANR sites with rare species, particularly those with large seeds.

Complementing regeneration

Tree planting should complement protection and ANR wherever i) regenerant density falls below the threshold explained above and/or ii) fewer than 30 tree species (or roughly 10% of estimated species richness determined by the target forest survey) are represented. First conceived in Queensland’s Wet Tropics World Heritage Area (Goosem & Tucker 2013), the framework species method is the least intensive and most effective of the tree planting options. Framework tree species are i) representative species of the target forest type, ii) survive and grow well on deforested sites, iii) have dense, spreading crowns that shade out weeds and iv) attract seed-dispersing wildlife. Mixtures of 20–30 such species, including both early and late successional species, are planted about 1.8 m apart from each other or from regenerants. Weeding and fertilizer application around both planted trees and regenerants are carried out during the first two rainy seasons (usually three times/year). For biodiversity recovery, remnants of the target forest type must survive within a few kilometres of the restoration site (as a seed source) and seed-dispersing animals must remain fairly common across the landscape.

In seasonally dry northern Thailand, framework species trials achieved canopy closure within two to three years. The species richness of the bird community rose from about 30–88 after six years (Toktang 2005). Seedlings of 73 species of non-planted trees established within eight to nine years (Sinhaseni 2008), most having germinated from seeds brought in by birds (particularly bulbuls), bats and civets. Above-ground carbon storage, net soil-carbon inputs from litterfall and accumulated soil-carbon all returned to levels that are typical of the target forest in 16–17, 14–16 and 21.5 years, respectively (Jantawong *et al.* 2017, Kavinchan 2015a & 2015b).

Maximum diversity methods

The framework species method does not work where natural seed dispersal has declined to such an extent that the rate of tree species richness recovery is unacceptably slow. Where seed sources and/or seed-dispersers are lacking, most (if not all) of the tree species that comprise the target forest must be planted. This is the maximum diversity approach of Goosem and Tucker (2013). The technique can be implemented by single plantings of mostly late succession tree species with intensive maintenance or by two-stage plantings, beginning with mostly pioneer trees and, after canopy closure, then with shade tolerant species. Although the aim is to plant most of the tree species that comprise the target forest, lack of seed supply and limited nursery capacity have limited maximum diversity trials to 60–90 tree species. The method is very expensive and has largely been confined to high value urban sites or mines.

Nurse trees

On the most severely degraded sites (such as mines), top soil is depleted or absent. An initial planting of "nurse" trees that ameliorate soil conditions is needed, before any of the above techniques can be applied. For such sites, we recommend planting mixtures of indigenous fig trees (*Ficus* spp) and legumes. Roots of the former crack open the substrate, allowing water and oxygen to penetrate, whilst the latter increase substrate nutrient levels, particularly nitrogen. Leguminous trees are an exceptionally speciose group and native species which are capable of growing on severely degraded sites and can always be found amongst the local tree flora.

Including endemic, endangered and threatened species

Re-introduction or assisted migration of endemic, endangered or threatened tree species can be included in all the above restoration methods. Focusing only on red list tree species is not particularly useful since such lists are incomplete, concentrate on commercially valuable trees and fail to acknowledge *local* rarity. Rare species present in the target forest, particularly those with large seeds, should be prioritized for testing in forest restoration trials. Phenology studies of such species are needed to determine the optimum seed collection time because irregular or intermittent flowering and/or fruit set may contribute to their rarity. Monitoring their field performance is essential, since rarity may be due to lack of seedling establishment, caused by predation, highly specific soil/microclimate requirements and/or lack of ability to compete with surrounding vegetation. Rare species are often particularly vulnerable to invasive exotic plant species.

The greatest barrier to the use of rare species in forest restoration is low seed availability. Where seed collection from the target forest ecosystem is impractical, seeds or cuttings may be available from botanical gardens and/or seed banks. Herbaria may help to identify species that were historically present near the restoration site, but which are now locally extirpated. Such species should be considered as high priorities for inclusion in restoration plantings. More partnerships between restorationists and botanical gardens would further the conservation of rare species in forest restoration projects (Hardwick *et al.* 2011).

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SUCCESSFUL GREENING MODELS OF SOME DISTURBED SITES IN PENINSULAR MALAYSIA

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ABSTRACT

This paper shares lessons derived from successful greening models of some disturbed sites in Peninsular Malaysia. Disturbed sites include ex-farmland, disturbed firefly habitat at riverbank and mine spoils. The paper outlines the importance of identifying key site constraint factors for growing plants in the disturbed sites. Some criteria used in selection of suitable species are discussed. Methods of site improvement employed for amelioration of each disturbed sites are also presented. The paper also stresses the importance of post-planting tending regimes for promoting sustainable stand development. All the greened models are self-sustainable after canopy closure. In addition, natural succession is evident in the greened sites where some wildlife have returned.

INTRODUCTION

Forest Research Institute Malaysia, since in her inception year in 1985 till to-date, has placed research and development (R&D) efforts in reclamation, rehabilitation and restoration of disturbed sites encompassing all sites in the terrestrial as well as wetland ecosystems. This paper only aims to focus on some of the successful models such as establishment of new forests on ex-tin mine, ex-farmland and secondary forest and riverbank as the breeding ground for firefly. These successful models are demonstration plots and also depositories of rainforest tree species, of which some of them belong to endangered, endemic and threatened species (EETs). This paper aims to outline the site constraints, site improvement methods, planting and tending techniques which will ensure the establishment and growth of these man-made forests on the disturbed sites.

Background

Site constraints of tree growing are determined by the forms of destruction or disturbances introduced or exerted to the pristine stage of the land, e.g. ex-tin mine is a totaled alteration of site properties. Hence, biophysical properties of the degraded sites must be carefully quantified and examined before any rehabilitative plans can be effectively implemented. Three successfully established models of man-made forest are documented here namely [1] ex-farmland and secondary forest, [2] denuded riverbank forest which is also a firefly habitat, and lastly a desert-like ex-tin mine.

Grassland and secondary forest

The successful model of rehabilitated grassland and secondary forest is demonstrated in the FRIM Campus, Kepong covering about 500 ha. This man-made forest was established from ex-farmland and secondary forest. The site was a severely disturbed, former lowland forest which was removed during Japanese occupation in 1945 and turned into vegetable farmland. Later, the farmland was left idle after the Japanese was defeated and turned into grassland. Some older plots eventually turned into young secondary forest through natural regeneration. The secondary forest grown on good mineral soil comprises Rengam and Tai Tak series. Plant biodiversity was loss but the soil properties were not degraded severely as heavy machineries were not used. The planting technology developed for enriching the grassland and secondary forest in FRIM could be applied for increasing the rainforest tree diversity in secondary forests and abandoned area of shifting cultivation in Malaysia which cover 4,600,000 ha and 4,800,000 ha, respectively (Ahmad Zainal, 1992).

Denuded firefly habitat

The model of rehabilitated denuded firefly habitat was established five years ago and the one ha demonstration plot is now with a mean stand height of 5 m. The model plot is part of the 99-acre parcel of a firefly conservation reserve. Illegal conversion of riverbank forest for agriculture activities such as establishment of oil palm plantation and vegetable farms involved removal of original riverbank vegetation. The destruction of the firefly habitat was due to removal of the original vegetation, construction of the roads which act as water control embankment, the usage of heavy machineries during construction activities and the preparation of vegetable beds.

Barren tin tailings

The worst form of degradation is tin mining where complete alteration of soil profile and its composition during extraction of tin ore. A man-made mixed species forest, Tin Tailings Afforestation Centre (TTAC), located in Bidor, Perak, is a model of greened ex-tin mine which covers 121.5 ha. The technology developed for greening the ex-tin mine could be applied for rehabilitation of ex-tin mine in the tropics. The extent of ex-tin mine in Malaysia is 113,750 ha.

Adverse site properties and site improvement

The site properties of the three degraded sites mentioned earlier were adversely altered due to the processes of degradation. Adversely altered site properties include microclimate, soils and water table level. These adverse changes to their site properties would determine the approach of rehabilitation and also cost of greening.

i) Microclimate

Microclimate is a localized climatic condition measured near the earth's surface (Geiger 1965). These environmental variables, which include temperature, light, wind speed, and relative humidity, provide useful environmental indicators for habitat selection and other activities (Chen *et al*. 1999). Microclimate determines ecological patterns in both plant and animal communities and also their survival. Microclimate plays an important role in ecological research especially as it affects regeneration (Shirley 1945). Adverse microclimate reduces decomposition activity of decomposers and adversely affects influx of nutrients to the soils. Soil temperature linearly affects decomposition below 25°C but decomposition rate may cease at soil temperature of 50°C, and the destructive temperature even limits dispersal of insects and herpetofauna (Chen *et al*. 1992 & 1999). Modified micro-sites formed after a degradation process in a forest can be complicated and exhibit great variabilities among them.

The most extreme microclimate is found in ex-tin mine, followed by denuded firefly habitat, grassland and lastly secondary forest. The high temperature and low humidity have resulted in high vapour pressure deficits (VPD). High VPD is not suitable for open planting of climax rainforest species. High VPD will result in low midday depression in gas-exchange activities, depress net photosynthesis and increase water loss which will result in low water use efficiency. Hence, high air temperature higher > 45°C will normally impede physiological activities of the leaf due to protein denaturation of its photosynthetic complexes. Hence, modification of the harsh microclimate shall be the first step before introducing the rainforest tree species especially low heat- and drought-tolerant EETs. Ways to improve the microclimate involve planting of heat- and drought-tolerant species especially acacias, *Hopea odorata*, *Macaranga* species and *Khaya* species as nurse tree species. After crown closure, or a reduction of 60% light intensity, the ground level will be suitable for growing the EETs seedlings.

ii) Soil physical properties

A general rule is observed before embarking on any rehabilitation efforts is to ascertain the integrity of soil structure. Changes of soil structure would affect its physical properties. Soil physical properties such as particle size distribution, mechanical impedance, water retention capacity and soil temperature affect the establishment of seedlings during natural colonization and also in replanting program. The degree of soil disturbance caused by mining is the most severe amongst other forms of degradation processes. In an ex-tin mine, the original rich forest soils were striped and later the ore-rich mineral soils were further extracted for tin through gravitational separation using water and gradient. Consequently, two extreme soil mixtures of ex-tin mine were coarse particles of sand and fine particles of slime. Normally, heavy machineries were employed for mining operation and also for land clearing activities and these cause high mechanical impedance. The degree of adverse soil physical properties for growing trees shall be in the order of ex-tin mine > denuded firefly habitat > ex-farmland or grassland > secondary forest.

Soil composition of degraded lands normally does not change much except in the case of ex-tin mine. Most of the human activities in impoverishing forestlands do not contribute to alteration of soil composition. Normally, mineral ores are extracted from the concentrate by water separation and this produces two extreme soil formations known as sand and slime tailings. Sand tailings have particle size more than 0.05 mm including sand and gravels. The sand and gravel tailings require additional fine soil particles such as silt and clay to improve their soil physical properties for growing tree species. The suitability of soil composition for growing trees shall be secondary forest > ex-farmland > denuded firefly habitat > ex-tin mine.

Main physical properties of sand tailings that require further improvement for growing plants include mechanical impedance. High mechanical impedance > 1.5 MPa is commonly encountered in ex-tin mine and logged-over forests or where heavy machineries are involved. Sand tailings, road shoulders, decking sites are common sites with high mechanical impedance. The average range of mechanical impedance measured on decking site is from 0.26 to 0.49 MPa compared to undisturbed forested site of 0.04 to 0.09 MPa (Wan Razali & Ang 1990, Kamaruzaman 1990).

The mechanical impedance of sand is reckoned to be high and causes impedance to root growth (Ang & Lim 1997). The compaction introduced to the sand tailings was due to the movement of heavy machinery during levelling. The penetration resistance of sand at 0–22.9 cm depth ranged from 0.5±0.2 to 2.2±1.2 MPa but higher values of penetration resistance that ranged from 2.2±1.2 to 3.2±2.3 MPa was determined at 23–61 cm depth (Ang *et al*. 1999). High mechanical impedance of sand tailings can be overcome by deep-hole planting technique, followed by application of peat or organic waste such as empty fruit bunches of oil palm. The average size of the planting hole is 1.5 m length x 1 m width x 1 m depth, and was prepared using an excavator. About 2/3 depth of the hole was filled with sand particles. Degraded site found to have high mechanical impedance or compacted site can be rehabilitated using a back-hoe to dig and loosen the soils to create a big planting hole of size 45 cm width x 1 m depth. Prior to planting, the planting hole will be filled with at least 0.5 kg of goat manure pellets. This method was found to be suitable for planting climax tree species. They are *Dyera costulata*, *H. odorata*, *Shorea roxburghii*, *Anthocephalus chinensis* and *S. macrophylla* (Wan Razali & Ang 1990, SFD 2005).

iii)Water table level

Sand tailings are often dry during drought period. Drought period of two weeks will dry up all the available water to 15 cm depth from the surface (Ang *et al.* 1999). The cause of such evaporative demand effect is mainly due to the particle size distribution of sand tailings which comprises > 90% coarse sand. The high porosity of sand has inverse relationship with its water retention capacity. The main approach adopted in the site preparation of the project site where the sand dunes are situated at > 4 m above standing water table level (aswl) was to reduce water loss from the root zone during dry period. The level of sand tailings determines its suitability for rehabilitation and restoration with plant species. If sand dunes are situated more than 4 m aswl, a drought of two weeks (rainfall < 4 mm/day) would dry up the available water of the 0–15 cm depth of sand dune (Ang *et al.* 1999). The dehydration of sand dunes in dry season is mainly due to its high composition of more than 90% sand and gravel. The high permeability of sand results in low water retention capacity and it is costly to irrigate the timber trees compared to high value agriculture produce. Hence, another approach was developed by planting tree seedlings in a pit below 45 cm surface of sand dunes situated at 4 m aswl using a big-hole planting technique. The planting hole of 1–1.5 m deep and 0.5 m–1 m width was enriched with empty fruit bunches of oil palm at the bottom and refilled to 0.45 cm below the surface of the sand dune. This method of planting proves to be a success in establishing dipterocarp and leguminous climax rainforest species on 6 to 10 m sand dunes in Bidor (Ang & Ho 2003).

iv) Soil chemical properties

The model of rehabilitated forest in FRIM is established on good mineral soils namely Tai Tak and Rengam series. These are rich soils that are good for agriculture activities. However, the soils at riverbank is unique containing heavy clay but very rich in NPK (nitrogen, phosphorus and potassium) and trace elements. No fertiliser application was done for the plots established along the riverbank because of the rich soils.

Sand tailings have lower concentration of macronutrients compared to the mineral soils. The pH ranges from 4.0–6.5 for both types of tin tailings (Ang & Lim 1999, Ang & Ho 2004). Soil properties of sand tailings have been the main obstacle for enhancing growth and survival of timber tree species. Sand has low fertility. Many studies showed that introduction of organic fertiliser either from plant materials or animal wastes to sand tailings would improve its fertility and also its physical properties. This approach has been used to improve the nutrient status of sand tailings in the project site. Low pH is the main concern for growing timber tree species on slime tailings. Application of ground magnesium limestone (GML) is absolutely necessary if the ex-mining land is originally a peat swamp forest. The soil pH of the project site is 4.0–6.5, and with the application of about 200 g GML per planting point, the growth of the seedlings was observed to be healthier at one year after planting.

v) Weed cover

Shifting cultivation site and grassland normally have one same problem, the ferocity of weeds especially *Imperata cylindrica* and *Melastoma malabathricum*. These weeds render the planting for rehabilitation and restoration purposes meaningless as the roots of the weed and their fast growth rate suppress the growth of the seedlings from competing for soil moisture and nutrients in the root region. Removal of weed cover is the main task before planting.

Three methods of weeding were practiced namely manual, mechanical and chemical methods. Manual weeding normally involves clearance of 0.5 m of radius from the planting point. It is not effective and very costly especially for large area. Mechanical weeding normally involves two rounds of disc ploughing to a depth of 45 cm and is proven to control weeds before planting. However, this method cannot be used after planting as it will destroy the roots of the plants. Hence, manual and chemical weeding methods are preferred after planting. Chemical weeding normally used glycerol-phosphate to destroy weeds but after three months regrowth of weed is normally observed. The cheapest way of controlling weed cover is through planting *Acacia mangium* seedlings. This can be done by first preparing a planting line with width of 0.5–1.5 m using a grass-cutter or a small tractor, followed by line planting of healthy *A. mangium* seedlings of 0.5–1 m. This is followed by another weeding cycle at three-month intervals, and fertilizing with 30 g of NPK or 120 g of 80% mature chicken manure pellet. The *A. mangium* if planted by 2 m x 3 m spacing would have crown closure within 2.5 years, depending on soil fertility.

Tending Practices in Post-planting

Post-planting maintenance of forest tree species on degraded sites is vital to ensure successful formation of healthy tree stands. Planting should be carried out during rainy season as it is good for the seedlings and saplings to be planted with soil water saturation at field capacity. Daily irrigation is needed if there is no rain. Irrigation can be stopped for loamy soils and sandy loam soils with good drainage system during the wet-season but during dry periods, the seedlings and saplings must be irrigated. Irrigation is not needed for seedlings grown in the greened firefly habitat as the moisture content at the site is always at field saturation capacity. However, for seedlings grown at the slope of sand tailings, which is about 3 m aswl, watering must be carried out at intervals of two dry days for three years post-planting period. Weeding needs to be carried out monthly followed by loosening of the soils at radius 50 cm from the planting point. Fertiliser application should be carried out after weeding, and in the wet periods. If watering is carried out, then fertiliser application can be done quarterly. The ratio of organic fertiliser: inorganic compound fertiliser at 5:1 is to be employed to provide good growth. The frequency of fertiliser application for seedlings is quarterly at the rate of 60–120 g/point/application, depending on the size of the seedlings. For seedlings between 0.5 and 1.5 m in height, 60g/point/application fertiliser should be applied whereas for seedlings >1.5 m in height, 120g/point/application is sufficient. Foliage fertiliser application is necessary for palm species and also at low pH site. The frequency should be twice monthly using 15N:15P:15K + trace elements.

Successful Models

Man-made forest of FRIM campus, Kepong

The mandate of establishing Forest Research Institute in 1925 was to provide planting technologies for turning degraded landscape into wood production area via reforestation

R&D. The former landscape of the present Forest Research Institute Malaysia comprises ex-tin mine, grassland and secondary forest. Planting activities since the last eight decades have now turned the mainly grassland and secondary forest sites into a gene bank of tropical rainforest species and some important exotic plantation species. Tree stands in FRIM include plantation species such as *A. aulococarpa, A. auriculiformis, A. mangium, Agathis bornensis, Araucarias, Azadirachta* sp., *Paraserianthes falcataria, Flindersia brayleyana, Khaya anthoteca, Shorea* sp., *Khaya* sp., *Pentaspadon motleyi, Vatica* sp., *Aquilaria malaccensis, Dryobalanops oblongifolia, Swietenia macrophylla, Neobalanocarpus heimii, Pterocarpus indicus,* etc. The collection of rainforest species in arboreta has turned FRIM campus into a national pride that demonstrates the commitment of the institute for conservation efforts. Natural regeneration of mainly primary lower strata species were observed under the planted stands. As the mixed species forest stands were established adjacent to a relatively undisturbed lowland forest, this explains the abundance of natural regeneration. FRIM houses 354 forest tree species of which 73 of them are classified under IUCN as threatened species. In addition, FRIM is also a popular ecotourism spot nationally and internationally (Latif & Ang 2013). The declaration of FRIM as a Natural Heritage Site in 10 February 2009 is a recognition of FRIM as the pride of the nation in plant biodiversity conservation and also as one of the major tourist attraction spots in Malaysia.

Man-made Forest of TTAC, Bidor

The reclamation and rehabilitation activities of the ex-tin mine covers 121.5 ha began in 1997, which is about two decades ago. The concept of reclamation using nurse trees which are heat- and drought-tolerant species, later by plating mixed timber species with EETs and other climax rainforest under the stands have turned the once desert-like ex-tin mine into a man-made rainforest comprising 92 tree species and covered a total greened land area of 99.6 ha. Out of which 21 tree species are self-regenerated, and 18 of them were brought by birds. TTAC now contains 25 EETs. The remaining 21.9 ha of water bodies are ex-mining pools are grown with lotus and full of aquatic life. The fauna include microorganisms, worms, insects, frogs, reptiles, birds and mammals. It is now a model of reclamation, rehabilitation and restoration of ex-tin mine which acts as a research centre and also demonstration plots for greening of ex-tin mine.

Rehabilitated habitat of firefly, Firefly Conservation Area, Kuala Selangor

Four tree species originally found in the habitat were planted in 2012. These tree species are *M. gigantea*, *Bridelia tomentosa*, *Nypha frutescens* and *Metroylon sagu*. The canopy closure of the mixed stand is observed at three years after planting. Since then, the rehabilitated site has a two-fold increase in firefly larva and snail population at two years after planting. Under the forest stand, firefly ascends at 7–8 pm after its mature phase. Their steady increase in quantity is recorded in Station No.5 by the Entomology Branch of FRIM (Figure 1). The rehabilitated firefly habitat is now a breeding ground for firefly.

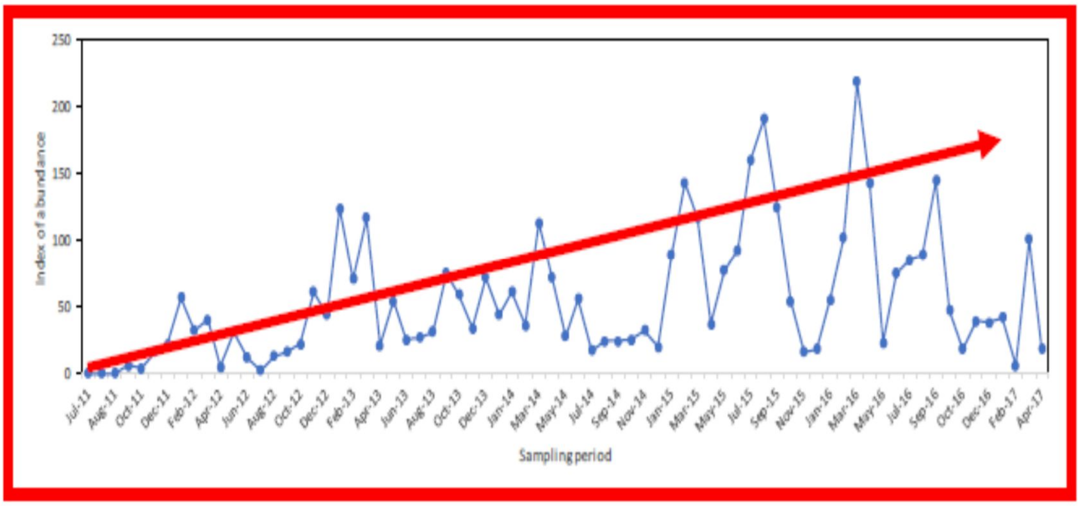

Figure 1. Firefly Abundance Index (FAI) at Station No.5 located behind the rehabilitated habitat, the FAI increases steadily from 2011 till 2017, a depression in the trend of FAI is due to larvae stage

CONCLUSION

Demonstration plots for reclamation, rehabilitation leading to restoration of ex-tin mine, denuded firefly habitat, grassland and secondary forest have been established and they are now self-sustainable. However, more EETs should be planted in FRIM campus and TTAC.

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FOREST PLANTATION CHARACTERISTICS ON EX-COAL MINED LAND IN INDONESIA: A CASE STUDY IN EAST KALIMANTAN

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ABSTRACT

Coal mining in forest area has caused the land to become severely degraded with the loss of vegetation, topsoil and subsoil. The original vegetation cover generally belongs to local species that becomes threatened if their conservation or cultivation is not done. With regard to ecology, economy and legality aspects, the coal mining company has an obligation to reclaim the mined land. Reclamation through the establishment of revegetation is considered as an effective option and hence can improve the soil fertility. The purpose of this paper is to describe the species composition and structure of forest plantation already conducted at a coal mining concession of PT Kaltim Prima Coal, East Kalimantan. The method used to determine the species composition, structure of forest plantation and site description was done through establishment sampling plots/ subplots of five, 14, and 19 years old plantation with three replications for tree, pole, sapling, seedlings and shrubs. Plots/ subplots in secondary forest were also established for comparison purposes. The results of this study showed that reclamation through forest plantation characterized by domination of exotic fast-growing species. This is expected to produce good vegetation structure since the plantation preceded five years earlier. The dominant species found in secondary natural forests include *Cananga* sp., *Macaranga* sp., *Palaquium* sp. and *Eusideroxylon zwageri*. However, dominant species found in plantations of five, 14 and 19 years old belong to fast-growing exotic species such as *Paraserianthes falcataria* and fast-growing local species such as *Hibiscus tiliaceous*, *Cassia suratensis*, *Macaranga* sp. and *Mallotus* sp. In the future, the introduction of commercial local species such as *Shorea* sp. for revegetation can be done by enrichment planting when the plantations are five to ten years old.

Keywords: coal mining, reclamation, forest plantation and local species

INTRODUCTION

Open mining of coal in forest area had caused the clearing of vegetation, top soil and subsoil or even soil parent material (depend on depth position of coal material) leading to a severely degraded land. This severely degraded land is characterized by open area without vegetation, poor soil fertility and limited fauna. In regard to ecology, economy, environment and legality aspects, the coal company has an obligation to reclaim this ex-coal mine. Reclamation through the establishment of vegetation is considered as an effective option (Stanturf *et al.* 2014) and hence can improve soil fertility (Mensah 2015). Important steps to improve soil fertility include reshaping the landscape followed introducing new vegetation. Species selection for revegetation depends on the proposed reclamation plan that is based on regulations whereby the species can be fast-growing and slow-growing trees, local and exotic species, and the percentage of each species. Planting fast-growing trees and ground vegetation that belong to the family *Leguminoceae* can accelerate the process of improvement on soil physical, chemical and biological characteristics (Sheoran *et al.* 2010). It is important to note that local species have a lot of benefits in terms of ecology and economy in the future (Burger & Zipper 2011, Burger *et al*., 2005, Mensah 2015, Lugo 1997).

The purpose of this paper is to describe the species and structure of forest plantations established at a given site description in a coal mining concession of PT Kaltim Prima Coal, East Kalimantan.

MATERIALS AND METHODS

The observation of species and structure of forest plantations and site description was done through the establishment of purposive sampling plot/ subplot of 5, 14 and 19 years old plantations with three replicates for tree, pole, sapling, seedling stages and shrubs. The other plot/ subplots for secondary forest were also established for comparison purpose.

RESULTS AND DISCUSSION

General Description of Research Area

The research area of Sangatta and Bengalon belong to East Kutai District, Province of East Kalimantan. Type of climate is wet (Af), generally with high annual rainfall of more than 1,500 mm/year, and in Sangatta with 3,042 mm/year (Hikmatullah *et al.* 2000). In Sangatta, there is a water deficit situation for two months between August and September, and water surplus starting from October to July (Hikmatullah *et al.* 2000). Major streams that are relatively large and long generally have a meandering drainage pattern downstream and upstream dendritic, like rivers in Sangatta and Bengalon. The species found in secondary natural forest were generally dominated by *Shorea* sp., *Eusideroxylon zwageri*, *Artocarpus* sp., *Mangifera* sp., *Eugenia* sp., *Octomeles sumatrana*, *Pterocarpus javanicum*, *Barringtonia* sp., *Dryobalanops* sp., *Intsia* sp. and *Palaquium* sp. Based on the soil map with a scale of 1:250,000, the observation plot at secondary natural forest belongs to Hapluduts, Plintudults, Hapludox, Dystropepts and Hapludalfs Complex with wavy topography (0–8%) to small hilly (15–30%) with the soil parent material of claystone and sandstone. The influences of various ages of forest plantations on soil properties are presented in Table 1. It shows that older forest plantations have higher pH and organic carbon (C) but lower Al_3^+.

Table 1. The influences of various ages of forest plantations on soil properties in Sangatta

Parameter	Age of plantation (years)		
	1–10	13–16	19–23
pH (H_2O)	5.48	5.65	6.25
Al^{3+} (me/100 g soil)	3.33	1.92	1.00
Organic carbon (%)	2.64	3.11	4.15

Source: Puslitbang Hutan (2017)

Forest Plantation Characteristics

Table 2. Dominant species, density and mean diameter at breast height (dbh) based on growth stages at each site of observation plots/ subplots

Site/ Density/ Mean diameter	Species/Plot/Stage				
	Plot of 20x20 m (tree: dbh of >30 cm)	Plot of 10x10 m (pole: dbh of 10–30 cm)	Plot of 5x5 m (sapling: dbh of 2–10 cm)	Plot of 2x2 m (seedling: dbh of <2cm)	Plot of 1x1 m (shrubs and herbs)
Secondary natural forest	*Cananga* sp.	*Macaranga* sp.	*Palaquium* sp.	*Cananga* sp. and *Eusideroxylon zwageri*	2 species of palms, *Vordia* sp. and others
Density/ha	58	300	533	8,333	2,666
Mean diameter (cm)	30.8	23.4	8.8	0.4	-
5 years old plantation	-	*Paraserianthes falcataria*	*Macaranga* sp.	*Mallotus* sp.	6 species (*Meremia* sp., ferns and others)
Density/ha	-	166	13,200	5,833	Covered
Mean diameter (cm)	-	22	5.8	0.92	-
14 years old plantation	*Cassia suratensis* and *Samanea saman*	*Cassia suratensis* and *Reutealis trisperma*	*Hibiscus tiliaceus*	*Lea indica* and *Shorea* sp.	6 species (*Meremia sp.*, ferns, and others)
Density/ha	50	133	400	12,540	Covered
Mean diameter (cm)	48.5	15.1	2.9	-	-
19 years old plantation	*Paraserianthes falcataria* and *Cassia suratensis*	*Paraserianthes falcataria* and *Cassia suratensis*	*Cassia suratensis*	*Calliandra callothyrsus*	6 species (*Meremia* sp., ferns and others)
Density/ha	75	100	1,333	2,500	3,333
Mean diameter (cm)	54.8	14.7	8.1	-	-

The dominant species found in 5, 14 and 19 years old plantations and at secondary natural forest are presented in Table 2. It showed that the dominant species in secondary natural forest consisted of *Cananga* sp., *Macaranga* sp. and *Eusideroxylon zwageri* while ground vegetation among others were *Vordia* sp. and *Meremia* sp. Meanwhile, the forest plantations were dominated by exotic species namely *Paraserianthes falcataria* and *Samanea saman* that are fast-growing species. Based on Table 2, it was observed that tree densities were in the following order: 19 years old (75 trees/ha), natural forest (58 trees/ha), 14 years old (50 trees/ha). However, there was yet to be a tree level in the five years old plantation. In the 5 years old plantation, the growth stage was still in the pole category with an average diameter at breast height (dbh) of 22.0 cm. This suggests that tree planting efforts that were carried out around the research area have shown success in reclamation of mined land.

Usage of Local Species

Local species that appeared naturally among others were *Shorea* sp., *Hibiscus tiliaceus*, *Macaranga* sp. and *Mallotus* sp. The emergence of local species indicated that the reclamation process through tree planting has shown positive results since the age of five years old. One of the commercial local species, *Shorea* spp., has a height of 200 cm in a five years old plantation by enrichment planting under a 14 years old plantation.

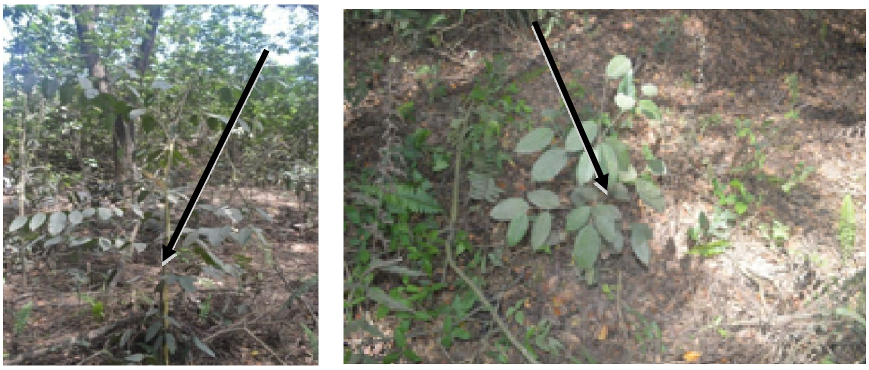

Figure 1. Enrichment planting (left) and natural regeneration of *Shorea sp.* (right) under a 14 years old plantation

Puslitbang Hutan (2017) described the other local plantation species in the whole concession area which consisted of *Aleurites moluccana*, *Alstonia angustifolia.*, *Annona* sp., *Archidendron havilandii*, *Arocarpus eritis*, *Artocarpus lanceifolius*, *Artocarpus* sp., *Colathea* sp., *Calophyllum inophyllum, Ceiba petandara, Chrysophyllum cainita, Cocos nucifera, Coffea* sp., *Durio acutifolius, Endertia spectabilis, Enterolobium cyclocarpum, Eugenia operculata, Eugenia* sp., *Ficus glomerata, Gluta* sp., *Mangifera indica, Parkia timoriana, Premna serratifolia, Premna* sp., *Prunus avium, Pteleocarpa lamponga, Pterospermum diadum, P. javanicum, Syzygium cordatum, Syzygium oleina, Tabernae montana, Terminalia catappa, Shorea belangeran, S. selanica, S. platyclados, S. leprosula, Hopea* sp. and *Dryobalanops* sp.

CONCLUSION

Land reclamation through forest plantation in the study area has shown landscape revegetation dominated by exotic fast-growing species and is considered to bear a good composition since the plantation was only at five years of age. In the future, the introduction of local commercial species for revegetation can be done by enrichment planting when plantation age is 5–10 years.

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REHABILITATION EFFORTS OF DISTURBED AREAS USING ENDEMIC SPECIES IN ZAMBALES DIVERSIFIED METALS CORPORATION (ZDMC), NORTHERN ZAMBALES, PHILIPPINES

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ABSTRACT

Changes in physical environment, rapid population growth, human interventions and growing industrial sectors are events that are significantly affecting the survival and adaptabilities of plants species nowadays. Like in a mining setting, where change in environment is evident, the rehabilitation of disturbed areas is very critical and important at the same time, giving considerations on the right choice of planting materials to be used, techniques from collecting to actual planting, plant species conservation and diversity.

This paper illustrates the efforts conducted by the Zambales Diversified Metals Corporation (ZDMC), a mining company, and its collaboration in a project of University of the Philippines-Los Banos, College of Forestry and Natural Resources (UPLB-CFNR) together with the Department of Environment and Natural Resources using endemic species found within the mining tenement to rehabilitate the disturbed areas. The collaboration project includes the establishment of a restoration plot using native plants collected within the mining tenement of ZDMC at Sta. Cruz, Zambales as well as identifying native trees and collection of seedlings of endemic species.

INTRODUCTION

The Sta. Cruz-Candelaria Mining Production Sharing Agreement (MPSA) of the Zambales Diversified Metal Corporation (ZDMC) covering 3,765 ha is located at Sitio Acoje, Barangay Lucapon South in the Municipality of Sta. Cruz and Sito Malimlim, Barangay Uacon in the Municipality of Candelaria, Province of Zambales, Philippines. Located in Zambales Mountains, ZDMC is a subsidiary of the DMCI and is one of the four large-scale mining companies included in the 50 operators listed in the Mining Industry Statistics in the Philippines.

It is 294 km away from Manila through the North Luzon Expressway. The area is bounded by coordinates 120°01’30’’ and 120°04’30’’ East and 15°37’00’’ and 15°44’30’’ North with altitude of 90 m above sea level (Figure 1). The climate of the area is classified as Type II and it is tropical with an average temperature of 27°C and 80% humidity. Average rainfall in the area is around 3,200 mm during the wet season from May to October (Fernando *et al*. 2013).

Figure 1. Location map of project site

MATERIALS AND METHODS

This project aims to rehabilitate 30 ha of disturbed areas using different restoration strategies to improve microclimate and enhance soil formation in the fastest and cheapest way. Specifically, it evaluates existing vegetation and screen grasses and trees best suited for mined-out areas under different schemes.

RESULTS AND DISCUSSION

The restoration/demonstration plot using endemic tree species in ZDMC was established on May 18, 2013 to showcase and determine the most appropriate species of endemic and native trees that can be used to restore the disturbed areas. The study also determined the species of trees best grown in the area, established a test plot and then assessed tree growth. A total of 620 seedlings composing four species native to the site were planted. After two years, the survival rate among species varied and decreased due to a long summer period in the area. A survival rate of 40% was obtained after a year. Measurements of the seedlings height and root collar diameter of the first batch of species, tanguile (*Shorea polysperma* (Blanco) Merr.), *Antidesma sp.*, paitan (*Syzygium costulatum* (C.B. Robinson) Merr.) and *Lithocarpus* sp. were done. Paitan had the highest percentage of survival followed by *Lithocarpus* sp., *Antidesma* sp., and *S. polysperma* with 61%, 49%, 42% and 7%, respectively after two years. The high survival rate of paitan indicates that the species could tolerate drought condition. The lowest survival rate and smallest measurements of Tanguile could be attributed to it being a shade-loving species and would not be appropriate to be planted in disturbed areas.

The planting space was 2x2 m. After 12 months, the total mean height and root collar diameter of *Antidesma* sp. (82.2 cm and 9.6 mm, respectively) were comparatively higher than the three other species planted. *Antidesma* sp. exhibited higher growth and bigger root collar diameter. Similarly, *Antidesma* sp. had a higher survival rate followed by *Syzygium* sp. Prelimiminary data shows that seedlings with kakawate (*Gliricidia sepium*) and ipil-ipil (*Leucaena leucocephala*) cuttings as nurse trees are taller than those without kakawate.

An alternative approach introduced legumes and other nitrogen-fixing species as nurse trees. Nitrogen-fixing species have a dramatic effect on soil fertility through production of readily decomposable nutrient rich litter and turnover of fine roots and nodules. Cuttings of ipil-ipil and kakawate were planted in between rows as nurse trees. Singh *et al.* (2002) reported that native leguminous species show greater improvement in soil fertility parameters in comparison to native non-leguminous species. In addition, native legumes are more efficient in bringing out differences in soil properties than exotic legumes in the short term.

Three grass species, *Paspalum destinicum*. *P. conjugatum* and *Oples manus*, native in the area were also planted to stabilize the soil, minimize soil erosion and dust pollution. Grasses are considered as a nurse crop for an early vegetation purpose. Grasses have both positive and negative effects on mined lands. Grasses, particularly C4 species, can offer superior tolerance to drought, low soil nutrients and other climatic stresses. Roots of grasses are fibrous which can slow erosion with soil forming tendency that eventually produces a layer of organic soil, stabilizes soil, conserves soil moisture and may compete with weedy species. The low survival rate of planted seedlings could be attributed to poor soil and extreme site conditions in the area. Maintenance and care of the seedlings such as watering, replanting and brushing by dedicated personnel as well as support from the management would help overcome the above-mentioned harsh environmental conditions.

The use of endemic and indigenous tree species which are suitable for harsh and limiting environmental conditions of mining sites are also recommended. Aside from traditional planting of nursery-grown stocks, the use of direct seeding and enhancement of the role of soil seed bank and conservation were also tried. Lessons learned from this study can serve as a guideline for ecologically sound and environmentally safe rehabilitation of mined-out areas in the country.

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PLANT SPECIES DIVERSITY, VEGETATION STRUCTURE AND ABOVEGROUND BIOMASS IN NATURAL REGENERATION FOREST AND *ACACIA MANGIUM* WILLD. PLANTATION IN AN EX-TIN MINE AT PHANG-NGA FORESTRY RESEARCH STATION, THAILAND

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ABSTRACT

The area of Phang-Nga Forestry Research Station has been degraded by tin mining which required clear cutting of trees and has an impact on the soil. The soil texture was sandy (sand 91.4% silt 3.3%, clay 5.3%) and very low in nutrients. The Faculty of Forestry, Kasetsart University planted fast growing species and grasses to improve soil quality and promote forest rehabilitation in abandoned mining areas. After 30 years of ecological rehabilitation, there are now many natural plant species and local species. The aim of this study was to evaluate plant species diversity, vegetation structure and aboveground biomass in a Natural Regeneration Forest as well as *Acacia mangium* Willd. plantation in an abandoned mining site at Phang-Nga Forestry Research Station, Phang-Nga Province, Thailand. Two sampling plots were distributed respectively in clay and sandy soil site with three replications each, giving a total of 12 plots. Results showed that overall 98 plant species, belonging to 80 genera and 49 families were found in abandoned mining at Phang-Nga Forestry Research Station. The nine species were from the Fabaceae family. The highest importance value index (IVI) of tree was *Acacia mangium* Willd and ranged from 67.61–235.30. The biodiversity in term of species diversity of Shannon-Wiener index indicated that FC and PC was highest (range from 0.60–2.21 in trees and sapling). Aboveground biomass was highest in PC (236.46 ton/ha) which consist of stem, branch and leaf biomass with 184.00, 21.00 and 3.51 ton/ha and lowest in PS (107.76 ton/ha). The total aboveground biomass tended to increase with the basal area and density of big trees (DBH > 30 cm). Forest ecosystem in abandoned mine at Phang-Nga Forestry Research Station could be improved by silvicultural practices for improved growth rate such as planting trees and management of gaps within canopy.

Keywords: aboveground biomass, plant diversity, abandoned mine

INTRODUCTION

Thailand has many important natural resources, especially mining, for industrial development and a source of income for the country. However, mining has a negative impact on forest ecosystems and soil properties. Environmental degradation causes mining waste, acid mine drainage and soil erosion. The plants have poor growth in abandoned mines. Restoration of mining areas with forest stands is important to reduce climate change. Phang-Nga Forestry Research Station was an ex-mining area and has been rehabilitated with fast growing species such as *Eucalyptus* sp., *Acacia auriculiformis*, *Casuarina equisetifolia*, *Acacia mangium*, *Dipterocarpus alatus*, *Terminalia alata*, *E. cetiodora*, *E. deglupta* and grasses were planted in the area in 1990. After 27 years, there are many natural and native species established in the areas. However, the diversity of local plant species, especially wood, is still relatively low, affecting yields and quality of the forest. Therefore, in order to initiate forest restoration, the productivity and quality of the forest must be improved. It is important to know the plant species and the vegetation structure as it will determine the species diversity and the appropriate planting pattern. The purpose of this study is to understand the plant species diversity vegetation structure and the aboveground biomass of a naturally regenerated forest and *A. mangium* Willd for utilization in appropriate forest management.

MATERIALS AND METHODS

The research was conducted in Phang-Nga Forestry Research Station, Phang-Nga Province, Thailand (GPS: 8°46′5″ and 98°16′7″). Total area was 72.24 ha was 10–20 m above sea level (masl). The climate is tropical monsoon with two seasons; dry season from December to March, and rainy season from April to November. The annual average rainfall is 1,634 mm per year and average temperature is 27.1°C (Jetsada *et al.* 2013). The observation was conducted in four land use systems: 1) Natural successional stage in clay soil zone (FC), 2) Natural successional stage in sandy soil zone (FS), 3) Acacia *mangium* Willd. plantation in clay soil zone (PC) and 4) *A. mangium* Willd. plantation in sandy soil zone (PS). The sampling plots were replicated 3 times, thus the total observation plots were 12. Observation of tree species diversity and aboveground biomass used a plot size of 40×40 m^2 each for tree census. Plot sized 10×10 m^2 was used to measure trees for diameter at breast height (DBH) ≥ 4.5 cm. At each corner of 10×10 m^2 plot, 4×4 m^2 plot was setup to measure saplings with DBH < 4.5 cm and height ≥ 1.30 m. DBH and height were measured using diameter tape and Haga hypsometer, respectively. All species were identified in the field. Specimens of unknown species were collected and later identified by experienced taxonomists.

Analysis on Plant Species Diversity

The observation of plant species diversity was:) a) plant density, (b) plant frequency, (c) basal area (d), importance value index and (e) biodiversity index. The species density represents the number of the whole species in a measurement unit (ha). Relative density was the percentage of individuals in each species and the total number of individuals in all species. The species frequency represents the number of quadrate in which each species occurs. The basal area describes the width of vegetation cover in an area where samples were taken in the following formula: BA (m^2) = $\Sigma\pi (D)^2/4$, where D is DBH. The importance value index (IVI) for trees and shrubs were calculated by summing the relative frequency (RF), relative density (RD) and relative dominance (RDo) for trees and shrubs. Importance value index was calculated from the values of relative frequency and relative density that the Importance Value Index is 0–300 %. The species diversity index was calculated following Shannon-Wiener index (1963), where: $H' = -\Sigma (n_i/N) \ln n_i/N$ and H' = Shannon-Wiener index of general diversity, n_i = importance value index of i^{th} species, N = sum of importance value index of all the species

Aboveground biomass

Aboveground biomass was calculated from allometric equations developed by Ogawa *et.al.* (1965) for natural forest and Wongprom *et al.* (2013) for *A. mangium* Willd.

RESULTS AND DISCUSSION

Number of species, Species Density and Basal Area

Total numbers of species in this study were 98 in 80 genera from 49 families. Most of the species belonged to the family Fabaceae (nine species) and followed by Phyllanthaceae and Myrtaceae (six species). The density of woody species (≥4.5 cm dbh) was highest in FC (1,433 trees/ha) and lowest in FS (938 trees/ha) (Table 1). *Acacia mangium* Willd. was the dominant species (64%–86% for the total stand density in most areas. The highest value of BA was found in PC cover (28.90 m^2/ha) followed by FS (24.33 m^2/ha) and the lowest in FC (20.94 m^2/ha) (Fig. 1).

Table 1. Number of species, species density and number of trees

	Land use system	Number of Species	Number of trees/ha	Number of saplings/ha
1	FC	52	1,433±469.12	1,967±469.12
2	FS	37	938±419.96	1,623±1,312.90
3	PC	29	1,363±409.87	2,498±382.91
4	PS	28	1,090±477.46	994±464.25

Note: FC = Natural successional stage in clay soil zone, FS = Natural successional stage in sandy soil zone, PC = *Acacia mangium Willd*. plantation in clay soil zone and PS = *Acacia mangium* Willd. plantation in sandy soil zone

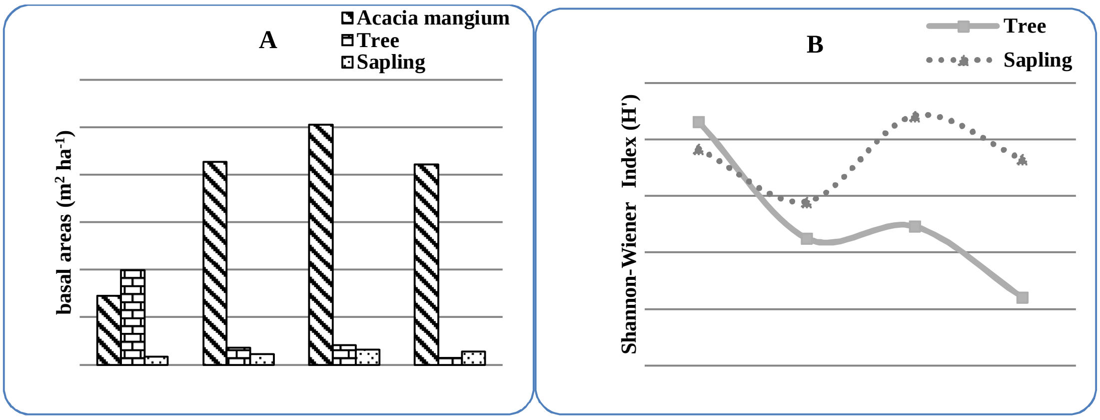

Figure 1. (A) Basal area based on DBH and (B) Shannon-Wiener Index in four land uses

Important Value Index (IVI) and Plant Diversity Index (DI)

A. mangium Willd. had the highest IVI in all land use areas (range from 67.61–235.30) for trees (DBH ≥ 4.5 cm) in PS plot. Saplings highest IVI was found in *Aporosa planchoniana* Baill. ex Müll. Arg and *A. mangium* Willd. The biodiversity in term of species diversity of Shannon-Wiener Index indicated that FC and PC had the highest value of species diversity of trees (2.15) and saplings (2.22) respectively (Figure 1). The species diversity in this study was lower than species diversity in tropical rainforest at Ton Nga Chang Wildlife Sanctuary which was 6.23 (DNP, 2013) as it was an undisturbed forest.

Aboveground biomass

The aboveground biomass was highest in FC (236.46 ton/ha) which consisted of stem (184.00), branch (21.00) and leaf biomass (3.51ton/ha) respectively (Table 2). The lowest values were found in PS (107.76 ton/ha) which consisted of stem (93.39), branch (5.34) and leaf biomass (1.42 ton/ha), respectively. The stem greatly contributed to the aboveground tree biomass (74–80%), followed by the branches (5–9%) and leaves (2%). (Table 2) The total aboveground biomass tended to increase with the basal area and density of big trees (DBH > 30 cm.) (Chormali 2002). The aboveground biomass in this study was lower than the average aboveground biomass in tropical rainforests in Kanchanaburi Province, Thailand from 141–275 Mg/ha (Terakunpisut, 2003).

Table 2. The partitioning of biomass accumulation according to each stand

Study site	FC	FS	PC	PS
Tree density (stem/ha)	3,400.00±469.12	2,560±1,312.90	3,860±382.91	2,560±1,312.92
Stem biomass (ton/ha)	84.47±6.50	111.02±49.42	184.00±88.98	93.39±28.29
Branch biomass (ton/ha)	11.64±12.19	10.76±9.90	21.20±24.02	5.34±4.39
Leaf biomass (ton/ha)	1.83±1.88	2.24±2.04	3.51±3.81	1.42±1.23
Total Aboveground biomass (ton/ha)	113.12±9.19	138.70±63.96	236.46±127.01	107.76±33.22

Note: FC = Natural successional stage in clay soil zone, FS = Natural successional stage in sandy soil zone, PC = *Acacia mangium Willd*. plantation in clay soil zone and PS = *Acacia mangium* Willd. plantation in sandy soil zone

CONCLUSION

Species composition was high in diversity and number of species in clay soil zone. The total number of species in this study was 98 in 80 genera from 49 families. The highest number of species was in FC. Highest IVI in all land use areas was *A. mangium* Willd. and the species diversity index was 2.15 for trees. Stem biomass in the main component of tree above biomass and tree biomass depends on forest type, vegetation structure, density and environmental factors. The forest in this study could be improved by silvicultural practices for increased productivity and quality.

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ARE THREATENED SPECIES SUITABLE FOR REHABILITATION PROGRAMMES?

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ABSTRACT

Species become threatened when they fall into one or several of the following categories, i.e., reduction in population size or geographic range or has inherently small population sizes. IUCN Red List Categories and Criteria provide threshold levels to assist assessment of species at the global scale and there are provisions for the assessment of species at the regional, national and sub-national scale. To date, of the 1,406 plant species in Peninsular Malaysia that have been assessed, 32% are threatened. For the majority of the Critically Threatened (CR) and Endangered (EN) species, this is caused by the reduction in geographic range, using forest cover as a proxy. CR and EN species are typically restricted to specific habitats and have life history and functional traits that are more severely impacted by drivers of threats. Bottlenecks to species survival are influenced by flowering, fruiting and recruitment strategies and their interactions with other biotic and environmental factors. In the mega-diverse tropical forests of Malaysia, these traits and their responses to anthropogenic activities are poorly understood. Rehabilitation and restoration of disturbed sites typically requires massive input of planting stock and these sites have conditions that are less than optimal for the growth of threatened species. This paper aims to elucidate the suitability of CR and EN species for rehabilitation programmes drawing on local perceptions of Red-Listing. Ultimately, for this approach to reach its full potential, there is a need to establish clear goals and objectives, cultivate long-term commitment by all stakeholders, have a better understanding of species behavior, and develop a plan that truly integrate conservation consideration with on-site management and monitoring.

INTRODUCTION

The use of indigenous species in rehabilitation activities has multi-fold benefits and as a result, this approach has been speculated as becoming increasingly important in conservation (Maunder 1992, Hodder & Bullock 1997, Rout *et al.* 2009). With the rapid expansion of degraded and altered habitats, habitat restoration approach is an intuitive strategy that may allow recovery of extant plant populations (Menges 2008). To some practitioners, this approach is further thought as a strategy that may function as *ex situ* conservation (Allen 1994).

In rehabilitation, it is well known that only a limited range of indigenous species is used (Oldfield 2009) and frequently these species are of the fast-growing and highly-adaptable type. Reports on the use of rare and threatened species are few and scanty. Menges (2008) examined the factors that contribute to the success of rare plant reintroduction such as type of propagules, translocation strategy, breeding systems, local adaptation, genetic variation, and interactions of plants with herbivores, disturbances and other ecological factors. Helenurm (1998), Morgan (1999) and Krauss *et al.* (2002) have reported that various plant species seemed particularly difficult to reintroduce. In addition, for legitimate reasons, many failed attempts have not been or could not be reported (Fahselt 2007). No specific examples, either successes or failures, are available for rare tropical plants, including tree species. Thus, based on the few studies that had reported the outcomes of reintroduction, it would be risky to consider rare plants as an appropriate first choice for rehabilitation.

A key measure of the ultimate fate of rehabilitation is the ability of the rare plants to flower and successfully set fruit and recruit (Morgan 2000, Tyndall & Groller 2006, Menges 2008). Godefriod *et al.* (2011) indicated in his review that in most efforts, survival, flowering and fruiting rates tend to decline with time. Failure to achieve this key indicator is often associated with methodology and environmental factors rather than the biology of the species (Godefriod *et al.* 2011). Whilst this is true, appropriate on-site conditions can never be provided without the understanding of key biological processes such as reproductive biology and regeneration, and the ability to survive in altered environments. Unfortunately, this understanding is lacking for tropical tree species.

DISCUSSION

Plants are labeled rare or threatened based on criteria that include biological, demographic, geographical and ecological features. In general, such species are typically restricted to specific habitats and have life history and functional traits that are more severely impacted by drivers of threats. Past work has elucidated that without a change in the manner current efforts for rehabilitation and restoration of disturbed sites are undertaken, the approach may be considered a form of threat.

Rehabilitation using rare species is recognized to be a high risk, high cost activity (Maunder 1992, Gorbunov *et al* 2008) and have the potential to fail in achieving its conservation-related objective in the long term. For a rehabilitation programme to be considered as an effective solution to *ex situ* conservation, the conservation goal must be explicit and there must be clear long-term, medium-term and short-term objectives. Likewise, at each stage, conservation priority will dictate and drive each set of objectives. These objectives will vary and short-term objectives will set out the fundamental conditions required to achieve the long-term objectives.

It is necessary for all partners and stakeholders to share or be aligned to the same desired principle, goals and objectives. Additionally, the rehabilitation programme must employ an integrated approach with respect to planning, development, implementation, monitoring and evaluation and financial commitment. Standard rehabilitation protocols are generally not appropriate to introduction of threatened plants because of the plants' specific ecological requirements. A different suite of management protocols needs to be developed to increase the probability of success and the effort should address the following:

1. Understanding key biological features and processes that determine successful recruitment. Species survival is influenced by flowering, fruiting and recruitment strategies and their interactions with other biotic and environmental factors. Having such data/ information is fundamental to the success of rehabilitation;
2. Choosing appropriate species for the rehabilitation and preparing a plan on how to obtain the massive input of planting materials;
3. Using materials (seeds and/or saplings) originating from multiple populations to increase genetic diversity;
4. Increasing substantially the number of introduced individuals from diverse populations to improve population fitness;
5. Manipulating less than optimal site conditions in preparation for planting;
6. Preparing integrated on-site post planting management that deals with, amongst others, herbivory, pests and diseases, competition from surrounding vegetation such as weeds, manipulation of light and water regimes and restoration of ground cover;
7. Long-term monitoring of planted materials is crucial. This is necessary because survival and growth rates vary with time and are under the influence of the capriciousness nature of environment. For tropical tree species, little can be learned from short-term surveillance as they are generally slow growing. In addition, demographic data has great use in elucidating causes of failures/ successes and thus contribute to the improvement of future efforts; and
8. Adequate documentation for planting materials which includes, amongst others, origin of planting material, planting details and temporal changes in survival and growth rates.

CONCLUSION

Following these guidelines, one can only be cautiously optimistic of success based on short-term results. Clearly a long-term perspective of success is required for a rehabilitation activity to function as *ex situ* conservation.

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VARIABILITY OF LANDFILL SOILS AT TREE PLANTING AREAS OF SUNGAI MELAKA RECREATION AND BEAUTIFICATION SITES

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ABSTRACT

Conversion of riverside areas for recreation and tourism causes changes to soil attributes. Sungai Melaka beautification project was initiated to promote tourism through planting of suitable trees and by having clean river. This study was aimed at identifying filled soils of the riverbank, recording depth of filled soils, producing a soil map and determining soil-tree suitability. Our findings showed that soil in the study area is acidic and the presence of jarosite layer may limit the number of species that can tolerate these conditions. Therefore, results from this study will be used for considerations in tree species selection, soil amelioration and fertilizer formulation.

INTRODUCTION

Riverside conversion for recreation and tourism involves massive earth work with introduction of soils from other locations having contrasting properties. This resulted in soils with diverse attributes and selection of tree species for planting is a challenging task. Sungai Melaka beautification project which aims to boast tourism and provide a venue for recreation is one such site where mixed layers of soils of different parent materials overlying alternately.

Thorough soil investigation was carried out at the Parcel 1 and Parcel 2 of the project site to assess and identify soil properties and their limitations for plant growth. Data generated from this study will be used as a guide for species selection, soil amelioration and fertilizer formulation. In order to achieve this, our approach was to evaluate the physical and chemical soil properties with regard to the requirement to nurture healthy trees.

This study was carried out i) to identify the kind of filled soils along the Parcel 1 and Parcel 2 of the riverbank, ii) to record the depth of filled soils till the original soils (marine clay) at the site, iii) to produce a map describing the type of filled soils and iv) to determine soil-tree suitability. Accurate information on soil attributes is crucial for tree planting at this site for correct selection of tree species.

MATERIALS AND METHODS

Study site

The areas allocated for tree planting were on the bank of Malacca river divided into two sites i.e. Parcel 1 and Parcel 2, approximately 5 km long, within latitude 102^o 14' 30" T and 102^o 15' 43" T and longitude 02^o 12' 25" N and 02^o 13' 31" N. Location marking was crafted on topography map at a scale 1:12,000.

Parcel 1 consists of a 2 km stretch along the riverbank with total land area of 14.6 ha from Hang Jebat bridge to Tun Abdul Razak bridge. Parcel 2 with a length of 3 km, covers an area of 14.8 ha starting from Tun Abdul Razak bridge and ending at water lock gate. Total area for soil evaluation was approximately 29.3 ha. Due to the narrow range of planting sites on both sides of the river, soil investigation procedures had to be adapated from the standard procedures practised on normal sites.

The grid system is usually used for soil examination whereby distance of auger point is 200 m x 200 m for a detailed soil survey. Since the study area was long and narrow, the approah had to be modified to line sampling along the stretch with standardised auger point distance of 100 m. Our assumption was that this sampling distance represents a very detailed soil survey. Nevertheless, wherever conspicuous differences in soil appearance were observed, sampling distance was less than 100 m.

At each sampling point, soil was augered down to 125 cm. For each examination point, soil parameters namely color, texture, structure, consistency, mottling, depth to rock layer and drainage class were recorded. Global positioning system (GPS) was used to mark sampling locations and these data was uploaded into Arcmap software to produce a soil map.

RESULTS AND DISCUSSION

Our observations showed that soil in the entire area was disturbed (DLD) with different degree of heterogeneity based on extensiveness of earthworks (Figure 1). The filled soils varied with soils obtained from outside areas (mineral soils) as well as marine clay from the riverbed. The cut and fill approach during earthworks led to formation of heterogenous soil layers.

Figure 1. The study site with mixed materials of filled soils

Due to high variability in soil texture, color, parent material source and layers, two main criteria were used to classify the soils i.e. depth to the original parent material (marine clay) and type of filled soils (either soils from inland, marine clay or riverine clay).

Layers of filled soils were easily distinguished by color and texture properties (Figure 2). The soils were described briefly in Table 1. The hectarage of each soil type was also presented in Table 1 with Type A1 covering almost 38% of the study area. This soil would be easier for tree selection as compared with acid sulphate soil of marrine clay origin where only a limited number of tree species can adapt. There were 10 types of soil categories identified and their distribution were mapped as shown in Figure 3.

Figure 2. Soil horizons showing layers of filled soils

All these soil types have their own limitations. Normal planting approach with minimal tending may not be sufficient for this greening programme. The site needed soil amelioration, good fertilizer regime, liming, plus high level of soil and water management to achieve good and healthy plant growth which can be rather costly.

Table 1. Details of the soil types at Sungai Melaka riverbank designated for planting

Depth to the marine clay layer	Type	Description	Total area (ha)
>1.5 m	A1	Filled soil derived from shale parent material. Most were of B and C horizons consisting of saprolite, mixed rocks, moderately friable to compact, some were dry and dusty. Limitations: Compacted soils and nutrient imbalance.	11.1
50 cm – 1.5 m	B1		1.0
>1.5 m	A2	Filled soil derived from marine clay originated from the project site river widening and deepening. Potential acid sulphate soil. Limitations: High clay soils, sticky when wet and hardened when dry.	0.4
50 cm – 1.5 m	B2		3.0
0 – 50 cm	C2		3.3
>1.5 m	A3	Soils derived from marine clay originated from project site, oxidized and having jarosite mottles. Potential to give negative impact on planted trees if not properly managed. Soils having jarosit usually have pH value less than 3.5. Limitation: Acid sulphate soil with pH <3.5.	0.4
50 cm – 1.5 m	B3		1.3
50cm – 1.5 m	B4	Filled soils derived from shale parent material mixed with soils of marine clay origin. The latter soil were layered on top of shale derived soil forming two conspicuous major filled soil layers but with dissimilar thickness. Limitations: Compacted soils and nutrient imbalance.	0.8
>1.5 m	A5	Filled soils similar to the Category 4, except for the layering whereby soil derived from marine clay were at lower layer while shale derived soil at the upper layer. Thickness of these two layers differ. Limitations: Compacted soils and nutrient imbalance.	2.9
50 cm – 1.5 m	B5		5.1
		Total	29.3

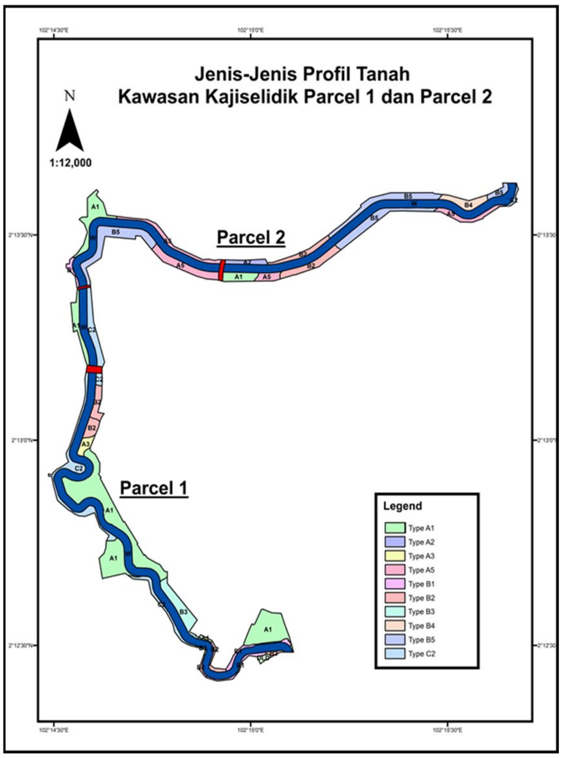

Figure 3**.** Distribution of the 10 soil types identified along the riverbank of Sungai Melaka

CONCLUSION

Overall survey findings showed the need for a good soil management system to achieve high survival and good tree growth. The Type A3 and B3 soils needed extra care due to the presence of jarosite layer that limits the number of tree species that can tolerate such condition. The recorded pH values based on laboratory analysis were between 2.38 and 3.28.

PHYTOREMEDIATION OF HEAVY METALS USING *ACACIA MANGIUM* IN RAHMAN HYDRAULIC TIN (RHT) TAILINGS

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ABSTRACT

Phytoremediation is a process that utilizes plants to filter and remove contaminants through biological, physical and chemical activities initiated by the plant. Acacias have the potential to rehabilitate soil through absorption and storage of heavy metals in its leaves, shoots and roots. This study was initiated to determine the amount of heavy metal uptake and translocation to harvestable parts as before and after planting Acacias on an ex-tin mining land. Three replicates of *Acacia* trees from the RHT tin tailings were felled and divided into roots, leaves and stems where wood discs from the heights of 0.3, 1.3 and 7.3 m were extracted from the stems. Soil samples were collected in triplicates at a depth of 0–65 cm, 65–80 cm and 80–100 cm, respectively for heavy metal analysis. Simultaneously, samples were collected at Bukit Hari as the control plot following a similar scheme. Soil and tissue analysis were done for aluminium (Al), iron (Fe), arsenic (As), lead (Pb), zinc (Zn), mercury (Hg), nickel (Ni) and copper (Cu). *Acacia mangium* absorbed best both Al and Fe compared to other elements. Zinc and As were moderately absorbed by *A. mangium* in the tin tailings.

Keywords: Acacias, ex-tin mining, heavy metal absorption, rehabilitation

INTRODUCTION

Malaysia was once a giant in the tin mining sector and formed the backbone of the country's economy. Due to over exploitation to feed the growing steel industry, most of the resources have been exhausted and these areas are left abandoned. Some suggest planting agricultural crops on these lands but a major concern is the presence of large amounts of heavy metals that are potentially toxic such as cadmium (Cd), lead (Pb) and arsenic (As) (Ang and Ang, 2000) which are detrimental to human health when occurs beyond permissible amounts (Ang *et al*. 2010). A more feasible option would be to establish *Acacia mangium* plantations mainly because of its notable track record as a phytoremediator. Acacias have the potential to rehabilitate the soil through absorption and storage of heavy metals in its leaves, shoots and roots (Veronica *et al.* 2011). Acacias are even used in treating sewage sludge soil to absorb large amounts of zinc (Zn), Pb, copper (Cu), Cd and chromium (Cr) (Nik *et al.* 2012). Phytoremediation is a process that utilizes plants to filter and remove contaminants through biological, physical and chemical activities initiated by the plant. Phytoremediators act as filters by first absorbing contaminants, degrading them and stabilizing the concentrations of contaminants in soil through plant uptake. Therefore, this study was initiated to determine the amount of heavy metal uptake and translocation to harvestable parts as well as to quantify the concentration of heavy metal before and after planting Acacias.

MATERIALS AND METHODS

The study was conducted in Rahman Hydraulic Tin Sdn. Bhd. in the vicinity of Klian Intan, Perak, situated between latitudes 05°25'N and longitudes 101°8' E. This area was previously mined for tin since the 1950s. The adjacent areas are surrounded by ex-tin mining ponds with large amount of tin wastes which consists of mud, liquid, sand, silt and sand. The planting area was limed and added with top soil as part of the rehabilitation program. Approximately 4 ha was planted with *A. mangium* on 17 December 2012 spaced at 2 m x 2 m and 4 m x 4 m. In December 2016, three Acacia trees were selected for sampling with diameter at breast height (DBH) and total height being taken prior to felling. The logs were cut into different lengths namely 0.3 m, 1.3 m and 7.3 m. The fresh weights of the leaves were weighed whole and 3 replicates were taken from each tree amounting to 200 g. The roots from each tree was excavated and sorted into big roots and small roots for biomass determination. The fresh weights of roots were weighed whole and three replications amounting to 1 kg were taken as samples. Tree branches were also measured and determined in a similar manner.

Soil samples were collected in triplicates at a depth of 0–65 cm, 65–80 cm and 80–100 cm. Soil samples and tree samples were also taken from Bukit Hari, FRIM Selangor which served as the control. Leaves, roots and shoots from both sites were retrieved and taken to the laboratory for further analysis. Soil samples were air dried and ground in a Wiley mill and then sieved using a 1 mm and 2 mm sieve. The tissue samples were oven dried at 70°C and ground with Wiley mill (1 mm sieved). The soil samples were digested using *Aqua-regia* method (EPA-ROC 1994) for extraction of heavy metals. Heavy metals in plant tissues were extracted using nitric acid and hydrogen peroxide by the microwave digestion method. The concentrations of heavy metals in the plant and soil extracts were then analysed using the Varian 725 Inductive Couple Plasma Optical Emission Spectrometer (ICP-OES).

RESULTS AND DISCUSSION

Aluminium (Al) concentration recorded in soils under tin tailings ranged from 0.86–6.14% whereby concentrations decrease with depth and are much lower than values obtained for the control (Bukit Hari) which implicate that Acacias were successful in absorbing Al (Table 1). Based on past reports, the pH of soil in tin tailings were very acidic and ranged from 2.4–3.3 (Suhaimi *et al.* 2015). When pH is less than 5.5, Al tends to accumulate resulting in a condition known as Al toxicity, restricting root growth (Mossor-Pietraszewska *et al.*1997). The phenomena of root restriction were seen in terms of biomass whereby the RHT plot recorded a much lower biomass (data not shown) compared to the control plot. The low levels of Al recorded in the leaves of RHT could be also due to Al ion translocated very slowly to upper parts of plants (Table 2) (Ma *et al.* 1997). However, Al concentration in wood discs were quite notable in the range of 24–53 mg/kg which indicate that woody components were more efficient in storing Al compared to leaves and roots (Table 2).

In iron (Fe), the concentration in soil ranged from 1–6% which is slightly higher than observed in the control while the concentrations in leaves and roots were 200 and 1,500–2,800 mg/kg, respectively (Tables 1 & 2). High concentrations of Fe at the rhizosphere region compared to the leaves are due to the creation of iron plaque (Fe_2O_3), hindering excessive amount of Fe entering the plant tissue (Harahap *et al*. 2014). Thus, relatively lower levels of Fe were observed in leaves (Table 2) and wood disc samples (Table 3). Phytoremediation methods, particularly phytoextraction, have been used on a variety of metal contaminants including Fe (Ebbs *et al.*, 1997) and works on the basis of transporting and accumulating large quantities of metals from the soil into harvestable parts of roots and aboveground shoot. According to the results, Cu in soil ranged from 50–79 mg/kg which were more than 70 times higher than the control (Table 1). Copper values were low in tissues of wood and roots thus confirming that *A. mangium* was able to absorb Cu in lesser quantities only. The values for Pb were 30–330 mg/kg in soil and increased with depths and were higher than control. Values for tissue samples overall were less than 5 mg/kg as most of the Pb were translocated to the roots compared to discs and leave samples. It was seen here that *A. mangium* was not able to sequester Pb in high quantities thus classified as a low phytoremediator. We believe that Pb was less mobile in soil as it may have bind strongly with oxides of Fe, manganese (Mn) and Al (Angelova *et al.* 2009). Concentration of Zn in the soil was 43 mg/kg in the 0–65 cm profile. This was not detrimental to trees. Tissue samples of discs showed some high values. Leaves were comparable to control (Table 2) but still within a normal range for tissue samples. Zinc was translocated to leaves compared to other parts of the trees which show a good example of moderate phytoremediation of *A. mangium* trees. Soil nickel (Ni) values were two to five folds higher than control (Table 1). However, Ni concentrations in discs and leaves were less than 1.5 mg/kg similar to control (Table 2). Roots showed 5 mg/kg had the highest amount among other tissue samples. Mercury (Hg) levels were somewhat absent in soil and tissue samples were traces in the sand tailings. Overall, As in soil was less than 1 mg/kg but the values increased with increasing depths (Table 1). Thus, the small roots showed levels more than 12 mg/kg which can be classified as a very good phytoremediator at more than 80 cm depth. Arsenic is readily adsorbed by iron oxides and oxyhydroxides at low or neutral pH (Smedley *et al*. 2002) reducing its mobility. Thus, in low pH conditions where Fe hydroxides are present, mobility and bioavailability of As is reduced (Alderton *et al.* 2014).

Table 1. Soil analysis results from Bukit Hari (CON) and RHT (TRT) area

Soil depth (cm)	Heavy metal concentrations															
	Total Al		Total Fe		Total As		Total Pb		Total Zn		Total Ni		Total Hg		Total Cu	
	(%)				(mg/kg)											
	CON	TRT	CON	TRT	CON	TRT	CON	TRT	CON	TRT	CON	TRT	CON	TRT	CON	TRT
0–65	9.51	6.14	2.22	5.12	Trace	0.02	63.27	30.38	28.43	43.14	6.11	34.14	ND	ND	1.45	50.35
65–80	9.93	1.64	2.81	2.11	Trace	0.12	115.24	211.86	29.60	ND	7.50	21.14	ND	ND	0.90	79.41
80–100	9.96	0.86	2.98	1.26	trace	0.19	147.62	330.24	31.97	ND	8.27	21.89	ND	ND	0.53	79.10

Table 2. Tissue analysis results from Bukit Hari (CON) and RHT (TRT) area

Tissue samples	Heavy metal concentrations															
	Fe		Al		As		Cu		Hg		Ni		Pb		Zn	
	(mg/kg)															
	CON	TRT	CON	TRT	CON	TRT	CON	TRT	CON	TRT	CON	TRT	CON	TRT	CON	TRT
Leaf	197.90	200.00	120.62	0.02	ND	12.76	9.09	9.75	ND	0.13	1.55	1.47	ND	0.51	17.1	16.83
Big roots	114.13	1500.00	265.34	0.26	0.80	11.04	1.88	3.16	ND	0.04	1.03	2.58	3.76	1.78	1.13	4.30
Small roots	ND	2800.00	ND	0.48	ND	18.22	ND	4.86	ND	0.05	ND	5.12	ND	4.88	ND	6.34

Table 3. Wood disc cross sections results from Bukit Hari (CON) and RHT (TRT) area

Wood disc (m)	Heavy metal concentrations															
	Fe		Al		As		Cu		Hg		Ni		Pb		Zn	
	(mg/kg)															
	CON	TRT	CON	TRT	CON	TRT	CON	TRT	CON	TRT	CON	TRT	CON	TRT	CON	TRT
0.3	83.04	76.64	71.23	52.42	4.02	ND	1.04	1.08	ND	ND	1.25	0.69	ND	0.45	3.13	ND
1.3	83.09	58.65	36.10	24.53	ND	1.18	0.75	1.19	ND	ND	0.63	0.91	ND	2.28	7.79	3.52
7.3	22.24	132.79	26.46	53.14	1.10	1.22	0.20	1.88	ND	ND	0.59	0.77	1.22	0.73	2.40	28.94

ND : Not Detected

CONCLUSION

We may conclude that *A. mangium* absorbed best both Al and Fe compared to other elements. Zinc and was moderately absorbed by *A. mangium* in the tin tailings. Other elements were poorly absorbed or were in trace concentrations and negligible. It is advised that tin tailings such as in the RHT area is afforested with *A. mangium*. This is because *A. mangium* is an important species for phytoremediation, and its ability to have high bioconcentration factor (BCF) and conducive for heavy metal translocation. Overall, afforestation of ex-mining sites should be actively promoted as it creates new value in terms economy and ecology. These areas can also be used for development of new forests and as potential sites for alternative crops.

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CULTIVATION AND MANAGEMENT PRACTICES OF *AQUILARIA* FOR AGARWOOD IN MALAYSIA

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ABSTRACT

Most species in the genus *Aquilaria* are agarwood-producing species and is likely to be affected by unsustainable resin collection. They are classified under Red List Category and Criteria: Critically Endangered (IUCN), 2012 and Threatened and Endangered (Appendix II, CITES, 2004). There are more than 15 known *Aquilaria* species in tropical Asia of which most are naturally found in South and Southeast Asia. Almost half of the total species are either naturally found or cultivated in Malaysia. However, among the most promising local species is *A. malaccensis*. It is also a popular species for domestication due to its distribution as well as highly sought after agarwood and other related products. However, the taxonomy of other species are either relatively unknown and their distribution are either be restricted or endemic to certain geographic regions. Agarwood is a highly prized incense, extremely rare but highly possible for domestication using good management practices and application of specific holistic technical inducement techniques, so as to luxuriously induce resin formation. The resins from these trees can be used for the production of diverse pharmaceutical, medicinal besides well-being and fragrance products. Unlike most forest plantation tree species, this species is fast-growing, hardy and can be harvested within a short rotation period through fatal harvest or sub-lethal harvest. This paper shares some early and mature growth performance of the *Aquilaria* species and discusses on some successful management practices in agarwood production.

Keywords: *Aquilaria malaccensis*, domestication, cultivation, incense, optimum growth

INTRODUCTION

The genus *Aquilaria* and *Gyrinop* from the Thymelaeaceae family produce a unique fragrant wood called agarwood or gaharu. With *ex-situ* cultivation and domestication, which can either occur within or outside a species natural geographic range, large scale planting of *Aquilaria* tree for agarwood and oil production has enormously gained momentum from many interested groups: researchers, universities, private sectors and individuals. All *Aquilaria* are agarwood-producing species and is likely to be particularly affected by unsustainable resin collection. The production of agarwood in *Aquilaria* is believed to be associated with the plant stress and defensive responses to wounding and microbial attack (Ng *et al.* 1997). Due to its high economic value, specific inducing response, slow nature of its production and great demand, indiscriminate felling of trees has led to the depletion of its natural resources. To prevent the unsustainable harvesting of *Aquilaria* genetic resources all species have been listed in Appendix II of the Convention on International Trade in Endangered Species of Fauna and Flora (CITES) since 1995 and have also been listed in the Red List of Threatened Plants published by International Union of Convention of Nature (IUCN 2014). Red List classifies these species as vulnerable base on the reduction of at least 20% over three generations caused by levels of exploitation and declined in population (Barden *et al*. 2000, Hilton-Taylor 2002). There are more than 15 known *Aquilaria* species in tropical Asia; with most found naturally in South and Southeast Asia with almost half of the total species are found and cultivated in Malaysia. It is a medium sized tree with light coloured soft wood but with no distinction in colour between sapwood and heartwood (Corner 1940, Desch 1954). It is the world most precious, expensive fragrance wood and has many long history on its uses, for religion ceremonies, medicinal values in digestive, sedative and antiemetic and perfumes. Among them, *A. malaccensis* is a very popular, well distributed, domesticated and highly sought after agarwood probably due to its rich strong spicy aroma smell.

International trade in agarwood usually involves wood, wood chips, powder, oil, and, and other luxurious finished products such as perfumes, incense and medicines (Figure 1). With this, Indonesia and Malaysia appear to be the main sources of agarwood (from all species). Despite lack of understanding on the requirements and silvicultural management of *Aquilaria* for both local and exotic species, there are other possible risk factors worth considering before venturing into planting projects (Lok & Zuhaidi 2016). These factors include comprehensive growth performance of the species at various sites, silviculture requirements, species-site suitability, molecular-genetic studies, possible marketing strategies, buyers and sellers preference and development of efficient-economic inducers for agarwood formation on cultivated trees. There are more than 2,477 ha reported to have been cultivated with *Aquilaria* species (Zahari 2013) and 3.5 million wild trees based on NFI 4 (Forestry Department Report 2002–2004) with some of the stands mature enough for inoculation and can be harvested. This paper aims to share the growth performance and discuss promising management practices for *ex-situ* cultivation of *Aquilaria*.

Figure 1. Products derived from agarwood trees: a) wood, b) wood chips and c) perfumes

MATERIALS AND METHODS

Site location

The plots in FRIM are located at about 3°14'N and 101°38'E with mean daily temperature that ranges from 27 to 30°C and annual rainfall between 2,000 to 2,900 mm. They are established in F44 on May, 1997 and F53 on April 2009, at the lower slope of the lower ridge of Bukit Hari, Selangor, Malaysia. Aspect is southerly and with an altitude of 200–220 m above sea-level. At both sites, the soil is of heavy clay loam granitic origin, reddish brown in colour with an average pH of 4.5. In F44, the trees were initially interplanted with *Azadirachta excelsa* at a planting distance of 3 x 3 m to study possible domestication in the open and growth performance with a fast growing tree while F53 was using monoculture cropping with a planting distance of 3 x 4 m. The trees were all planted with young potted seedlings obtained from the private nurseries and wilding collected at FRIM's ground. However, trees of other species were collected from other individual plots available locally at different locations.

RESULTS AND DISCUSSION

Table 1. Mean annual increment (MAI), mean diameter and height for different *Aquilaria* species

Species	Age	MAI	Mean Diameter (cm)	MAI	Mean Height (m)
Aquilaria malaccensis (FRIM)	5	2.8	14.0	2.0	9.8
Aquilaria malaccensis (FRIM)	7	3.2	22.1	2.1	14.5
Aquilaria malaccensis (FRIM)	13	1.4	18.3	1.1	13.8
Aquilaria malaccensis (FRIM)	19	2.4	45.8	1.6	30.8
Aquilaria beccariana (Sabah)	6	1.7	10.2	1.1	6.6
Aquilaria hybrid (Perak)	2	1.6	3.2	1.2	2.4
	3	3.8	11.4	1.7	5.4
Aquilaria sinensis (Selangor)	3	2.1	6.0	1.2	3.6
Aquilaria crassna (Cambodia)	6	2.1	12.6	1.3	7.8
Aquilaria crassna (Vietnam)	4	1.6	6.4	1.1	4.7

Note: n = 100 trees/plot

Table 2. Frequency of branching stems in *Aquilaria malaccensis*

Number of stems	Number of trees (%)
1	203 (62)
2	69 (22)
3	35 (11)
4	12 (4)
5	4 (1)
TOTAL	323

a) Growth performance of *ex-situ* cultivated *Aquilaria*

One of the first attempts to cultivate *A. malaccensis* in Malaysia started in 1928 (Lok & Zuhaidi 1996). The original population density of 833/ha been reduced to 31/ha by 1995. A high mortality rate was observed due to inadequate maintenance and lack of understanding on silvicultural treatments. There were several attempts carried out to domesticate this species for rehabilitation of deforested sites. Some results obtained showed that 5-year-old *A. malaccensis* is fast growing and can achieved mean annual increment (MAI) diameter and height of 2.8 cm and 2.0 m, respectively (Table 2). Similar growth rates can also be achieved by *A. crassna* and *A. sinensis*.

b) Stem numbers

High generic variations on the tree form are possible because of poor genetic selection of planting materials. Frequency of multiple stems range from one to five stems (Table 1). About one to three stems per tree are strongly recommended to maximize agarwood production. The results obtained also indicate that there are almost 62, 22 and 11% of the trees with one, two and three stems respectively.

Management practices and domestication considerations

Some of the important considerations recommended:
1. Propagation techniques by seedlings and tissue culture. Seedling is hardy, easily transported but hardening process is required for adaptation to the site.
2. It is possible to domesticate from the wild but light shade is recommended.
3. Optimum planting pattern and spacing-square planting.
4. Pruning and inducement techniques to promote optimum growth for inducement.
5. Other silvicultural treatments include tending and weeding, fertilizer treatments and pest and diseases.

Figure 2. Clear-felling and site preparation for site rehabilitation with *Aquilaria* species

Figure 3. Cultivated five years old stand of *Aquilaria malaccensis*

CONCLUSION

The demand for agarwood is predicted to increase with the depletion of natural resources. As such, there is a great concern for more conservation and preservation efforts through domestication and good management practices for *Aquilaria* species in order to sustain production of agarwood. Use of agarwood is no doubt an important commodity similar to timber products. In this aspect, more management skills should be developed with integrated strategy for conservation of *A. malaccensis* and other species for large *in-situ* and *ex-situ* cultivation.

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EFFECTS OF DIFFERENT SOIL AMENDMENTS ON GROWTH OF *BAMBUSA VULGARIS* IN EX-MINING LAND IN DENGKIL, SELANGOR, MALAYSIA

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ABSTRACT

This study was carried out at Paya Indah Wetland, Dengkil, Selangor. The objective of this study was to convert this tin tailings area into a bamboo plantation. Bamboo is an important plant that is used by many countries for soil conservation and site rehabilitation. The effects of soil modification in planting-hole using paddy husk charcoal, bamboo charcoal and woodchips compost as soil enrichment was examined. The parameters measured were survival, total height growth and shoot productions of planted *Bambusa vulgaris*. High survival rates (93–98%) were observed for all treated and control (no treatment) plots. After eighteen months of observations, the results revealed that there were no significant differences among all treatments. Numbers of new shoots produced under these different treatments were 9.2, 9.0, 8.4 and 8.3 for bamboo charcoal, woodchips compost, paddy husk charcoal and control plots, respectively. Bamboo charcoal showed highest number of new shoots produced while paddy husk charcoal treatment produced highest mean clump height at 3.72 m. Findings from this study indicated that soil enrichment improves survival rate, production of new shoots and mean clump height of bamboos compared to those in non-treated control plots.

Keywords: Degraded, soil enrichment, charcoal, *Bambusa vulgaris*, shoots production

INTRODUCTION

Bamboo is a woody grass belonging to the sub family *Bambusoideae* of the family *Poaceae* (*Gramineae*). There are 59 known species of bamboo in Malaysia (Wong 1995). The Genera found in Malaysia are *Bambusa, Dendrocalamus, Dinochloa, Gigantochloa, Racemobambos, Schizostachyum, Thyrsostachys, Chusqua, Phyllostachys* and *Yushania* (Azmy *et. al.* 1997). It thrives best in sites with well-drained sandy to clay loam soils with slight acidic condition of pH 5.0–6.5 (Amir Saaiffudin *et al*. 2014). In Malaysia, bamboos have been found on hillslope, riverbanks, logged-over areas and flat land. The vegetation can be of pure stand or mixed with other tree species in the forest (Ng & Md. Noor 1980). Bamboo can grow on degraded and marginal soils even where many plant species have difficulty to be established. It has also been used by many countries for soil conservation and site rehabilitation. A study by Abd Razak (1991) showed that *Bambusa vulgaris*, compared to other bamboo species, can grow well on tin tailings provided soil treatment is given and proper fertilizer is applied. Converting degraded and marginal land into plantations of bamboo can restore canopy cover, reduce soil erosion and stabilize water tables. It can also provide revenue for communities in surrounding areas.

Tin tailings area in Malaysia consist of 80% sand tailings on which it is difficult to establish vegetation because of the absence of soil organic matter and the predominance of coarse materials (Lim *et al.* 1981). A key strategy for amending this type of soil is by manipulating the content of soil organic matter which helps to induce positive soil micro-ecosystem and increase plants productivity. Soil treatment and initial application of fertilizers are known to increase the number of culms produced, density and growth rates. These practices also help to improve the organic matter content, stability and nutrient-retention ability of the soil. Hence, this study aims to determine the effects of using different types of organic soil treatments on survival, shoot production and growth performance of *B. vulgaris* planted on degraded tin tailing site.

MATERIALS AND METHODS

The trial was established at Paya Indah Wetland Wildlife Sanctuary. The area is located approximately 8 km west of Dengkil town (02° 52 11.7' N 101° 36 55.3' E) and 28 m above sea level. The land slopes were between 3° and 5° with average temperature of 28.2°C. The average rainfall is 2,287 mm a year. This area receives high rainfall in the month of October and November. Paya Indah Wetland is a tin tailings area and has problematic soil characterized by heterogeneous layers consists of sand, silt, clay, gravel and decomposed organic materials. The soil drainage is well to moderately well-drained and has a good permeability. Three subsamples of the soil were taken randomly from each replicate to prepare a composite sample at soil depth of 0–25 cm and 25–65 cm from the soil surface. The samples were brought to laboratory for analysis. To prepare for planting, the site had been clear-felled using excavators and the slashed piles were stacked at the distance of 20 m apart. In order to minimize soil disturbance, the stacking is made tight and included as little soil as possible.

Branch cuttings of *Bambusa vulgaris* were used as planting materials. They were collected from healthy culms before being potted in 9 x 12 inches polybags for four months to allow the development of roots. Larger planting holes (60 x 60 x 50 cm) were adopted with a spacing of 5 m x 5 m which is equivalent to 400 culms/ha. At the time of planting, the root ball was lowered to 20 cm below the sand surface to allow better water retention near the root zone.

The soil treatments used were paddy husk charcoal, bamboo charcoal and wood chips compost. The materials were then weighted at 6 kg/hole before being crushed finely and mixed with the dug up soil. The soil mixture were put into the planting hole and firmly packed around the saplings. Treatments were arranged in a randomized complete block design (RCBD) with two replications of three soil treatments and a control plot. Each replicate consisted of 6 subplots of 16 saplings (4 lines x 4 saplings). The four treatments were randomly assigned within the subplots in each replicate. A total of 384 saplings (2 replicates x 12 subplots x 16 saplings) were planted in this trial site.

The plots maintenance was done mechanically by clearing the competing vegetation using brush cutter. The frequency of clearing varied with the growth rates of competing vegetation. Measurements were done at four months intervals in the first year and six months afterwards (0, 4, 8, 12 and 18 months). The parameters measured were the number of new culms and clumps height. The survival rate was calculated by counting the number of surviving clumps in every treatment after eighteen months of planting. Statistical analysis of differences between treatments was analyzed using SAS version 9.1 PROC GLM (Generalized Linear Model) and the significance level was set at 0.05.

RESULTS AND DISCUSSION

The soil was slightly acidic (pH 3.5–3.6) with very low cation exchange capacity (CEC) of 1.96 cmol/kg at the surface layers (0–25 cm). The organic C content is moderate (0.9–1.5 %) and the available nutrient contents of the soil were to be judged as low to very low. The soil properties of the study site are presented in Tables 1 & 2.

Table1. Soil chemical properties at study site

Soil Properties	Soil Depth (cm)	
	0–25	25–65
Organic C (%)	0.9	1.5
Total N (%)	0.25	0.36
Available P (mg/kg)	1.60	2.50
K (cmol/kg)	0.02	0.08
CEC (cmol/kg)	1.96	18.5
pH (water)	3.50	3.60

The soil texture of top layer (0–25 cm) consists of sandy loam to sandy clay loam mixed with or without gravel, colour ranges from very dark grayish brown (10YR 3/2) to grayish brown (10YR 5/2). At the depth of 45–80 cm, the soil texture consists of clay loam and the colour is yellowish brown (10YR 5/8). The soil is well-drained and has good permeability.

Table 2. Soil physical properties at study site

Soil Properties	Soil Depth (cm)	
	0–25	25–65
Coarse sand (%)	44	24
Fine sand (%)	23	16
Silt (%)	15	23
Clay (%)	24	41

The mean total number of new culms produced and the survival rate from the different soil treatments are shown in Table 2. The survival rate at age 1.5 years ranges from 93–98 %. The highest survival of 98% was recorded by T1 (paddy husk biochar) followed by T3 (wood chips compost) and T2 (bamboo biochar). Lowest survival of 93% was observed in T4 (control) plots. The stand mortality was mainly caused by the occurrence of drought season in May–July 2015. With proper soil treatment and fertilization, a two years old *B. vulgaris* stand in a sand tailings site has recorded survival of 92% (Abd Razak 1991).

The analysis for differences of culms production across 1.5 years of observation from different soil treatments (Table 3) confirms that the initial height growth and mean new culms production was not significantly affected ($p<0.05$) by the soil treatments. Mean new culms productions for treated soil were higher compared to the non-treated control soil. The analysis showed that T2 (bamboo charcoal) ranked top followed by T3 (wood chips compost). The lowest new culms production were recorded in T4 (control) and T4 (paddy husk charcoal) which produced only 8.3 and 8.4 new culms, respectively. The clumps mean height data shows that paddy husk charcoal and bamboo charcoal ranked highest while non-treated control produces the shortest clumps during this observation period.

Table 3. New culms production, mean total height and culms survival 18 months after planting

Treatment	Soil treatment	Mean new culms productions	Mean clumps height (m/yr)	Survival (%)
T1	Paddy husk charcoal	8.4[a]	3.7[a]	98
T2	Bamboo charcoal	9.2[a]	3.7[a]	95
T3	Wood chips compost	9.0[a]	3.6[a]	97
T4	Control	8.3[a]	3.3[a]	93

Note: Values with the same letters are not significantly different ($p>0.05$)

Physicochemical properties of biochar or charcoal such as high porosity, high surface area, high charge density, high cation exchange capacity, high plant available nutrient contents and sometimes high pH associated with biochar have contributed in improving soil fertility (Glaser *et al*. 2002). It has been suggested that biochar amendments could lead to a change in the microbial community in soils, both in structure, abundance and activity (Lehmann *et al*. 2011). However, there are few trials which show insignificant differences in soil organic matter level by the application of diverse carbon sources (straw, manure, compost). Compost is also known to create a favorable environment to plant and root growth.

CONCLUSION

The results from this trial, after 1.5 years, are relatively early in the rotation and more obvious differences are likely to appear over the next few years. These current analyses provide early indications on growth performance and survival of *B. vulgaris* towards soil treatments in this specific site. The analysis showed no significant difference between means of new culms production for all treated and non-treated soils. Bamboo charcoal soil treatment gave highest number of new culms production with 11% more new culms compared to the non-treated soil. This soil treatment also gave high survival rate (95%) and was able to be very productive under the limitations of this particular site. Charcoal and compost application to soil does influence various soil physico-chemical properties due to the high specific surface area of charcoal, higher ability of nutrient retention and thus nutrient availability were enhanced after its application. The choice of using soil treatment should therefore based on successful field trials with regards to the habitat requirements of this species.

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IDENTIFYING FRAMEWORK TREE SPECIES FOR RESTORING FOREST ECOSYSTEMS IN SIEM REAP PROVINCE, CAMBODIA

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ABSTRACT

This study identified framework tree species for restoring forest ecosystems in Siem Reap Province. Framework species are those that thrive on exposed deforested sites, shade out weeds and attract seed-dispersing animal. We compared initial field performance (survival and growth) among 19 indigenous forest tree species and determined the extent to which each of them met framework species field performance criteria. Furthermore, the effects of fertiliser treatments were tested in a randomized complete block design experiment, with three to four replicates and four treatments. Eight species were classified as excellent framework species based on previously established field performance standards namely *Gardenia sootepensis* Hutch, *G. angkorensis* Pit., *Canarium subulatum* Guill, *Dalbergia cochinchinensis* Pierre, *Hopea odorata* Roxb., *Xylia xylocarpa* (Roxb.), *Shindora siamensis* Teysm .ex Miq.var. Siamensis and *S. siamensis* Teysm.ex Miq.var cochinchinensis whilst nine others were ranked as “acceptable”. Fertilisers significantly increased survival but had little or no significant effect on growth. The most effective fertilizer treatment was 100 g NPK, applied three times in each of the first and second rainy season after planting, immediately after ring-weeding around the planted trees.

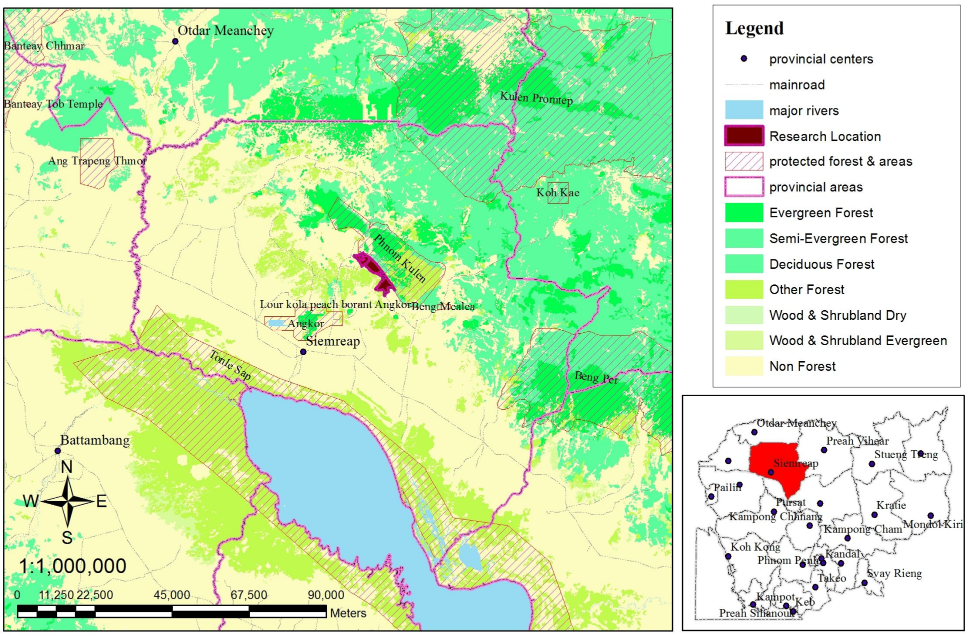
INTRODUCTION

Deforestation and forest degradation are major concerns in Cambodia. Consequently, efforts are underway to reforest thousands of hectares. One of the most promising methods of forest restoration is the framework species technique (Elliott *et al.* 2013). Framework tree species are native tree species with high survival and growth rates when planted out into exposed deforested sites, have dense spreading crowns to shade out weeds and serve as provision of wildlife resources, at an early age, to attract seed-dispersing animals. The technique was first conceived in Queensland, Australia (Goosem & Tucker 1995) and has since been adapted to restore various forest types in Thailand by Chiang Mai University’s Forest Restoration Research Unit (FORRU-CMU) (Elliott *et al.* 2013). The method rapidly increases forest biomass (and carbon storage) and structural complexity, recovers biodiversity and restores ecological functioning. From 2005 to 2011, the Forestry Administration and FORRU-CMU collaborated on a project to test the effectiveness of the technique to restore seasonally dry tropical forests in Siem Reap Province, funded by the UK's Darwin Initiative. In this paper, we report on trials designed to select appropriate framework species for the study area and on experiments that tested the effects of fertilizer on field performance.

MATERIALS AND METHODS

<u>Study site description</u>

The study site was a highly degraded former forest land in the buffer zone of Phnom Kulen National Park located at latitude 13°34.047'N & longitude 104°2.985'E, elevation 85 m above sea level with annual rainfall approximately 1,559 mm per year and relative humidity 79.3%. The area was dominated with grasses and other herbs, interspersed with natural regenerants[2]. The forest condition in the experimental plot was completely degraded due to encroachment for farming and settlement, land speculation and illegal logging. The site is part of the catchment area for the Siem Reap River which flows into Tonle Sap Lake.



<u>Rapid site assessment</u>

A baseline vegetation survey was carried out with circular sample plots of 5 m radius. Within each circle, all natural regenerants were counted, signs of fire or cattle and soil conditions recorded and the cover and average height of herbaceous weeds estimated (Sobon 2013). Estimated density of natural regenerants was 2,667/ha in 2010 and 2,474 in 2011.

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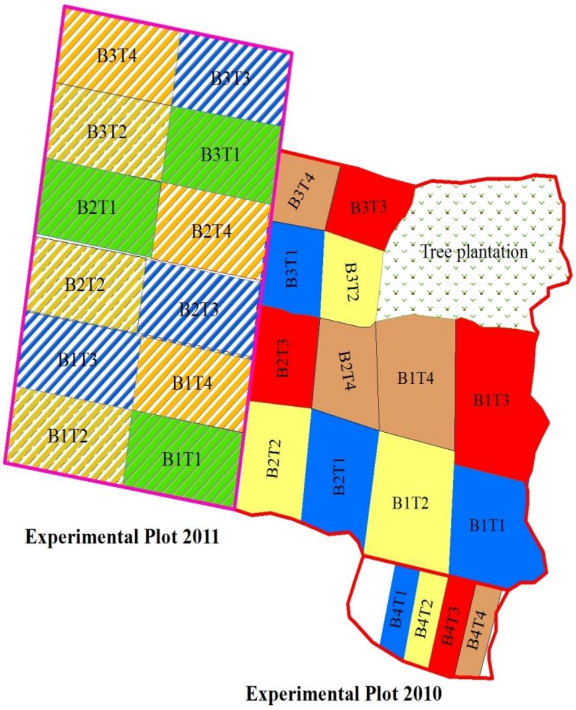
[2]Naturally occurring tree seedlings & saplings >1m tall, mature trees and live tree stumps, capable of coppicing.

Experimental design

In June 2010, 3.25 ha were planted with 1,440 saplings of nine candidate framework tree species (divided into four blocks and 16 plots). In June 2011, 3 ha were planted with 1,800 saplings of 10 species (divided into three blocks and 12 plots). Soil samples were collected from the plots and analyzed for NPK and pH. Four fertilizer treatments were tested in each of the planting years: in 2010, 50 g and 100 g NPK: 15-15-15, and 50 g and 100 g Taiwan organic: 10-5-2 (4 replicates), and in 2011, 50 g and 100 g organic: 3-3-2, and 50 g and 100 g NPK ($NP_2O_5K_2O$): 16-16-8 (three replicates). Saplings were planted 1.8 m apart from each other or from natural regenerants to raise total stocking density of natural + planted trees to 3,100/ha. Standard planting and tree care procedures followed FORRU (2008) and are detailed in Sobon (2013). Weeding and fertilizer treatments were applied every four to six weeks during the first and second rainy seasons, three times per rainy season in total. Fire breaks were cleared and fences were constructed to protect the trees from cattle. Baseline monitoring was carried out one day after planting and at the end of the first and second rainy seasons. All labelled trees were monitored. Tree height and crown width were measured. Root collar diameter (RCD) was measured using Vernier calipers. A simple health score was assigned to each tree on a scale of 0 to 3; 0 if the tree appeared to be dead, 1 for trees in very poor condition, 2 for trees showing some signs of damage but retaining some healthy foliage and 3 for trees in perfect or nearly perfect health.



Data Analysis

Survival and growth data, relative growth rates for height (RGRH) and root collar diameter (RGRRCD), were transformed and analyzed using one-way ANOVA to compare field performance among species and the effectiveness of the various fertilizer treatments on performance parameters following standard procedures (FORRU 2008).

RESULTS & DISCUSSION

Species performance

Nine of the 19 species tested attained excellent survival rates (exceeding 70%) at 18 months after planting: *Walsura trichostemon* Miq, *Shorea. siamensis* Teysm. ex Miq. var. *siamensis*, *S. siamensis* Teysm. ex Miq.var. *cochinchinensis*, *Canarium subulatum* Guill, *Cratoxlum cochinchinensis* (Lour.) Bl., *Hopea odorata* Roxb. var. *odorata*, *Gardenia sootepensis* Hutch, *Xylia.*

xylocarpa (Roxb.) Taub. var. *kerrii* and *Dalbergia cochinchinensis* Pierre in Lan. Nine others attained acceptable survival (50–69%): *Knema globularia* (Lam.) Warb, *Hydnocarpus ilicifolia* King Common, *Diospyros ehretioides* Wall.ex G.Don and *Diospyros sylvatica* Roxb.

Five species achieved excellent growth, attaining mean heights of ≥1 m by the end of the second growing season: *C. subulatum*, *H. odorata*, *G. sootepensis*, *X. xylocarpa* var. *kerrii* and *D. cochinchinensis*. These species also attained acceptable or marginally acceptable mean crown widths of up to 1 m. Canopy closure is initiated when mean crown width exceeds 1.8 m (FORRU, 2008).

Effects of fertilizer treatments

i) Survival

Averaging across species for the plots in year 2010, 100 g NPK fertilizer (15-15-15) significantly increased survival (p=0.015) compared with other treatments. In 2011, the plots fertilized with both 100 g NPK (16-16-8) and 100g organic fertilizer (3-3-2) significantly increased survival (p= 0.000) compared with other treatments.

ii) Growth

The effects of different fertilizer treatments on growth (RGRH and RGRRCD) were insignificant. Averaging across species for trees planted in 2010, highest RGRH (42.69 ± 18.93%/year) was obtained with 50 g NPK fertilizer (15-15-15) and lowest (39.71 ± 22.04 %/year) with 100 g Taiwan Organic fertilizer (10-5-2). In the 2011, highest RGRH (52.62 ± 15.33%/year) was obtained with the 100g NPK fertilizer (16-16-8) and lowest (34.48 ± 15.73%/year) with the 50 g NPK fertilizer (16-16-8). Averaging across all species, for tree planted in 2010, highest RGRRCD was attained with 100 g NPK (15-15-15) (70.25 ± 28.23 %/year) and lowest with 50 g Taiwan Organic (10-5-2) (52.15 ± 28.69%/year). In the 2011 plots, highest growth was attained with 100 g Organic (3-3-2) (55.03 ± 20.40%/year) and lowest with 50 g NPK (16-16-8) 50g (35.48 ± 24.94%/year).

CONCLUSION

Tree framework species selection

Considering both survival and growth, eight of the tested species are highly recommended as excellent for planting to restore lowland deciduous forests in Siem Reap province (according to standards established by Elliott *et al.* (2003): *Gardenia sootepensis* Hutch, *Gardemia angkorensis* Pit, *Canarium subulatum* Guill, *Dalbergia cochinchinensis* Pierre, *Hopea odorata* Roxb., *Xylia xylocarpa* (Roxb.), *Sindora siamensis* Teysm .ex Miq.var. Siamensis (Banla) and *Sindora siamensis* Teysm .ex Miq.var.cochinchinensis (Khnam banla). Species with moderate growth but broad crowns may also be acceptable if mixed with other higher performing species: *i.e. Afzelia xylocarpa* (Kurz) Craib, *Knema globularia* (Lam.) Warb, *Dialium cochinchinensis* Pierre, *Diospyros sylvatica* Roxb, *Walsura trichostemon* Miq, *Diospyros ehretioides* Wall.ex G.Don, *Cratoxlum cochinchinensis* (Lour.) Bl., *Dioecrescis* *erythroclada* (Kurz) Tirv. and *Hydnocarpus anthelmintica* Pierre ex Lanes. These species may also be suitable for similar seasonally dry tropical forest ecosystems across Indochina, but further testing in other areas is advised.

Effectiveness of fertilizer on sapling performance

Fertilizers significantly increased sapling survival ($p \leq 0.05$) and height/diameter growth. Failure to detect a significant growth response to fertilizer is counter-intuitive and requires further investigation. NPK fertilizer 100 g (15-15-15) and 100 g NPK (16-16-8) were the most effective fertilizer treatments. However, an economic analysis is required to determine if application fertilizer to increase survival rates only is cost-effective.

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STATUS AND CONSERVATION OF THREATENED TREE SPECIES IN VIETNAM

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ABSTRACT

Biodiversity conservation has been a long-term goal of decision makers. However, global deforestation has pushed many species to the risk of extinction, while threatening numerous other species. Despite huge restoration and conservation efforts around the world, threatened species have been steadily added into the IUCN Red List. The status and conservation of threatened tree species in Vietnam is presented in this paper.

INTRODUCTION

Vietnam is located in one of the 25 world's biodiversity hotspots (Myers *et al*. 2000). The high variability in tropical monsoon climate in combination with complex terrain of Vietnam have supported various forest types ranging from tropical to semi-temperate forests (Pham *et al*. 2006) which are home to many endemic species. Forest resources play critical roles in supplying the needs for livelihoods, foods for millions of people, and provided important biological, ecological and economical values. However, forests have been facing multiple threats. The loss of a large proportion of forest areas and many species are clear and the consequences to biodiversity are huge. There are lots of concerns about the loss of the hidden values of vanishing species and their habitats. Therefore, conservation of these species has been put under an ever-increasing pressure. Over the last two decades of conservation programmes, Vietnam has reached further in conservation of indigenous and threatened tree species. This paper presents on: (1) the new challenges in conservation of threatened tree species; (2) the status of IUCN Red List tree species in Vietnam; and (3) summary of achievements over two decades of conservation of threatened tree species in Vietnam.

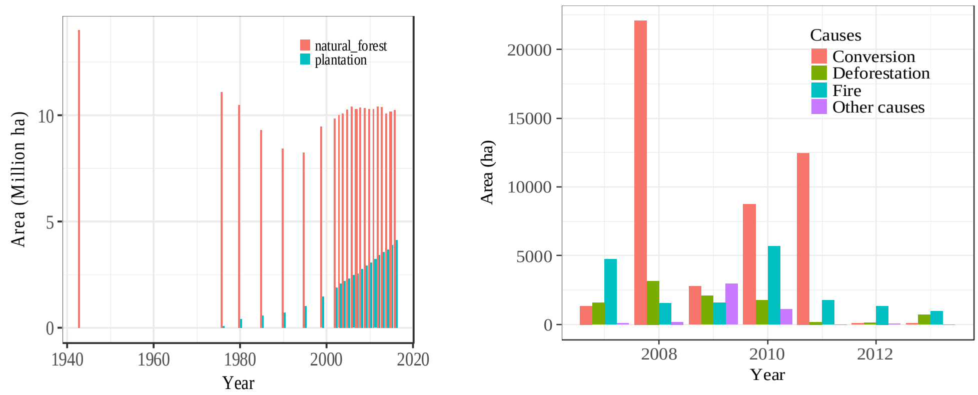
MATERIALS AND METHODS

Statistics, legal and scientific documents related to status and conservation of IUCN and Vietnam red list were reviewed from the literature.

RESULTS AND DISCUSSION

Forests in Vietnam and new challenges for conservation of threatened species

The forest areas in Vietnam significantly decreased before the 1990s but have rapidly recovered over the last two decades due to steady increase of plantation areas (Figure 1a). Before the 1990s, the main causes of forest loss were direct and indirect effects of the wars (e.g., bombarding, chemical spraying, etc.), post-war forest clearance for agricultural cultivation and logging (legally and illegally).

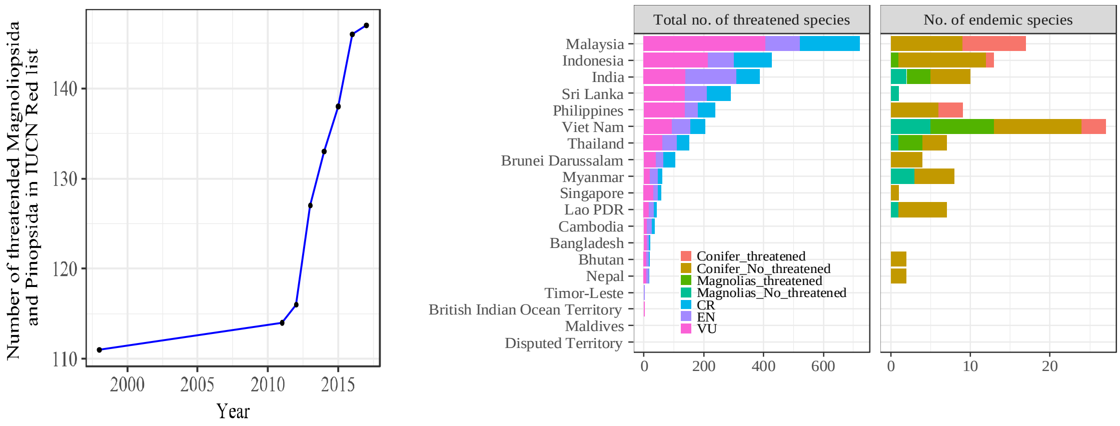


(a) (b)

Figure 1. (a) Forest areas of Vietnam from 1943–2016 (Source: http://www.kiemlam.org.vn/); (b) Major causes of forest loss 2007–2013 (Source: http://www.kiemlam.org.vn)

The major causes of species and habitat loss after 2000s were forest clearance, forest fire and forest logging (legally and illegally) (Figure 1b). Over the last two decades, hundreds of thousand hectares of forests were cleared for agricultural production and infrastructure development, particularly for constructing hydropower plants. For example, Vietnam had only a few hydropower plants before 2000s but this figure has surged to nearly 1,000 including all small, medium and large ones after 2000s (Le & Dao 2016). Forest destruction for construction of hydropower plants and other associated infrastructure has significant influences on the biodiversity, particularly habitats of various species (Anonymous 2009, Le & Dao 2016).

Since 2000s, despite the increase in forest areas, threatened species have been annually added to the IUCN Red List (Figure 2a). Vietnam was ranked sixth out of 19 countries in South and Southeast Asia in the number of IUCN Red List species, but first in the number of endemic conifers and magnolias species (Figure 2b).



(a) (b)

Figure 2. (a) Accumulated curve for the number of threatened Magnoliopsida and Pinopsida of Vietnam in IUCN Red List from 1998–2017 (Source: http://www.iucnredlist.org/); (b)The number of endemic conifer and magnolia species of South-Southeast Asia in IUCN Red List updated in May 2017

Millions of people in the mountainous areas of Vietnam depend on resources from natural forests for their livelihood yet most of these forests are now protected. The high market demand for precious timbers, non-timber forest products, foods and other resources from the forests have promoted illegal logging and harvesting of forest resources.

Vietnam has joined IUCN since 1993. Based on IUCN criteria and categories, the first Vietnam Red List was published in 1994 (for animals) and 1996 (for plants). The latest Vietnam Red List of plant was published in 2006 which included 282 Magnoliopsida and 26 Gymnosperm species (Nguyen *et al.* 2007). The Decree 32/2006/ND-CP of the Government listed 13 species of group I (i.e., prohibiting exploitation and use for commercial purposes) and 31 species of group IIA (i.e., restricting exploitation and use for commercial purposes). Decree 160/2013/ND-CP of the Government also listed 17 threatened, precious and rare species for protection and conservation priorities.

<u>Rehabilitation, restoration and conservation of IUCN Red List species</u>

i) Rehabilitation and restoration

Forest rehabilitation and restoration in Vietnam have focused on afforestation and reforestation using exotic and indigenous species. In the Decision No. 1976/2014/QD-TTg of the Government, the country planned, by 2020 and towards 2030, to establish 176 restricted areas (totalling 2.4 million ha), including 34 National Parks, 58 natural reserve areas, 14 habitat/species conservation areas and 61 landscape conservation areas and forests for research.

Studies related to conservation of threatened species in Vietnam range from genetic to habitat levels. These studies have focused on understanding: (1) the distribution, (2) the ecology and genetic varieties, (3) seed collection, seed storage and vegetative propagation and (4) developing *in-situ* and *ex-situ* conservation methods for threatened species.

There are many threatened species but with limited resources for conservation. Conservation strategies of the country (Nguyen 2000) are focused on: (1) threatened, scientifically valuable tree species, (2) threatened, economically valuable tree species and (3) threatened, important tree species for planting.

ii) Conservation of IUCN Red List species and local red list species

Over the last two decades, the Government has promulgated dozens of legal documents supporting the protection, conservation and development of threatened and indigenous species (Figure 3). The Government also has regular funding for forest tree genetic conservation programmes. The conservation activities of Vietnam have also received lots of support from international organisations.

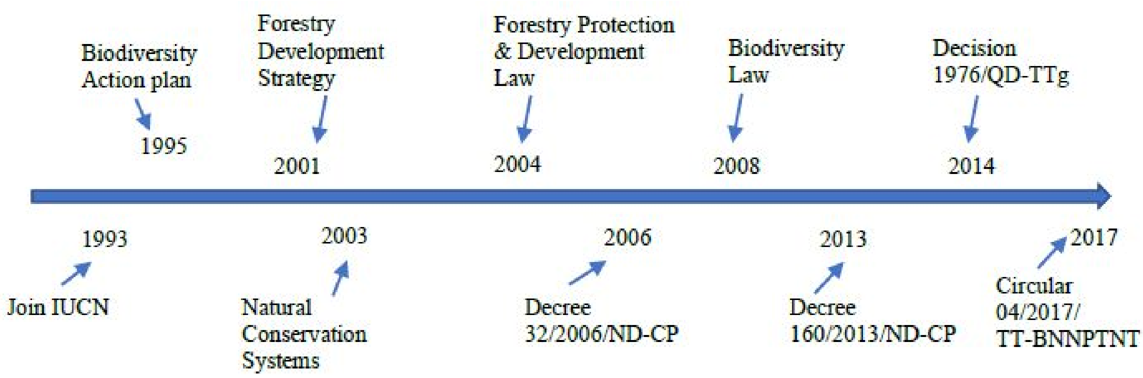


Figure 3. Major legal documents related to biodiversity conservations

Several major achievements of the projects on genetic resource conservation of forest trees (Nguyen 2006, Phi 2016) over the last two decades are:

(1) More than 1,000 mother trees selected from different provenances of nearly 100 indigenous species and more than 20 exotic species for genetic conservation;
(2) Genetic diversity of tens of indigenous species evaluated;
(3) A seed bank that contains seeds of a few thousands tree species established;
(4) Seedlings successfully produced by vegetative propagation method for some threatened species, yet some remain difficulties;
(5) Hundreds of hectares of *ex-situ* conservation established and
(6) Level threat for hundreds of gymnosperm and angiosperm species, and more than 200 bamboo species evaluated.

The challenges in conservation of threatened species as drawn from several projects are:

(1) They have narrow distribution, small population size, and often occur on high mountainous areas;
(2) Their seed production is highly variable resulting in difficulties in seed collections;
(3) The seeds are often not viable for a long time, resulting in difficulties in seed storage;

(4) Seedling mortality rate is high due to many reasons (particularly diseases and shading regimes);
(5) Some species are very difficult to produce by vegetative propagation methods;
(6) Their habitats have been continually destroyed;
(7) Many species have been highly sought after by illegal hunters for trading in black markets;
(8) Lack of funding for developing *in-situ* and *ex-situ* conservation strategies for threatened species.

CONCLUSION

Although the forests areas of Vietnam have steadily increased over the last two decades but the number of threatened species also increase. In the new era, biodiversity management is facing new challenges which will require better management and more sustainable approaches to benefit both human and nature. More efforts should be given to evaluate the status of threatened species to propose timely conservation methods.

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POPULATION OF THREATENED DIPTEROCARP SPECIES IN THE FORESTS UNDER VARIOUS PAST DISTURBANCES IN THE DONG NAI BIOSPHERE RESERVE, SOUTHERN VIETNAM

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ABSTRACT

Dipterocarpaceae holds their eminence as the family of the world's tallest tree species in the tropics and the family with numerous high commercial timber values. More than 70% of the species of the family were threatened. The species of Dipterocarpaceae predominate the forests in the central and the south of Vietnam. While 76% of the Dipterocarp species in Vietnam were threatened, little is known about their population in the natural habitats. We investigated the population of these species in three forest types under various past disturbances in the Dong Nai Biosphere Reserve aiming to propose appropriate methods for conserving these species.

INTRODUCTION

Dipterocarpace is an important tree family with a large proportion of high timber value species (Appanah 1998, Nguyen 2005). The family includes an estimate of 600 species occurring in Asia, Africa and South America (Nguyen 2005), but the majority of these species occur in Asia. In South and Southeast Asia only, there are 361 threatened and 3 extinct species in the IUCN Red list 2017. In Vietnam, a total of 42 deciduous and evergreen dipterocarp species had been identified (Nguyen 2005) and 32 of them (all evergreen) were threatened as in the IUCN Red list 2017. Some of the dipterocarp species in Vietnam are widespread across the country but most of them are restricted to and highly concentrated in the Central and the South of Vietnam. Over the past few decades, dipterocarp forests in the south of Vietnam were severly damaged in quality and quantity mainly due to the war, logging and land use conversion. The Dong Nai Biosphere Reserve, which spread over an area of 969,781 ha in the south of Vietnam, is recognized by UNESCO as the 580th's world Biosphere Reserve. One of the important missions of the Dong Nai Biosphere Reserve is to conserve the large native habitats, including the dipterocarp species, which are also homes to its unique fauna and of critical cultural values to the local people. Of the 32 threatened species in Vietnam, at least 14 of them occur in the Dong Nai Biosphere Reserve. Despite the importance of high conservation value species in this area, little is known about the population of these species. We study populations of the threatened Dipterocarp species in native ecosystems of the Dong Nai Biosphere Reserve and investigate the patterns of the populations that were subjected to various disturbance types in the past. This study aims to propose appropriate conservation methods for these high conservation value species/forests.

MATERIALS AND METHODS

In order to understand the structure and biodiversity of the forests in the Dong Nai Biosphere Reserve after recovering for 20–35 years from various disturbances, a network of 143 study plots of 1,000 m^2 were randomly established across the area in 2015 and 2016. These included 119 plots in evergreen forest (111 logged-over forest, six Agent Orange spraying and two undisturbed forests), 11 plots in forests mixed with bamboo (Mixed-forest) and 13 plots in semi-deciduous forests. Measurements for diameter at breast height (DBH) were conducted on trees ≥ 10 cm DBH in 1,000 m^2 plot (plot D; 50 x 20 m); trees of 5–10 cm DBH were measured in one 100 m^2 sub-plot (plot C) at the central of the plot D; trees of 1–5 cm DBH were measured in two 10 m^2 sub-sub-plot (plot B) at the two opposite corners of the plot D; all seedlings (DBH < 1 cm) were measured in 20 plots measuring 1 m^2 each (plot A) arranged in a grid of 12.5 x 5 m within plot D. Here, we only present the information on their population, structure and regeneration status of threatened dipterocarp species in IUCN Red list.

RESULTS & DISCUSSION

<u>Population of the threatened species in the Dong Nai Biosphere Reserve</u>

There were a total of 1,272 individuals (DBH ≥ 1 cm) from 11 threatened dipterocarp species occuring across 143 investigated plots and subplots (plots B and C; number of trees has not been scaled up to plot level) (Table 1). Most of the threatened dipterocarp species restrictly occured in the evergreen forests, suggesting the importance of conserving this forest type for high conservation value species/habitats of the Dipterocarps.

The population of *Hopea recopei*, *Dipterocarpus dyeri* and *H. pierrei* in the native habitats remained relatively high, particularly *H. recopei*, while the population of the other species were (critically) low (Table 1). *Hopea recopei* not only had a very high population density but was also found in all natural forest ecosystems of Dong Nai Biosphere Reserve. Of the three critically endangered species, *D. dyeri* was abundant in the evergreen forest and sometimes found in the semi-deciduous and mixed-forests, yet only two individuals of *Shorea falcata* and three individuals of *D. baudii* were found. Similarly, the other endangered and vulnerable species such as *Shorea roxburghii*, *Vatica cinerea*, *Anisoptera costata* and *H. odorata* occured at a very low frequency in the natural ecosystems (Table 1).

Table 1. Population of threatened dipterocarp trees (DBH ≥ 1 cm) in 143 study plots

No	Species	Threatened category (IUCN 2017)	Evergreen	Semi-deciduous	Mixed-forest	Total
1	*Shorea falcata*	CR	0	2	0	2
2	*Dipterocarpus baudii*	CR	3	0	0	3
3	*Dipterocarpus dyeri*	CR	196	1	2	199
4	*Hopea recopei*	E	922	16	6	944
5	*Dipterocarpus costatus*	E	10	1	0	11
6	*Dipterocarpus alatus*	E	31	0	1	32
7	*Hopea pierrei*	E	68	0	0	68
8	*Shorea roxburghii*	E	1	0	0	1
9	*Vatica cinerea*	E	2	0	0	2
10	*Anisoptera costata*	E	5	0	0	5
11	*Hopea odorata*	VU	5	0	0	5
	Total		1,243	20	9	1,272

Note: CR = Critically endangered; E = Endangered; VU = Vulnerable

<u>The structure of the endangered species</u>

Most of the species that occured at low frequency (i.e., *S. falcata, D. baudii, S. roxburghii, V. cinerea*, *A. costata*) were less than 30 cm DBH (data not shown). Interestingly, one *H. odorata* of 158 cm DBH was found (Figure 1). The N/D structures of the five most abundant threatened dipterocarp species (Figure 1) showed that *D. costatus* had a few remaining individuals above 20 cm DBH but no trees below this size were found. A number of individuals above 60 cm DBH remained in the structure of *D. dyeri*, yet trees of this size rarely occured in the population of the other four threatened dipterocarp species (Figure 1). Although *H. recopei* had the highest population density among the studied species, most individuals of this species were below 40 cm DBH. *Dipterocarpus alatus* and *H. pierrei* had low population density but most individuals were also below 40 cm DBH which suggests that there might be only few mother trees for these species at landscape scale.

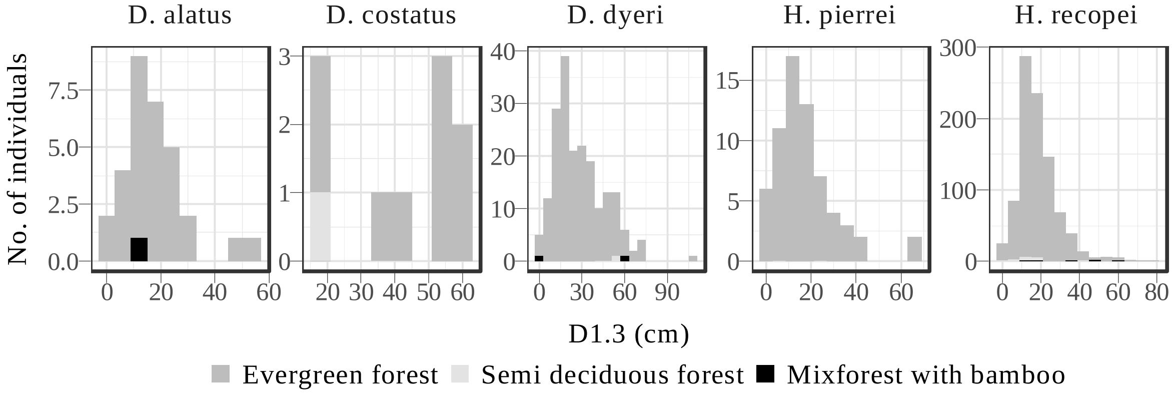

Figure 1. N/D distribution of five most common threatened dipterocarp species in 195 plots

Hopea recopei, *D. dyeri* and *D. alatus* occured on a wide range of disturbed sites (Table 2). Notably, these three species were also found on the sites that were heavily disturbed by chemical spraying (Agent Orange) during the war. The other species have restricted occurrence on harvested or undisturbed sites, yet they tended to occur more frequently on selectively harvested than depleted harvest sites. Interestingly, all 68 individuals of *H. pierrei* were found only in the forests that were selectively harvested. This may suggest that the light regime or the site conditions of the selectively harvested forests were more appropriate for *H. pierrei* than those of the depeleted harvest sites.

Table 2. The occurrence of threatened dipterocarps under various past disturbance types

Species	Agent Orange spraying	Depleted harvest	Selected harvest	Undisturbed forest	Total
Shorea falcata	0	0	0	2	2
Dipterocarpus baudii	0	0	3	0	3
Dipterocarpus dyeri	4	59	129	7	199
Hopea recopei	53	520	366	5	944
Dipterocarpus costatus	0	1	10	0	11
Dipterocarpus alatus	2	19	11	0	32
Hopea pierrei	0	0	68	0	68
Shorea roxburghii	0	1	0	0	1
Vatica cinerea	0	2	0	0	2
Anisoptera costata	0	1	4	0	5
Hopea odorata	0	1	3	1	5
Total	59	604	594	15	1,272

Regeneration

In total, 854 seedlings (DBH < 1 cm) of eight (out of 11) threatened dipterocarp species were found in plot D with 143 plots (not scaled up to plot level). Two distinct features in the structure of the seedling layer of the threatened dipterocarp species were the decrease in the number of seedlings as the height classes increased and the lack of seedlings above 1 m tall was critical (Table 3). While *D. dyeri* was abundant in the tree layer with many trees of reproductive sizes, only four seedlings of this species were found. Notably, seedlings of *H. recopei* and *H. pierrei* of all height classes were found and accounted for 93% of the seedlings. Eight seedlings of *H. recopei* also occurred in chemical sprayed sites but no seedling of other species was found on these sites.

Table 3. Number of seedlings of threatened dipterocarp species by height classes and forest types

Species	Forest type	<0.2 m	0.2–0.5 m	0.6–1.0 m	1.1–1.5 m	1.6–2.0 m	Total
Shorea falcata	Evergreen forest	0	0	1	0	0	1
Dipterocarpus baudii	Evergreen forest	0	6	0	0	0	6
Dipterocarpus dyeri	Evergreen forest	1	3	0	0	0	4
Hopea recopei	Evergreen forest	489	117	49	21	12	688
Hopea recopei	Semi-deciduous forest	10	4	4	3	0	21
Hopea recopei	Mixed forest with bamboo	27	6	5	0	1	39
Anisoptera costata	Mixed forest with bamboo	0	0	0	0	1	1
Dipterocapus alatus	Evergreen forest	1	1	0	0	0	2
Hopea pierrei	Evergreen forest	0	21	10	15	3	49
Anisoptera costata	Evergreen forest	10	3	0	0	0	13
Hopea odorata	Evergreen forest	14	12	3	1	0	30
Total		552	173	72	40	17	854

CONCLUSION

This study provided a quantitative understanding on the population, structure and regeneration status of 11 out of 32 threatened dipterocarp species in Vietnam. Of the common threatened dipterocarp species, *H. recopei* demonstrated an excellent development of its population. Little effort is needed to conserve *H. recopei*, yet huge conservation effort should focus on the other threatened species. For *D. dyeri*, it is clear that more attention is needed to assist its regeneration. Assisted regenation should also be applied to other low population density species such as *H. odorata*, *A. costata*, *D. alatus*, *V. cinerea*, *D. costatus*, *D. baudii* and *S. falcata*. Proper silviculture treatments and forest management practices are highly recommended to maintain the natural habitats for these species. *In-situ* and *ex-situ* conservation methods may be applied to some of these (critically) endangered species to conserve their genetic resources.

ACKNOWLEDGEMENTS

The author thank the Ministry of Science and Technology of Vietnam for financial support for the project no. ĐTĐL.XH.10/15. Support from the Dong Nai Biosphere Reserve over the course of the project is highly appreciated.

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THE FIVE Cs OF THE AQUATIC PLANT CONSERVATION OUTREACH PROGRAMME OF LAKE CHINI — CAUSE, CHOICE, CAPACITY, COMMUNICATION AND CONTINUITY

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ABSTRACT

The locally extinct aquatic carnivorous plant, *Utricularia punctata* (Lentibulariaceae), was reintroduced into Lake Chini. A series of conservation outreach programme was then designed to target the ill-informed stakeholders. Borrowing a humorous Singaporean phrase "Five Cs", key aspects of the outreach programme was discussed. I) Cause. The cause and effect of environmental stresses linked to *U. punctata* extinction is explained by a snake and ladder board game dubbed the *Naga Tangga*; II) Choice. The reasons for choosing an indicator species were elucidated; III) Capacity. Capacity building was conducted for targeted stakeholders based on the capacities of the project team members; IV) Communication. A holistic approach to effective communication, using the 4W1H model was carried out; and V) Continuity. A metaphor of a germinating *U. punctata* is used to illustrate the development from Phase 1 (Reintroduction) to Phase 2 (Stakeholder outreach programme). The programme was demonstrated as a model for the conservation outreach programme of rare plants and received good responses from local as well as international participants.

Keywords: rehabilitation, indicator species, IUCN Red List, stakeholder engagement.

INTRODUCTION

The Forest Research Institute Malaysia (FRIM) botanical team has been carrying out the restoration of a native bladderwort in Lake Chini since 2014 (Chew *et al*. 2016a). The rare aquatic carnivorous plant, *Utricularia punctata* (Lentibulariaceae), was previously recorded from Lake Bera, Lake Chini and Kota Tinggi River. However, field searches in 2009 discovered its local extinction from the latter two sites (Chew & Siti-Munirah 2010), yielding it a Vulnerable B2ab(iii) IUCN Red List Status (Chew & Haron 2011). In 2014–2015, trial plantings were carried out in Lake Chini with stocks from Lake Bera that re-established small but flood-resistant populations at sites not affected by erosion runoffs (Chew *et al*. 2016b).

Modifications were made to ensure higher transplanting rates and an up-scaled rewilding was carried out in 2016, including the establishment of demonstration plots close to tourist amenities (Chew *et al*. 2016c). Throughout Phase 1 reintroduction activities, it was identified that stakeholders involved in managing the lake and the local communities were ill-informed of the state of rare plants unique to the habitat. Phase 2 thus embarked on conservation dialogues targeting various stakeholders.

An outreach programme is defined as a service providing activity targeting the non-audience, where success is determined by the relationships developed. Effective outreach requires flexible communication to appeal to a diverse group, meeting those in need at their locations. The Chini programme was tailored with these aspects in mind, employing the social media and injecting humorous elements when explaining complex scientific concepts to the lay person.

MATERIALS AND METHODS

"Five Cs" is a witty phrase coined and popularised in Singapore to refer to the aspiration of ordinary people on desirable material success. Here, it is borrowed to describe five key aspects of the conservation outreach programme in a catchy structure.

I The Cause

Objective: To explain the cause and effect of environmental stress in Lake Chini that are linked to the local extinction of a rare species.

The Snakes and Ladders is a classic board game based on an Indian archetype version where a player's progression up the board represented a karmic journey complicated by ladders of virtues and snakes of vices. The version customised for Chini (Figure 1) is dubbed *Naga Tangga* in Malay, literally translated as Dragons and Ladders, featuring the Seri Gumum Naga of the indigenous Jakun mythology.

The fiery mouth of each dragon is lodged in a square that highlights a certain bad practise, the number of squares it straddles is relative to the presupposed seriousness of the threat. Vice versa, the basal square of each ladder is ascribed to a beneficial event, the extent it ascends comparative to the assumed advantages. The first square has a universal symbol for environmental conservation, while the final square is *Utricularia punctata* in full bloom.

Besides visual presentations, each event is elaborated briefly in the right column followed by short descriptions of the species, the threat it faces and harmful actions to avoid. Complementing the game board is a set of counters depicting the floral illustration and species epithet of four *Utricularia* native to Lake Chini. In other words, each design element is conceived to provide a wholesome fun-learning experience.

II The Choice

Objective: To elucidate the reasons for choosing an indicator species as a tool for investigating and detecting environmental pain points to be avoided.

In situ monitoring of environmental stressors requires significant resources and rarely reflects intermittent events. Likewise, laboratory tests lack the realism of a highly dynamic ecosystem. Living organisms provide convenient full-time monitors of stressors. An old approach of using biological indicators measures the actual responses of organisms to environmental quality (Connon *et al*. 2012). *Utricularia punctata* has specialised niche requirements and is thus a species of choice.

Coloured ads are commonly devoted to announcing winners of a myriad of contest with commanding profile pictures of the victors and captions detailing the winning points of the leading entrants. The format was adopted to clarify why *Utricularia punctata* was chosen among a range of aquatic plants in addition to showcasing associated species and explaining the concept of indicator species (Figure 2).

III The Capacity

Objective: To identify capacity building activities for stakeholders based on the capabilities and scientific capacities of project team members.

Capacity building addresses specialised management issues depending on the purview of the capacity builders. The conceptual approach of the outreach programme is to focus on improving the awareness of the poorly-informed stakeholders on scientific facts pertaining to rare and endangered species. This removes the obstacles that inhibit changes to better management practices to achieve sustainable conservation results.

The outreach programme team is made up of botanists and technical assistants whereas the target group are mainly non-scientist. The team produced various tools, e.g. dual-language posters to explain the fundamentals of the project and other relevant scientific facts. The general public was informed of project updates using conventional media of magazines, bulletins (Figure 3), and social media including FRIM web news, Facebook post on the official Facebook page of FRIM etc.

IV The Communication

Objective: To identify a holistic approach to effective communication.

Effective communication is a two way information-sharing process which involves one party sending a message that is easily understood by the receiving party and can substantially contribute to the success of an outreach programme. The 4W1H model was used to aid the thought process of what appropriate activities to embark on, when and where to conduct them, how to conduct. These include the type of communication tools needed and identification of target audience.

The younger generation of the local community in Lake Chini was identified as a target group and the *Naga Tangga* board game was designed to explain complex scientific concepts to targeted primary school children. The same product was appreciated by tertiary students and scientists of other disciplines proving that the thought process that had gone into developing a holistic communication tool contributes substantially to its effectiveness.

The communication tools developed were tested during on-site dialogues with various stakeholders and modified with feedbacks from the participants. For example, posters designed to explain facts had raised more questions as the stakeholders began to comprehend the issue presented to them, such that these questions would be the directional guide for the team in future research.

V Continuity

Objective: To explain the continuity of conservation efforts from Reintroduction in Phase 1 to Stakeholder outreach programme in Phase 2.

The conservation efforts of *U. punctata* progressed from Phase 1 to Phase 2 as an attempt to encourage the stakeholders to take up a better environmental stewardship role for long term conservation of a rare and threatened species. The project poster (Figure 4) explains the concept using the metaphor of a geminating *U. punctata* seed, with each of its three leaf branches explicating a main objective of Phase 2.

RESULTS AND DISCUSSION

The effort to engage multiple audience in Phase 2 had received good responses from local as well as international participants. A total of 13 local stakeholders were engaged in a series of capacity building dialogues, besides one NGO and five tertiary education institutions. The choice of species, the cause of its local extinction and suggestions for good management practices were communicated using the *Naga Tangga* boardgame, posters, other published articles and life specimens as interpretive tools. These tools were later distributed freely to the respective stakeholders for their usage. The long term goal of species conservation is beyond the scope of Phase 2. Nonetheless, the programme has been demonstrated as a model for the conservation outreach programme of rare plants.

ACKNOWLEDGEMENTS

Continuous financial supports from the NRE Ministry of Malaysia enabled the rehabilitation experiment to evolve into a stakeholder-engagement programme. We also thank the FRIM researchers for their invaluable inputs: Chua LSL, Chung RCK, Kiew R, Abd Rahman K, Cheah YH, Mohamad-Aidil N, Angan A and Mohd Hairul MA.

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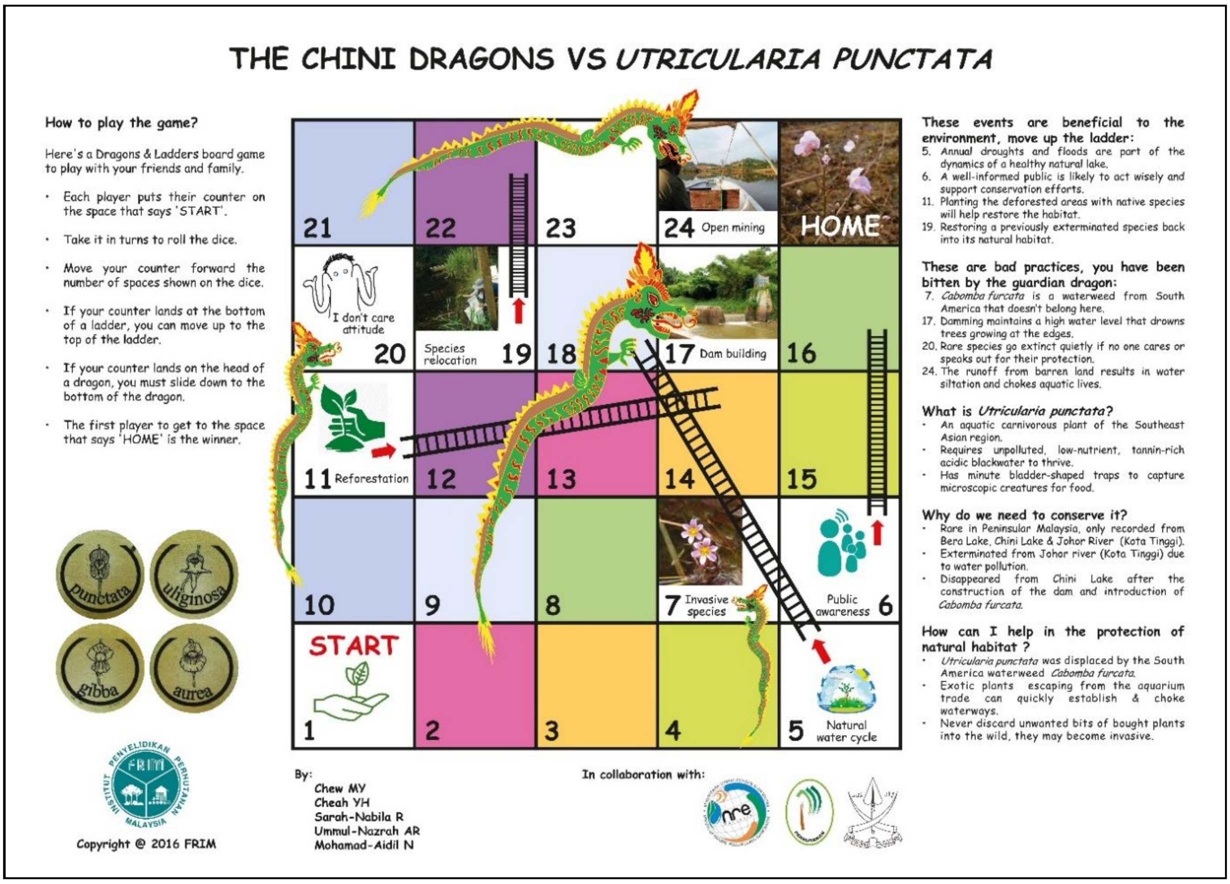

Figure 1. The Dragons and Ladders board game of environmental causes and effects

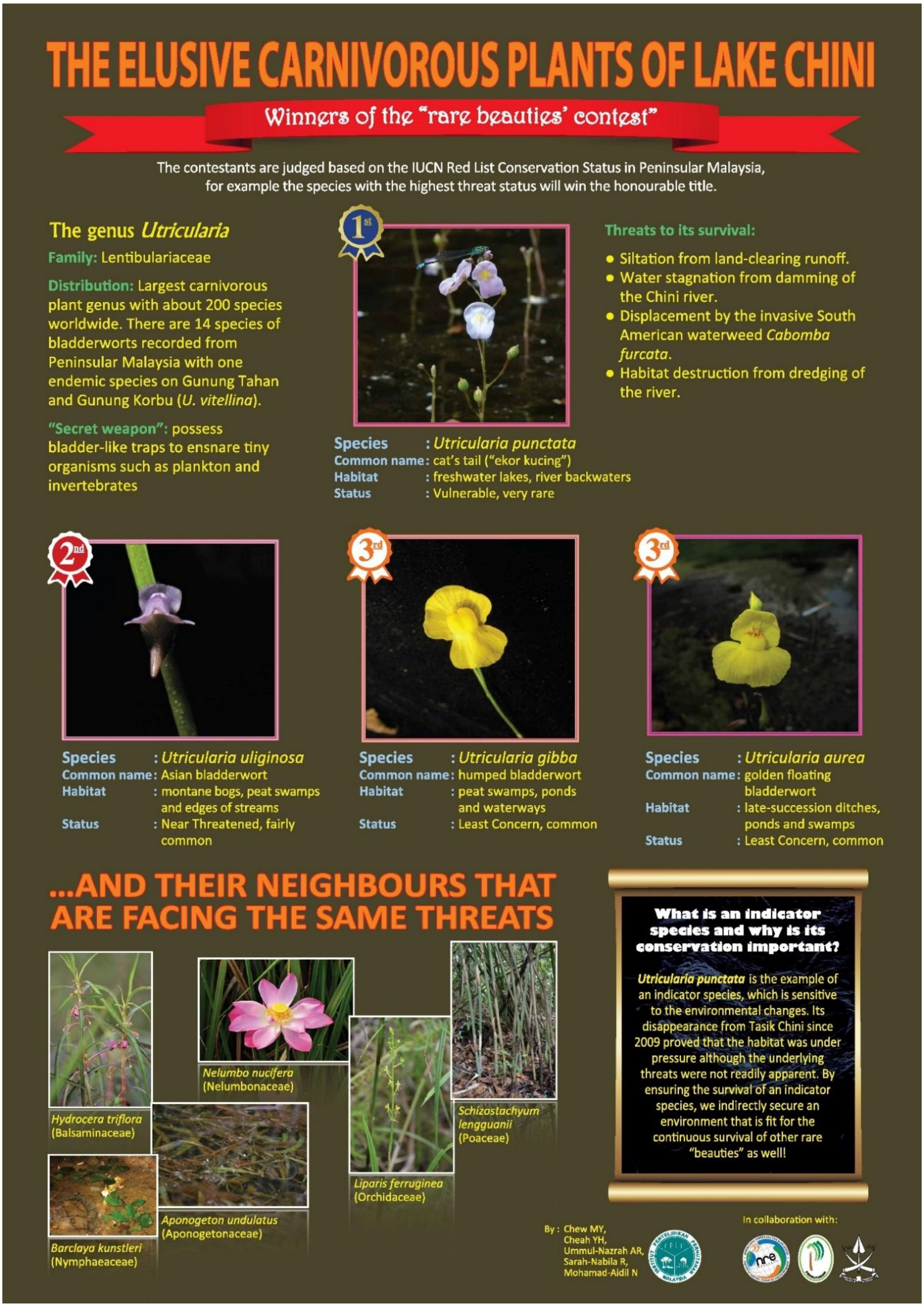

Figure 2. The winner announcement poster of the choice indicator species

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SEPTEMBER 2016

FRIM PULIH SEMULA TASIK CHINI

FRIM Restores Tasik Chini

HIGHLIGHTS OF THIS ISSUE

- Masyarakat Bantu Pulih Flora Tasik Chini
- Kaedah Terbaik Tanam Semula Teratai
- Tanam Buluh Pulih Keadaan Tanah
- Teknologi Geospatial Kenal Pasti Hutan Terosot
- Uniknya Tanah di Tasik Chini
- Ekor Kucing Returns to Tasik Chini
- Enaknya Cendawan Liar
- All Eyes on Flying Beauties of Fraser's Hill

Focus article

In 2009, the stagnant open waters of Tasik Chini, choked by overgrowth of the red cabomba, displacing native species including lotus and ekor kucing

EKOR KUCING RETURNS TO TASIK CHINI

Ekor Kucing Kembali ke Tasik Chini

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Twenty years ago, Tasik Chini was well-known for its blooming lotuses, while aquatic plants such as the ekor kucing *(Utricularia punctata)* thrived in the lake. Tourists came to the lake via land transportation or boats cruising down Sungai Pahang to Sungai Chini. Being a small and windy tributary, Sungai Chini is only navigable when water level is high, usually during rainy season which was unsuitable for excursions. With the hope of maximising tourism earnings, a weir was built from 1994 to 1995 over the Sungai Chini mouth to maintain high water level for year-round navigation.

The weir caused backed-up water to drown the seasonal swamp forest fringing the lake, and sediments accumulated in stagnant waters. During the same period, a noxious weed known as the red cabomba *(Cabomba furcata)* emerged due to increase of water turbidity. The murky environment caused the lotus population to collapse, undermined the attraction of Tasik Chini and caused a drastic drop in visitors' number.

Red cabomba is an exotic South American species which was initially imported for the ornamental fish trade. When discarded in waterways, bits of the plant flourished under favourable conditions. The cabomba was regarded as a global invasive alien species and was blacklisted. Within a period of 10 years, the water-weed has choked the open-water passages of Tasik Chini to smother and displace native aquatics, particularly the ekor kucing.

Red cabomba was imported from South America for its decorative leaves for the ornamental fish trade

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Figure 3. An article in 'FRIM in Focus' featuring the project

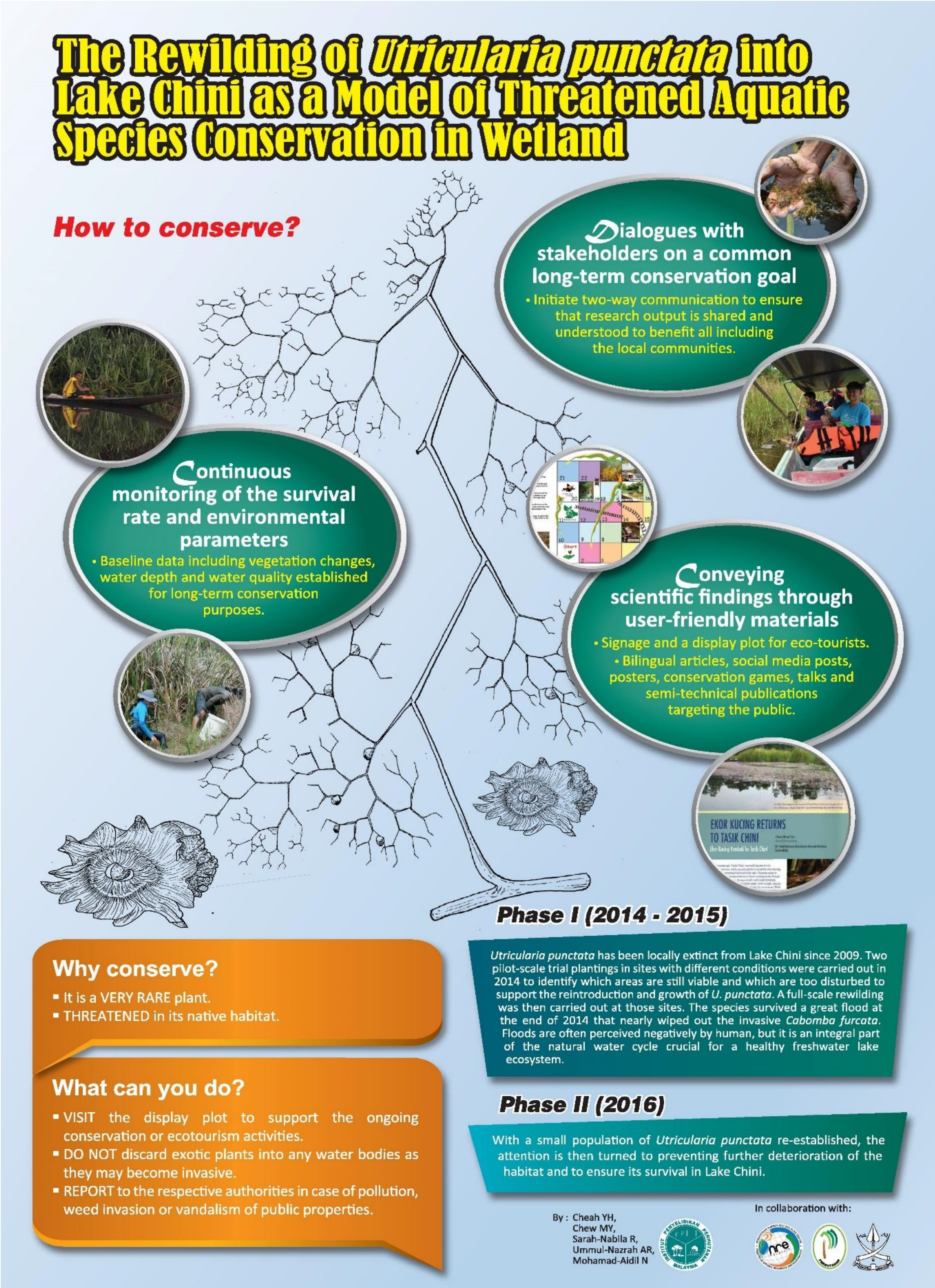

Figure 4. The project poster composition traces the stages of sprouting seeds

EX-SITU CONSERVATION OF DIPTEROCARP SPECIES IN PENINSULAR MALAYSIA

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ABSTRACT

Seeds and wildings of common, rare and endanger species of lowland dipterocarp species are being collected for the National Dipterocarp Germplasm Bank. Both seeds and wildlings have their own advantages and disadvantages. If there are ample seeds, it is easy to obtain a large number of planting materials but dipterocarps do not have regular flowering/ fruiting season. In order to obtain more planting materials, collection of wildings is also an option. Wildings collection can be done throughout the year with a good survival rate except during dry season. This method can help to increase the number of planting materials for a 2-year project when seeds are not available. Disadvantages of wildings collection include limited number of wildlings and wildlings that may not meet project requirements. Furthermore, the wildlings need to be acclimatised. Nevertheless, collection of seeds and wildlings will complement each other to supply planting materials for planting activities in the project.

Keywords: lowland dipterocarp, seed collection, wilding collection, National Dipterocarp Germplasm Bank, rare and endangered species

INTRODUCTION

Dipterocarp forest is one of the forest types that are of vital economic and ecological importance in Peninsular Malaysia. Currently, many populations of dipterocarps are on the decline in Peninsular Malaysia because of land use changes, harvesting and severity with the passage of time (Chua *et al*. 2010). The decline in forest areas and resources resulted in a need to utilize these resources suitably.

A new on-going project undertaken by Forest Research Institute Malaysia or FRIM, named National Dipterocarp Germplasm Bank or NDGB is located in Institute of Land and Survey (INSTUN). This project was approved and funded by The National Conservation Trust Fund for Natural Resources or NCTF which is under the Ministry of Environmental and Natural Resources in January 2017 is the way forward to address the issue.

The main objective of the project is to collect lowland dipterocarps which included common, endangered and rare species in peninsular Malaysia, nursed and the final stage, planting on selected site in INSTUN.

MATERIALS AND METHODS

Collection of planting materials (seeds or wildings) are based on survey or primary existing phenology reports from In-house monitoring, Forest Health and Conservation, Forest Biodiversity Department, Forest Research Institute Malaysia (FRIM) and Forestry Department Peninsular Malaysia. Malaysia Plant Red List Peninsular Malaysian Dipterocarpaceae was also being used as references to collect dipterocarps species according to conservation status.

Four species were collected for this study. *Dipterocarpus rigidus* Ridl. (Keruing cogan) is listed as endangered (EN), *Neobalanocarpus heimii* (King) P.S. Ashton (Chengal) listed as near threatened (NT), *Hopea ferrea* Lanessan (Giam malut) listed as NT and *Dipterocarpus baudii* Korth. (Keruing bulu) listed as least concern (LC) species in the Malaysia plant red list: Peninsular Malaysian Dipterocarpaceae (Chua *et al*. 2010).

<u>Seed Collection and Germination Activities</u>

Previously, in the month of March 2017 and April 2017, seeds collection of *D. rigidus* were done at Mata Ayer Forest Reserve, Perlis and *N. heimii* at FRIM, Kepong, Selangor. Germination for the two species were done in FRIM Mata Ayer Research Station, Perlis.

Dipterocarpus rigidus stand is in an open area which was cleared for *Eurycoma longifolia* Jack (Tongkat ali) planting trial. *Neobalanocarpus heimii* is a single tree stand planted near a parking space at FRIM Campus. 150 seeds were selected randomly from both of the collection. Data were collected within 1–2.5 months.

Method for seed collections is advanced line using catapult. Canvas sheet is spread under the tree to facilitate seeds collection. Seeds are collected by shaking the branch of the tree using nylon rope. Best time to use this method is when the wind is calm and early in the morning. Seeds collected must be processed, dewing and sown in sowing beds in a few days because of the nature of the recalcitrant seeds. Most of the recalcitrant seeds are sown in a shade area to avoid the seed desiccated during germination. Media for seed germination is medium size riverine sand. Rates of germination are recorded.

<u>Wilding Collections and Acclimation Process</u>

Three species of wildings collection were done for *H. ferrea* in Perlis State Park, while *N. heimii* and *D. baudii* both were collected in FRIM's Campus, Kepong Selangor.

Wildings of *H. ferrea* were collected on 23 February 2017 in a dry season. The last event of rain was recorded in 26 January with 0.35 cm (CEASTech 2017). The wildings were divided into two groups i.e. standard wildings (less than 30 cm) and large wildings (more than 30 cm). 61 standard wildings and 12 large wildings were collected and potted. Minimum, average and maximum height for standard wildings were 7.0 cm, 14.8 cm and 24.3 cm, respectively while for large wildings, the height measurements were 62.1 cm, 71.5 cm and 84.2 cm, respectively. The collection was done during dry season to examine survival of wildings under harsh condition. A total of 320 *D. baudii* wildings were collected on the 2 April 2017. Minimum, average and maximum height measurements were 3.2 cm, 9.3 cm and 14.0 cm, respectively. Potting was carried out on 6 April 2017 followed by acclimatisation of the wildlings.

A total of 112 *N. heimii* wildings were collected on the 18 April 2017. Minimum, average and maximum height measurements were 12 cm, 24.5 cm and 49.2 cm, respectively. Potting was carried out on 20 April 2017 followed by acclimatisation of the wildlings.

Collection of wildlings was done following the standard operating procedure (SOP) for collecting, handling and acclimatisation process. Collection of wildlings from forest floor requires proper planning and handling, especially during long distance travel, and temporary storage for a few days before traveling to nursery for acclimatisation process. The best time to collect wildings is during raining season and early in the morning when the forest floor is damp. Wildings should have two or more developed leaf form to ensure recovery in the nursery. FRIM's nursery have developed a technique for handling large wildings (0.3–0.6 m) using extra-large (73 x 127 cm) heavy duty transparent polyethylene bag that is able to maintain humidity and avoid loss of water from wildings. A stick is used to loosen the soil around the roots. Wildings are retrieved carefully to avoid damaging the root and the soil is shaken off the root before potting in the polyethylene bags.

A paper towel was used to wrap the root system from an individual wildling or a group of wildlings. The paper towel was then moistened using a hand held water spray. This is to avoid the root system from drying out. All the wildings were then packed inside a transparent plastic bag filled with air. Water was sprayed inside the bag to maintain a high moisture condition before the bag was tightened using a plastic clamp or raffia string. The plastic bag containing wildings could be easily carried, transported and stored under shade before unpacking. The day after arrival at the nursery, wildings were potted in polybags with appropriate size according to the height of wildings before being transferred under shade for acclimatisation. Potting media used was top soil mixed with river sand at a ratio of 2:1.

For acclimatisation, the area is a heavily shaded using two separate layers of 70–80% black netting shade. Wildings are watered twice daily for three months. This is to ensure higher recovery from water stress. Mortality rate was recorded for three months. The wildings were then moved to the plant shed which are usually shaded using single layer 60–70% black or green netting for growing phase.

RESULTS AND DISCUSSION

Seed collection and germination activities

Table 1. Germination rate of collected seeds

No	Species	Number of seed tested	Number of seed germinated	Germination (%)	Duration (month)
1.	*Dipterocarpus rigidus*	150	61	41	2.5
2.	*Neobalancarpus heimii*	150	123	82	1

Dipterocarp seeds are prone to insect pest. Daljeet-Singh (1974) reported that weevils were responsible for 80% of the total seed damage in all case studies except *Shorea macrophylla*, in which the most damaging pests were the Colytidae. Poor germination rate for *D. rigidus* was due to unidentified larvae that were found inside most of the seeds that rot when being germinated. *Dipterocarpus rigidus* was the only tree stand that produced seeds in the area which was cleared and planted with *Eurycoma longifolia*. Thus, *D. rigidus* was most likely to be susceptible to pest attack. As for *N. heimii*, 82% germination rate is slightly higher compared with Yap (1981) at 80%.

Wilding collections and acclimatization activities

Table 2. Survival of collected *Hopea ferrea* wildlings

Height of wildings	Wildings potted	Number of survival	Survival (%)
Standard < 0.3 m	61	33	54
Large 0.3–0.6 m	12	3	25

Species	Wildings potted	Number of survival	Survival (%)
Hopea ferrea	73	36	49
Neobalanocarpus heimii	112	105	94
Dipterocarpus baudii	320	300	94

The lower survival percentage of large *H. ferrea* is due to the wildings were over-height, older wildings presumably past over the previous season and are collected in dry season. The guidelines of FDPM (1998) stated that only newly germinated wildings about one to three months old and from 10 to 15 cm in height (normally with 2–4 pairs of leaves) should be collected.

The collection of large wildings was done to determine the suitability of the SOP for wildings collection and handling. The results showed that survival was high for *N. heimii* and *D.*

baudii when collection of standard-sized wildings was done during wet season and in the early morning to avoid additional stress.

CONCLUSION

The success n collection of common, rare and endangered species for *National Dipterocarp Germplasm Bank* depends on proper planning and execution. Identifying location of trees that produce seeds is based on monitoring and phenology observations. Decision to used resources, tools and method are based on what type of planting stock to be collected and site accessibility.

Proper handling from seed collection, processing and sowing using established techniques will help to increase germination rate. Wilding collection of lowland dipterocarp species can be carried out due to its availability throughout the year. Improvement of collection and acclimation techniques will also help to increase recovery and wildling survival in the nursery.

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GERMINATION AND STORAGE STUDIES OF *DRYOBALANOPS AROMATICA* SEEDS

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ABSTRACT

Dryobalanops aromatica, commonly known as Borneo camphor (kapor), is one of the species in the Dipterocarpaceae family. The species name 'aromatica' is derived from Latin and refers to the smell of its dammar. The study was undertaken with aims to determine suitable duration (5, 7 and 14 days) and temperature (20°C and 26°C) to store *D. aromatica* seeds. The seeds were examined with wings intact in cotton bags. Germination was best achieved at initial test where germination percentage was 100% at 43.9% moisture content. It was found that similar germination percentage (92.5%) was obtained when stored for five days at both temperatures. However, after a seven-day storage, germination percentage was relatively higher at 20°C (85%) than at 26°C (62.5%). Significant reduction in average germination percentage was observed with increasing storage time compared to the initial test. A high fungal contamination was observed especially in the 14-day storage resulting in low seed germination. The ability of seeds to retain viability is an important factor for successful production of planting stock.

Keywords: germination percentage, storage duration, storage temperature

INTRODUCTION

Dryobalanops aromatica, commonly known as Borneo camphor, camphor tree, Malay camphor or Sumatran camphor, is a species of plant in the Dipterocarpacea family. The species name 'aromatica' is derived from Latin and refers to the smell of the dammar. A mature tree produces seeds once every two to three years (Chin *et al*. 1988). The importance of its timber and the concern for depletion of its genetic resources, *D. aromatica* had been proposed to be conserved in Peninsular Malaysia (ITTO 2000). Conservation status of *D. aromatica* is near threatened in Malaysia (including Sabah and Sarawak) and least concern for Peninsular Malaysia (Chua 2010). The wood is moderately heavy, soft to moderately hard, moderately durable, being resistant to fungi and dry wood borers, and moderately resistant to termites. It seasons slowly with only a slight risk of checking or distortion, once dry it is stable in service. It is used for a wide range of applications including house construction, bridges, boards, heavy carpentry, joinery, panelling, turnery, tool handles, boxes and crates.

Dryobalanops aromatica forms oil to reserve food in the seed. Kamariah *et al*. (2012) stated that aromatic oil produced by *D. aromatica* contained important well-known chemical components for flavour, fragrance, food, cosmetics and pharmaceutical industries.

Seed storability is considerably influenced by the kind or variety of seeds. Some seeds are naturally short-lived e.g. onions and soybeans. A seed lot having vigorous, undeteriorated seeds can be stored longer than deteriorated lots. Depending on the severity of the damage or degree of deterioration, seed quality can decline rapidly. Seed lot with good germination at the beginning of the storage is also capable of losing its viability.

The study was undertaken with an aim to determine a suitable storage period (5, 7 and 14 days) and temperature (20°C and 26°C) to store *D. aromatica* seeds with the wings intact in cotton bags.

MATERIALS AND METHODS

Freshly ripened seeds of *D. aromatica* were collected from Forest Research Institute Malaysia (FRIM) ground. The seeds were cleaned for impurities and later mixed thoroughly to minimize effects of single plant on germination.

The seed lot was put to undergo room drying prior to initial germination and moisture content tests. The fresh seeds were tested for their initial germination potential (10 seeds in four replicates) and moisture content (three seeds in three replicates).

Seeds were also subjected to combined treatments of different i) temperatures (26°C in room temperature and 20°C in refrigerator) and ii) storage period (5, 7 and 14 days). These seeds were stored with wings intact in six cotton bags (20 x 30 cm) for the six combined treatments.

For germination potential test, four replicates with each having 10 seeds in a Petri dish (150 mm diameter) lined with a single layer of paper towel saturated with distilled water. The Petri dishes were placed in the seed germination chamber at 30±2°C with alternating light (16/8 hours photoperiod). The seeds were constantly kept moist using distilled water. The seed is considered to have germinated when the radicle has developed normally and visible at about 2–3mm.

The calculation for germination potential is as follows:

$$\text{Germination (\%)} = \frac{\text{No. of germinated healthy seeds}}{\text{No. of seeds being tested}} \times 100$$

Meanwhile, for determination of moisture content, three replicates were prepared. Each replicate contained three seeds which were oven dried at 103°C for 17 hours following ISTA (1999). The moisture content of seeds was calculated by weight (fresh weight basis) according to the following formula:

$$\text{Moisture content (\%)} = \frac{\text{Fresh weight of seed} - \text{Dry weight of seed}}{\text{Fresh weight of seed}} \times 100$$

This experiment was designed to determine the reliable storage temperature and period to prolong the viability of the seeds. The germination percentage obtained prior to storage served as a control value and a way to evaluate the variability in germination for periodical storage periods. By recording changes in the germination percentage and the time required for seeds to germinate, deterioration can be evaluated.

The germination percentages were tested for statistical significance using analysis of variance (ANOVA) at 5% level of significance after arc sine transformation of the values followed by Duncan's multiple range test for multiple comparison to determine the effects of temperature, storage period and their interactions.

RESULTS & DISCUSSION

Freshly harvested seeds had no dormancy. Germination was highest with 100% germination at the initial test using fresh seeds. Initiation of germination was observed after two days of sowing from the 5-day and 7-day storage at both temperatures.

Table 1. Comparison of treatments by means of germination at different storage temperature and period

Storage period (days)	Storage temperature 20°C	Storage temperature 26°C	Mean (%)
	Germination potential (%)		
5	92.5 ± 5.0	92.5 ± 9.7	92.5[a]
7	85.0 ± 12.9	62.5 ± 22.2	73.75[b]
14	24.6 ± 23.1	0.0	12.33[c]
Mean (%)	67.4[d]	51.7[e]	

Note:
1) Means with different letters are significantly different at 5% using Duncan's multiple range test
2) Means of columns and rows are analyzed differently

Table 1 shows the means of germination percentage achieved after 32 days of the germination period. The germination percentage of *D. aromatica* seeds differed significantly in the combined treatments. Multivariate ANOVA revealed significant effect of different storage temperature, storage period, and their interaction on seeds germination percentage. A minimum of two to eight days (average three days) were required for germination onset and 22 to 32 days (average 19 days) for the completion of seed germination for all combined treatments.

It was found that similar germination percentage (92.5%) was obtained when seeds were stored for 5-day at both temperatures. After the 7-day storage at 20°C, the germination percentage was relatively higher (85%) than storage at 26°C (62.5%). However, after the 14-day storage at 20°C, germination has decreased to 24.6% and no germination was observed at

26°C. Significant fall (P< 0.0001) in germination percent was observed with the increase in storage period.

Collectively, the seeds stored at 20°C showed significantly (P<0.0001) higher germination percentage (67.4%) than at 26°C (51.7%). Significant reduction in average germination percent was observed with the increasing storage period compared to the initial test.

Table 2. Comparison of treatments by mean of moisture content at different temperatures and storage period

Storage period (days)	Storage temperature 20°C	Storage temperature 26°C	Mean (%)
	Moisture content (%)		
5	41.3 ± 1.2	36.4 ± 2.8	38.8[a]
7	35.9 ± 10.9	33.2 ± 2.7	34.6[ab]
14	34.9 ± 0.6	24.0 ± 0.7	29.5[b]
Mean (%)	37.4[c]	31.2[d]	

Note:

1) Means with different letters are significantly different at 5% using Duncan's multiple range test
2) Means of columns and rows are analyzed differently

Generally moisture content of recalcitrant seeds was reported to be in the range of 30–70% (Chin *et al.* 1984). The initial moisture content on the fresh seeds was 43.9%. Table 2 shows the moisture content achieved at the different storage period. After the seeds were stored for 5 days, the moisture content showed slight decrease from 41.3% at 20°C and 36.4% at 26°C. The moisture loss was observed for the subsequent storage periods at both temperatures.

Fungal contamination, especially in the 14-day storage, was observed although some seeds had germinated. This suggests that seeds should be desiccated about 20% prior to storage to minimize the loss of seed viability (Anandalakshmi *et al.* 2005).

CONCLUSION

Fresh seeds, when shed from the mother tree, used in the study had relatively high moisture contents and were sensitive to desiccation. However, if the seeds are properly dried before storage, seed viability could be maintained and the fungal growth could be minimized. In conclusion, the seeds stored with intact wings in cotton bag at 20°C for a duration of five to seven days showed better germination percentage.

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RESTORATION OF MARGINAL SITES USING LEGUMINOUS TREE SPECIES, *PTEROCARPUS INDICUS:* PRACTICES AND CHALLENGES

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ABSTRACT

Pterocarpus indicus or angsana is a promising nitrogen-fixing tree species for forest plantation with desirable characteristics as a reforestation crop and can be planted in marginal site conditions due to its symbiosis relationships with the host plants. There are some constraints or excess of soil macronutrients such as nitrogen (N) and phosphorus (P) are crucial and critical establishment problems in the tropics which may not sustain plants or tree growth. As such, frequent fertilization and site selection are important silvicultural considerations for many forestry plantations established in SE Asia countries. wherein addition, there are some legume tree species which may be prone to high or low P requirements for optimum growth, nodule bacteria formation and capability for nitrogen fixation, which may further enhance N production. However, there is still a lack of knowledge regarding the potential of this tropical woody legume. Currently, attention is being focussed on their roles in nutrient cycling, their usefulness in reforestation projects on poor, sandy and marginal soils. There are many challenges of using woody legumes, for instance becoming invaders of new habitats such as using Australian acacias in Asian region. Hence, this paper discusses some of the challenges and promising prospects of utilising *P. indicus* to optimize forest productivity even after out-planting.

Keywords: promising, nitrogen-fixing, optimum growth, productivity and out-planting

INTRODUCTION

Tropical deforestation is often associated with the conversion of forest lands to agriculture uses mostly to replace land that has lost productivity due to unsuitable farming practices, shifting cultivation, mining and illegal felling among others (Whitmore 1984, Lamb 1994). This is also true in Malaysia where deforestation and forest degradation occurs due to over-logging, mining and conversion of forests to agricultural plantations (Appanah & Ismail 1996, Appanah & Razak, 1998). As most tropical plantations are likely to be on either poor or marginal sites, essential nutrients or soil fertility for tree growth are poorly available (Evans & Turnbull 2004). For example, phosphorus (P) is reported to be one of the major limitations to tree growth on reforestation sites but information available on P fertilizers is scarce. Deficiencies in N and P may also lead to poor stand form, reduced microbial activity and trees are more susceptible to pest and diseases during early growth or after out-planting (Dell *et al*. 2001).

Currently, fertilization is a major consideration factor in many industrial tree estates in South East (SE) Asia. Some legumes are known to have a high P requirement for optimum growth, nodule formation and nitrogen fixation. Direct uptake of these nutrients via beneficial soil symbionts can play important roles in N and P cycling. Studies have shown that other nitrogen-fixing bacteria's allow N to be directly available to plants as NH_3 in the symbiotic associations using the nitrogenase enzyme in bacteroids of root nodules (Giller & Wilson 1991). Currently, some commercial timber species which are N-fixing trees play important roles as pioneer species in the restoration of marginal sites (Sprent 2001). The recommended genus include *Acacia, Casuarina, Dalbergia, Paraserianthes and Pterocarpus.* However, despite their abundance, diversity and economic importance, few have been examined for their ability to nodulate and fix atmospheric N symbiotically with root nodule bacteria. At present, about 57% and 20% of the genera and species in the tropical legumes have been examined for nodulation.

Pterocarpus indicus or angsana is a large promising timber tree. It is native to SE Asia, belongs to the family Leguminosae-subfamily Papilionoideae and a close relative to the red rosewood, *Dalbergia*. However, due to excessive harvesting, the species is now classified as vulnerable by International Union for Conservation of Nature and Natural Resources (IUCN, 2006) and trading the species is restricted with the listing in Appendix 2 under the Convention of International Trade in Endangered Species (CITES) (Rojo 1977, Soeriannegara & Kartawinata 1985, Oldfield *et al*. 1998). The wood is classified as moderately heavy, hard, strong and durable (550-900 kg/m^3 at 15% moisture).

Under favourable conditions, *P. indicus* growth is rapid, leading to mean annual diameter and height increment greater than 4 cm and 1.5 m respectively (Foxworthy 1927). It has bright yellowish red to golden brown heartwood, ranked as the finest for furniture, cabinet works, panelling and in specialized joinery (Eddowes 1977). It was reported to grow in a variety of soil types ranging from fertile agricultural to rocky soils and along inundated river banks, swamps and lagoons (Allen & Allen 1981, Ng 1992). Hence, in order to achieve satisfactory tree growth these nutrients must be adequately supplied using appropriate silvicultural operations and good management practices. This paper discussed some of the management challenges and practicality aspects using nitrogen-fixing trees for site restoration and afforestation programmes.

Figure 1. Potential trees, *Pterocarpus indicus* a) mature stands b) extracted root rhizobia and c) roadsides planting using cuttings

<u>Why nitrogen-fixing trees?</u>

Nitrogen-fixing trees are extraordinary whereby deep rooted roots are colonized by certain bacteria that extract nitrogen from the atmospheric air and convert or "fix" it into a form required for their plant growth. It is an example of a symbiotic relationship (between plant and bacteria), and the name for the process is "nitrogen fixation." Often these trees usually exhibit rapid growth and biomass accumulation, grow in a type of pods, enrich soil with total available N and even associated with crop rotation. There are a wide variety of important N-fixing trees, still unexploited, are very promising for use in plantations for soil restorations. However, little is still not known on the management and silvicultural aspects and these trees have been overlooked. More serious and comprehensive programmes should be given to utilize these tropical tree species.

<u>Silvicultural potential and characteristics of *Pterocarpus indicus*</u>

1. Seed germination

Germination is epigeous with one fruit producing one to three seeds. It is estimated that about 245 seeds are available in every 100 g of seeds. However, seeds are preferred over dewinged, scarified fruit for sowing due to shorter germination period of 1–2 weeks compared to above two months. Temperature range of 25–35 °C can also affect the germination rate between 75-85% without any pre-treatment done.

2. Natural and artificial regeneration-cuttings and stem size

Pterocarpus indicus can behave like a pioneer species but grow fast and hardy in the open although some shade is required in the early establishment (Ng 1992). It was reported that earlier attempts to cultivate this species was not successful due to the lack of silvicultural understanding and the seriousness in establishing plantation. It is also unique among the trees due to its capacity to root from stem cuttings. A high survival is possible with survival rate > 90% and grow rapidly upon transplanted trees (Wong, 1982). Cutting is also used as it can propagate and survive in various soil types, perpetuating desirable characteristics and suitable for urban planting.

3. Growth and yield

Little has been published regarding the growth and yield. Growth data available are summarized in Table 1 (Lok 1996). However, it was suggested that early maintenance is necessary to improve plant growth after out-planting. Adequate organic and NPK fertilizers should be applied every quarterly or six months once. Pruning should be considered for cuttings to remove undesirable branches and prevent knot formation that affects growth and wood quality (Evan 1982).

4. Pests and diseases

Pterocarpus indicus is fairly disease and pest resistant. During the period, 1875–1955 it was reported that most of the planted trees were infected with fungal pathogen as attributed by a leafhopper (Corner 1988). However, leaf defoliators, *Neolithocollettis pentadesma* and *Crematopsyche pendula* were reported in 1990's resulting in necrosis and holes and defoliations throughout trees planted in the open and along roadsides.

5. Phosphorus and nitrogen requirements

Studies showed that *P. indicus* growth can grow with low P and any addition of P will have good response in plantations when established on marginal soils (Nik Muhamad & Paudyal 1999). The tree is able to nodulate with diverse genera of root nodule bacterias which may be effective for nitrogen-fixation. If effective nodulation occurs in the forest nursery, there is no need to add any inorganic N fertilizer in the field.

Table 1. Growth data of *Pterocarpus indicus* available on planted stands

Age	Total height (m)	Diameter at breast height (cm)	Girth at breast height (m)
5	8	-	0.3
60	7.1	-	0.5
100	27	-	4.6
-	36.4	12.6	3.6
-	-	2.4-4.4	1.0-1.6
-	15.2	-	-
-	30.3	-	-
-	-	-	>4

CONCLUSION

Pterocarpus indicus is a promising tree species with the capability to strive well with low P and fix N using effective root nodule bacteria. It can be propagated easily through cuttings, comprises various sizes, strive and grow well on marginal soil conditions. The desirable characteristics show that the species is promising and can be considered as a choice candidate for forest plantation due to its ability to nodulate and fix N and grow in low P soils.

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BIOCHAR: A NEW FRONTIER IN ESTABLISHMENT OF FORESTS ON MARGINAL SOILS

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INTRODUCTION

The demand for high quality timber products has taken its toll on the natural forest stands that are slowly depleting. Logging has adversely affected the biodiversity of indigenous tree species such as *Shorea roxburghii, S. materialis, Dipterocarpus grandiflorus* and many more (Chua *et al*. 2010). Thus, the current need to establish new areas for forest conservation has initiated the utilization of degraded and marginal soils for the establishment of forests. Most degraded areas are bound to be low in fertility and water holding capacity for the suitable establishment of forest stands. Examples of poor or degraded soils include ex-mining areas, BRIS (Beach Ridges Interspersed with Swales) and peat. Soil amelioration play a vital role in enhancing the potential of these areas for this initiative. Delineating the best management practices in afforestation efforts will not only garner new knowledge for forest plantation industry but also rehabilitate poor soils, provide income for local planters and increase the current conservation efforts by the country to combat global warming.

Our current focus for establishment of new forests is on BRIS. BRIS soil is usually found near shorelines and estuaries. They are formed through the deposition process of the oceanic sand and mud movement by the tidal waves. The material forming the beach ridges are predominantly sand (Figure 1). BRIS is well known to be sandy, very low in fertility due to the absence of clay, somewhat excessively drained, having low cation exchange capacity (CEC) and base saturation. Some of the common soil series which are found in BRIS are Jambu, Baging, Pauh, Rhu Tapai, and Rudua soil series. Although classified as unproductive, dune ecosystems are known to support various ecosystem services which protect the inlands. BRIS is known to support lowland mixed dipterocarps such as *S. materialis,* wetland species such as *Melaleuca cajuputi* in swamps and heath vegetation such as *Garcinia* and *Syzygium* species (Salim *et al*. 2013).

Our current efforts in enriching the BRIS involve the utilization of biochar as a soil amendment media besides organic compost which has been investigated extensively. Biochar is a charcoal based material that is fine textured and has many pores. It is produced through pyrolysis which is the heating of organic matter such as wood, manure, bamboo, rice husks or leaves in a closed container in the absence or limited oxygen at low temperatures to retain carbon (Lehmann & Joseph, 2009). These specific conditions make biochar as it is by contributing to its special characteristics such as large surface area per unit volume and its ability to remain in soils with minimal biological decay. Biochar can lock up rapidly decomposing carbon in plant biomass in a much more durable form and is considered as a long term sink for reducing carbon emissions (12–84%) when its incorporated into soil. Biochar has the ability to increase plant growth, reduce nutrient leaching, increase water holding capacity and enhance microbial activity. Although the optimum application rate of biochar has not been elucidated, an informal observation of crops applied with biochar at rates between 5 and 20 % by volume of soil has shown positive results in terms of growth. Reports have shown that biochar with the combination of N fertilizers has the ability to increase yield of kenaf planted on BRIS up to 83% compared to the application of N fertilizers only (Malisa *et al.* 2011).

MATERIALS AND METHODS

The study was initiated in FRIM Research Station located in Setiu, Terengganu. Two indigenous species of *S. roxburghii* and *Calophyllum inophyllum* were selected to be planted for the first phase of the study (Figure 2) on BRIS. Three treatments were administered which were T1 (control): NPK compound fertilizer, T2: NPK compound fertilizer + organic compost and T3: NPK compound fertilizer + rice husk biochar (Figure 3). Each treatment had 4 replications. Each replication for *S. roxburghii* and C. *inophyllum* had 12 and 9 seedlings, respectively. Seedlings of 1 meter in height were planted using 3 x 3 m planting distance on BRIS (Figure 4). The mean basal diameter and the height of the seedlings were recorded after planting.

RESULTS & DISCUSSION

Currently, measurements and monitoring are underway. We foresee that the incorporation of soil amendments (i.e. biochar) in degraded areas promises the successful establishment of new forests that may provide a multi-advantage forest ecosystem. May it be for income generation for local people or for biodiversity augmentation and conservation purposes for the nation.

Figure 1. BRIS soil with high sand content

Figure 2. Seedlings were left for hardening two weeks prior to planting

Figure 3. Application of biochar and top soil into planting hole

Figure 4. Planting activities of selected species

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GROWTH EVALUATION OF BAMBOOS PLANTED IN LAKE CHINI

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ABSTRACT

This study reports on the evaluation on the survival and growth of four selected bamboo species planted on bund area in Laut 9, Lake Chini. The bund consists of mixed soil texture from clay to sandy clay and is classified as acidic soil with soil pH ranges from 3.0–4.0. The assessment was carried out 10 months after planting. All four species had more than 96% survival producing an average of 6.3 culms/clump. *Bambusa multiplex* had an average of 9.9 culms/clump and 100% survival indicating its ability to adapt is better compared with the other three species. The results indicated that bamboo can survive under problematic soil conditions.

INTRODUCTION

Researches from various countries show that productivity of bamboo depends on location, soil type and the bamboo species itself. Knowledge on the survival and growth, particularly on shoot sprouting and culm production, of selected bamboo species are important to assess whether these species can be planted commercially. For this purpose, information on soil suitability and other silviculture management are needed for optimal production. So, it is of great interest to investigate the suitability of growing bamboo on idle paddy field because there are large areas available for planting. Information on the survival and growth of selected bamboos in this study will further serve to assess the ability of adaptation and to select suitable bamboo species for planting in these areas. The objective of this study is to evaluate the suitability and effectiveness of selected bamboo species for stabilisation and reclamation of problematic soil.

METHODS & MATERIALS

<u>Cultivation of bamboo in Laut 9, Lake Chini</u>

The bamboos were planted in May 2015. A total of 128 bamboo seedlings have been planted consisting of *Dendrocalamus asper* (buluh betung), *Gigantochloa albociliata* (buluh madu), *Bambusa multiplex* (buluh pagar) and *Schizostachyum zollingeri* (buluh nipis). Planting distance is 5 x 5 m. Weeding and fertilizer application have been carried out after planting as part of maintenance work in the area. Fertilizers applied at each planting point consisted of 200 g CRIP, 1 kg organic fertilizer and 300 g NPK 15:15:15.

RESULTS AND DISCUSSION

Soil characteristics

Cultivation of bamboos in Laut 9 involves a man-made bund about 500 m long, 4 m wide and 4 m high which consists of reclaimed soil that was obtained from Lake Chini. The aim of this bund is to prevent soil erosion from the mining area into the lake. In addition, the bund provides protection to the banks of the lake during flood season. Soil texture varies from clay to sandy clay. The area is open and the range of soil pH is 3.0–4.0 (Table 1). Soil characteristics of the site are shown in Table 1.

Table 1. Soil characteristics of man-made bund

Soil Characteristics	
pH	3.0 – 4.0
Nitrogen (%)	0.14
Carbon (%)	3.76
Available phosphorus (ppm)	2.02
Soil texture	Clay to sandy clay
Site topography	Flat

Survival rate and growth performance

The results indicated that bamboo can tolerate and survive in this kind problematic soil. The average survival was high with 96.7% for *D. asper, B. multiplex* and *S. zollingeri* with 100% survival whereas *G. albociliata* recorded 97% survival (Table 2).

Table 2. Mean number of culms production and survival rate at 9 months after planting

Species	No. of seedlings planted	Mean no. of culms/clump	Survival (%)
Dendrocalamus asper	14	3.2	100
Gigantochloa albociliata	84	4.5	97
Schizostachyum zollingeri	15	7.7	100
Bambusa multiplex	15	9.9	100
Mean		6.3	96.75

Observations on the growth of bamboo in this area for nine months revealed that *B. multiplex* produced the highest number of culms with an average of 9.9 culms/clump. This was followed by *S. zollinger* that produced an average of 7.7 culms/clump, *G. albociliata* produced 4.5 culms/clump and *D. asper* produced the lowest yield with only 3.2 culms/clump. However, the average productivity for all the bamboo species was 6.3 culms/clump.

Species adaptation

From the observations conducted, the bamboo species planted can grow and tolerate the acidic soil condition. Data on culm productivity and on survival show that *B. multiplex* performed better compared with the other three species. Growth of bamboo is also quite fast and this can be an effective alternative for reclamation in addition to the ability to stabilize the soil during flood season.

CONCLUSION

From our observations, it was found that bamboo has the potential to grow in the affected areas at Laut 9, Lake Chini. The fast growth rate of bamboo is suitable for reclamation effort and or managing the problem of soil stability as in this area is often flooded. This study indicates that bamboos can be grown in acidic soil condition with good drainage system.

INCREASING TREE DIVERSITY INDEX THROUGH PLANTING OF 30 INDIGENOUS RAINFOREST TREE SPECIES ON A 5 HA SLIME TAILINGS

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ABSTRACT

A 5-ha mixed *Acacia mangium*, *Khaya ivorensis* and *Hopea odorata* stands was enriched by planting of 8,000 seedlings and saplings comprising of 30 rainforest tree species. The Phase I of tree diversity planting program is part of the corporate social responsibility good effort carried out by AEON Co. (M) Bhd which is also known as Japan-Malaysia Friendship Forest. The programme covers a total planting of 30,000 seedlings/saplings of 30 tree species over a 15–20 ha block of greened slime tailings. The planting of remaining 22,000 seedlings and saplings shall be carried out accordingly. The initial Shannon's diversity index (H) and Equitability (E_H) of 16 tree species of natural regeneration under the three plantation species is 1.80 and 0.65, respectively. The species richness comprises of two exotic species, seven secondary species and six primary species. The enrichment planting under the mixed stand introduced 30 indigenous rainforest species comprising 10 IUCN Red List species from the categories of endangered, threatened and endemic species and the rest are yet to be evaluated in the IUCN Red List. The introduced species and their quantity contribute to the increase of H and H_E of the regeneration under the mixed stand to 2.84 and 0.72, respectively. Planting of indigenous rainforest tree species, which are not brought by avian dispersers especially the IUCN Red List species, is needed to speed up the restoration process of the greened slime tailings.

Keywords: tree diversity planting, indigenous species, domestication, IUCN Red-list species, wildlife

INTRODUCTION

The tree planting program was officiated by His Royal Highness Sultan of Perak on 14 September 2014 whereby 30 indigenous forest tree species were planted by 1,000 participants from Malaysia and Japan. The effort was initiated to enrich a man-made forest established on an ex-tin mine of FRIM Research Station (Tin Tailings Afforestation Center — TTAC), Bidor, Perak to support a more diversified wildlife and also acts as a preservation center for rare, endangered and endemic species. A total of 8,000 seedlings and saplings of 30 rainforest tree species were planted in a 5-ha site of a poorly stocked greened ex-tin mine in TTAC. The high mortality of the greened ex-tin mine was due to damages caused by buffaloes. The joint-effort planting programme is also known as Malaysia-Japan Friendship Forest. The tree diversity planting concept was first demonstrated in the tree planting history of Malaysia (Ang *et al.* 2015). These selected species consist of trees for shelter, food and also nesting of various species frugivorous avian fauna. Some of these species are in the of International Union of Conservation of Nature (IUCN) Red List. Eventually, the stand shall serve as a man-made forest which has many beneficial functions to mankind. It will also act as a biodiversity depository of lowland wildlife especially by providing food, shelter and nesting for the avian fauna. The aims of this paper is to share the establishment method and the changes of tree diversity in the mixed stand at 33 months after planting.

MATERIALS AND METHODS

The enriched greened ex-tin mine was divided into four blocks namely Blocks A & B covering 1.57 ha and the Blocks C&D covering about 3.43 ha. For the purpose of this study, only Blocks A & B were sampled to examine the effects of survival and natural regeneration on the tree diversity index. The tree species of the site before and after planting were enumerated and recorded (Ang *et al.* 2015). The stand composition and total stem number at one year after planting remains at 8,000 as refilling activities were carried out quarterly. The calculation of tree diversity index according to Shannon (1948) of the site was carried out before and after planting.

Table 1: Shannon's diversity Index of Japanese-Malaysia Friendship Forest

NO	Species	Status	Red lists	Quantity	Pi	ln(Pi)	(-1*Pi*LN(Pi))
1	*Acacia auriculiformis*	Introduced	*LC*	24	0.004	-5.432	0.024
2	*Acacia mangium*	Regenerated	*NA*	3	0.001	-7.511	0.004
3	*Adenanthera pavonina*	Introduced	*NA*	936	0.171	-1.768	0.302
4	*Aquilaria malaccensis*	Introduced	*VU*	38	0.007	-4.972	0.034
5	*Ardisia elliptica*	Introduced	*NA*	49	0.009	-4.718	0.042
6	*Arytera littoralis*	Introduced	*LC*	25	0.005	-5.391	0.025
7	*Bouea macrophylla*	Introduced	*NA*	2	0.000	-7.916	0.003
8	*Bridelia tomentosa*	Regenerated/ introduced	*NA*	698	0.127	-2.061	0.262
9	*Careya arborea*	Introduced	*NA*	198	0.036	-3.321	0.120
10	*Cananga odorata*	Introduced	*NA*	198	0.036	-3.321	0.120

11	*Dipterocarpus baudii*	Introduced	*CR*	1	0.000	-8.610	0.002
12	*Dryobalanops aromatica*	Introduced	*NA*	22	0.004	-5.519	0.022
13	*Dryobalanops oblongifolia*	Introduced	*NA*	21	0.004	-5.565	0.021
14	*Dyera costulata*	Introduced	*LC*	94	0.017	-4.066	0.070
15	*Elaeocarpus petiolatus*	Regenerated	*NA*	4	0.001	-7.223	0.005
16	*Evodia glabra*	Regenerated	*NC*	74	0.013	-4.306	0.058
17	*Fagraea racemosa*	Regenerated	*NA*	11	0.002	-6.212	0.012
18	*Ficus hispida*	Introduced/ Regenerated	*NA*	446	0.081	-2.509	0.204
19	*Ficus roxburghii*	Introduced	*NA*	14	0.003	-5.971	0.015
20	*Garcinia hombroniana*	Introduced	*NA*	462	0.084	-2.474	0.208
21	*Gnetum gnemon*	Introduced	*LC*	1	0.000	-8.610	0.002
22	*Hopea ferruginea*	Introduced	*CR*	317	0.058	-2.851	0.165
23	*Hopea odorata*	Introduced	*VU*	797	0.145	-1.929	0.280
24	*Khaya ivorensis*	Introduced	*VU*	79	0.014	-4.240	0.061
25	*Kopsia flavida*	Introduced	*NA*	2	0.000	-7.916	0.003
26	*Macaranga gigantea*	Regenerated	*NA*	126	0.023	-3.773	0.087
27	*Mallotus paniculatus*	Regenerated	*NA*	29	0.005	-5.242	0.028
28	*Macaranga triloba*	Regenerated	*NA*	4	0.001	-7.223	0.005
29	*Melaleuca leucadendron*	Introduced	*NA*	4	0.001	-7.223	0.005
30	*Melastoma malabathricum*	Regenerated	*NA*	1	0.000	-8.610	0.002
31	*Milletia atropurpurea*	Introduced	*NC*	1	0.000	-8.610	0.002
32	*Neobalanocarpus heimii*	Introduced	*VU*	77	0.014	-4.266	0.060
33	*Palaquium gutta*	Introduced	*NA*	46	0.008	-4.781	0.040
34	*Pentaspadon motleyi*	Introduced	*DD*	67	0.012	-4.405	0.054
35	*Sandoricum koetjape*	Introduced	*NA*	6	0.001	-6.818	0.007
36	*Shorea acuminata*	Introduced	*CR*	1	0.000	-8.610	0.002
37	*Shorea assamica*	Introduced	*NA*	38	0.007	-4.972	0.034
38	*Shorea curtisii*	Introduced	*LR/LC*	49	0.009	-4.718	0.042
39	*Shorea leprosula*	Introduced	*EN*	5	0.001	-7.000	0.006
40	*Shorea macroptera*	Introduced	*NA*	29	0.005	-5.242	0.028

41	*Shorea ovalis*	Introduced	*NA*	158	0.029	-3.547	0.102
42	*Shorea parvifolia*	Introduced	*NA*	4	0.001	-7.223	0.005
43	*Shorea platyclados*	Introduced	*EN*	6	0.001	-6.818	0.007
44	*Shorea roxburghii*	Introduced	*EN*	94	0.017	-4.066	0.070
45	*Sindora echinocalyx*	Introduced	*NA*	79	0.014	-4.240	0.061
46	*Sterculia parviflora*	Introduced	*LR/LC*	50	0.009	-4.698	0.043
47	*Syzygium polyanthum*	Introduced	*LC*	7	0.001	-6.664	0.009
48	*Terrentia fragrance*	Regenerated	*NC*	1	0.000	-8.610	0.002
49	*Terminalia ivorensis*	Introduced	*VU*	2	0.000	-7.916	0.003
50	*Trema orientalis*	Regenerated	*NA*	5	0.001	-7.000	0.006
51	*Vitex pubescens*	Regenerated	*NA*	79	0.014	-4.240	0.061
				5484	1.000		
		Shannon's Index					2.835
		Ln (No of Species)					3.932
		EH					0.721

NC, NA, CR, LC, VU, DD and LR denotes a taxon has not yet been assessed for the IUCN Red List versions 2.3 & 3.1, and also is not in the Catalogue of Life, a taxon has not been assessed for the IUCN Red List versions 2.3 & 3.1, but in the Catalogue of Life, Critically Endangered, Least concern, Vulnerable, Data Deficient and Lower Risk, respectively.

Establishment methods and tending procedures

A planting line of 3 to 4 m width and deep ploughed to 1.5 m was constructed using a back hoe. Existing trees, except Acacias, were kept for providing shade. After the planting line was constructed, a planting hole of 50 cm radius and depth was prepared and the slime was mixed with a composition of 2:1 ratio cocopeat and biochar which act as refilled enriched soil for the seedlings or saplings. The spacing of planting varies between emergent and main canopy species, and lower canopy species. The irregular spacing demands an in-depth knowledge on the natural distribution of the forest tree species. Tree diversity planting does not have a fixed spacing but the planting shall be arranged according to their natural vertical distribution profile. The stand is properly tended with monthly weeding, loosening of soils and also fertilizer application according to its prescribed regime of three times annually.

RESULTS AND DISCUSSION

The tree species composition under the mixed *Dyera costulata* and *Khaya ivorensis* stand is only 16 species and has tree diversity index of 1.88 and evenness of 0.71. The number increased to 44 species after planting with 30 rainforest tee species (Table 2). Seven of them are introduced tree species amongst the IUCN Red List species, Version 3.0 namely one critically endangered species (CR) which is *Shorea acuminata*, two endangered species (EN) namely *S. platyclados* and *S. roxburghii*, and four vulnerable species (VU) namely *Hopea odorata*, *Terminalia ivorensis*, *K. ivorensis* and *Neobalanocarpus heimii*. The tree stand diversity after one year with 30 species planted has Shannon's index of 2.74 and Evenness of 0.72. The enriched tree stand grown on slime tailings had increased 150% in tree diversity index compared to the mixed stand before the planting programme. However, without further planting, the tree diversity index of the stand increased by about 3.3% at two years interval, and average of 1.15% per year. The increase was caused by the density of the regenerated species brought by avian seed dispersers. However, none of them is listed in the IUCN Red List. Hence, enrichment planting would help to speed up the diversity increment of the mixed stand.

Table 2. Changes of Shannon's Index of the Japan-Malaysia Friendship Forest

Year	*2014	*2015	2017
Total tree species	16	44	51
Shannon's Index	1.88	2.74	2.83
H_E	0.71	0.72	0.72
IUCN Redlist	2	7	7

*Adapted from Ang *et al.* (2015).

CONCLUSION

Tree planting programme should have a component on domestication of endangered, rare and threatened indigenous rainforest tree species in order to add value to the planting. Malaysia-Japan Friendship Forest established in TTAC serves as an example of a multipurpose greening effort which included *ex-situ* conservation of rainforest tree species. The greened ex-tin mine also acts as a biodiversity depository. The indigenous rainforest tree species which serves as food and shelter for avian fauna and other wildlife were planted. Hence, the enriched mixed species stand will have the potential to support a more diversified wildlife. In addition, the uniqueness of this planting programme is the domestication of seven IUCN Red List species.

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SURVIVAL AND VEGETATIVE GROWTHS OF SOME SELECTED RAINFOREST TREE SPECIES INTER-PLANTED UNDER *HOPEA ODORATA* STAND AT SLIME TAILINGS IN PENINSULAR MALAYSIA

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ABSTRACT

Asian Forest Cooperation Project (AFoCo) has funded a research and development project in Malaysia for enriching the single species stand established in an ex-tin mine in 2011. The project covered only for a period of 12 months. A 1-ha study plot was established in Tin Tailings Afforestation Centre (TTAC). Twenty indigenous rainforest tree species were planted and their five-year-old survival and mean annual increment of diameter and total height are reported in this study. The paper also highlights some silvicultural treatments in the stand management.

Keywords: enrichment planting, restoration, domestication, ex-tin mine

INTRODUCTION

Forest Research Institute Malaysia (FRIM) has developed rehabilitation technologies for the greening of ex-tin mine (Ang *et al*. 2006). The greened site has been a model for rehabilitation of ex-tin mines in Malaysia (Ang 2012). ASEAN Korea Environmental Cooperation Project (AKECOP) had supported the rehabilitation programme in Tin Tailings Afforestation Centre (TTAC) since 2002 and the project was completed in 2016. We observed poor regeneration of trees in the greened slime tailing site comprising mixed planting of *Acacia mangium, A. auriculifomis, Hopea odorata* and *Khaya ivorensis.* Woody tree and shrub species that are dispersed by avian dispersal agents were found under the mixed stands. The isolated greened ex-tin mine remains lack of primary forest species with fruits that are not edible for birds or bats. An enrichment planting, using climax rainforest tree species that produce seeds not dispersed by the avian group, was carried out in TTAC in Bidor. This is part of the project to fulfill the blue print of the TTAC (Zoal *et al*. 2012). From 2013 till 2016, AKECOP funded the tending of the demonstration plot established by ASEAN-Korean Forest Cooperation Project (AFoCo) in 2011–2012. The demonstration plot is a mixed stand of 20 rainforest tree species under the nurse species *H. odorata*. This study aims to document the survival and vegetative growth of the 20 species at five years after planting under the *H. odorata* stand.

MATERIALS AND METHODS

Study site

A 1.5 ha of slime tailings site located in Tin Tailings Afforestation Centre (TTAC) had been enriched with 20 indigenous tree species. The soil at the site was loosened to 1 m depth and applied with 1 kg ashes per planting point.

The seedlings of the 20 selected indigenous rainforest species (Table 1) were acclimatized in the TTAC for a period of three months. They have an average height of 45–50 cm and collar diameter of < 1cm. They were planted during the wet season in December 2011. Eight of the 20 rainforest tree species are referred to as threatened species according to IUCN Red List version 2.3, of which two are non-dipterocarps and six dipterocarps.

Tending regime

Tending practices including line weeding followed by circle weeding of 50 cm radius was carried out for each planting point bi-monthly, and followed by application of a mixture of organic fertilizer of 80% chicken manure with 10 g NPK (15:15:15) at three months intervals.

Table 1. Species planted in the greened slime tailings

Non-dipterocarps	**Dipterocarps**
Garcinia hombroniana (NE)	**Shorea assamica* (CR)
Melaleuca cajuputi (NE)	*Shorea parvifolia* (NE)
Sindora coriacea (NE)	**Shorea acuminata* (CR)
Careya arborea (NE)	*Shorea curtisii* (LC/LR)
Cananga odorata (NE)	*Dryobalanops aromatica* (NE)
**Agathis borneensis* (EN)	**Hopea pubescens* (CR)
Palaquium gutta (NE)	**Neobalanocarpus heimii* (VU)
**Aquilaria malaccensis* (VU)	**Shorea roxburghii* (EN)
Pentaspadon motleyi (DD)	**Shorea platyclados* (EN)
	Shorea ovalis (NE)
	Shorea macroptera (NE)

*denotes species listed in IUCN Red List Categories and Criteria Version 2.3 as threatened taxa include Extinct (EX), Endangered (EN), Critically Endangered (CR) and vulnerable (VU); the other species are classified as Near Threatened (NT), Least Concern (LC)/Lower Risk (LR), Data Deficient (DD) and Not Evaluated (NE) (Chua *et al*. 2010)

RESULTS AND DISCUSSION

Survival

Survival count and measurement of total height were carried out in June 2012, May 2013, July 2015 and June 2017. The survival of the enrichment species is reduced from an average of 91.8% to 53% from 2012 to 2017, respectively (Table 2). Mortality of the planting is due to destruction of seedlings by wild boars (Table 2).

Table 2. Survival of tropical rainforest species seedlings grown on greened slime tailings

			Survival (%)				
	Block	Quantity	12-Jun	13-May	14-Jul	15-Jul	17-Jun
Jalan Biodiversiti	A	720	98.3	75.1	62.2	54.0	50.0
Jalan Pasir	B	720	91.8	76.1	64.7	59.0	56.0
Mean Survival (%)			95.1	75.6	63.5	56.5	53.0

*Seedlings of ash treatment were planted in Nov 2011 & replanted in May 2012. Seedlings of control treatment were planted in May 2012

Generally, dipterocarp species had higher survival count than non-dipterocraps grown on the greened slime tailings (Table 3). *Shorea roxburghii* had a survival of more than 80% followed by *Neobalanocarpus heimii* and *Dryobalanops aromatica*. *Shorea roxburghii* is known to be suitable for adapting in open conditions especially in the enrichment planting programme and also for planting in parks. *Shorea platyclados* had the lowest survival of 54.2% as it suffered severely from wild boar attacks. For the non-dipterocarps planted under the *H. odorata* stand, *Pentaspadon motleyi* had the highest survival followed by *Sindora coriacea.* The group of species with lowest survival comprised *Cananga odorata, Careya arborea* and *Melaleuca cajuputi.*

Table 3. Survival of 20 rainforest species grown on the greened slime tailings at five years after planting

No	Species	Survival (%)		
		Jln Biod (%)	Jln Pasir (%)	Mean (%)
	Dipterocarps			
1	*Shorea roxburghii*	86.1	86.1	86.1
2	*Neobalanocarpus heimii*	80.5	63.9	72.2
3	*Dryobalanops aromatica*	75.0	66.7	70.8
4	*Shorea parvifolia*	72.2	55.6	63.9
5	*Shorea acuminata*	63.9	63.9	63.9
6	*Shorea curtisii*	55.6	55.6	55.6
7	*Shorea macroptera*	55.6	55.6	55.6
8	*Shorea assamica*	47.2	63.9	55.6
9	*Shorea ovalis*	52.7	55.6	54.2
10	*Hopea pubescens*	55.6	47.0	51.3
11	*Shorea platyclados*	33.3	50.0	41.6
	Non-dipterocarps			
12	*Pentaspadon motleyi*	80.5	80.6	80.6
13	*Sindora coriacea*	50.0	50.0	50.0
14	*Agathis borneensis*	41.7	50.0	45.8
15	*Aquilaria malaccensis*	36.1	55.6	45.8
16	*Garcinia homobroniana*	52.8	25.0	38.9
17	*Palaquium gutta*	47.2	27.8	37.5
18	*Cananga odorata*	11.1	11.1	11.1
19	*Careya arborea*	13.8	8.3	11.0
20	*Melaleuca cajuputi*	0	2.7	1.35

Mean diameter at breast height (DBH) and mean annual DBH increment

The mean diameter at breast height and mean annual DBH increment are tabulated (Table 4). Twenty species of rainforest tree species could be grouped into four groups. The first group comprises of *S. acuminata*, *S. parvifolia*, and *S. platylados* are relatively fast growers and have their range of DBH from 6.25 to 6.9 cm (Table 4). The second group of rainforest species had mean top height of 4.8–5.1 cm including *S. ovalis, S. macroptera, S. curtisii, Hopea pubescens* and *P. motleyi*. The third group of tree species namely *S. assamica*, *N. heimii*, *S. roxburghii*, *C. odorata*, *Palaquium gutta, Agathis borneensis, Sindora coriacea* and *Garcinia homobroniana* had a range of top height from 3.65 to 4.85 cm. Lastly, *Careya arborea* was identified as the slowest grower due to its low drought tolerant morphological properties and also easily attract wild boar attacks. Their mean annual height increment follows the same trend of mean diameter (Table 4).

Table 4. Mean diameter at breast height and mean annual increment of diameter at breast height (DBH)

	Dipterocarps	Jalan Biodiversiti	Jalan Pasir	Mean DBH (cm)	Mean annual DBH increment (cm/y)
1	*Shorea acuminata*	7.9(2.5)	5.9(1.4)	6.9(1.9)a	1.38(0.39)
2	*Shorea parvifolia*	7.2(2.4)	6.4(3.2)	6.8(2.8)a	1.36(0.56)
3	*Shorea platyclados*	6.7(2.4)	5.8(2.5)	6.25(2.4)a	1.25(0.49)
4	*Dryobalanops aromatica*	5.1(2.1)	5(1.7)	5.05(1.8)b	1.01(0.37)
5	*Shorea assamica*	5.7(2)	4.4(1.1)	5.05(1.6)b	1.01(0.31)
6	*Shorea ovalis*	5.4(1.4)	4.5(2.2)	4.95(1.8)b	0.99(0.36)
7	*Shorea macroptera*	4.9(1.8)	4.8(1.5)	4.85(1.6)b	0.97(0.33)
8	*Shorea roxburghii*	3.8(2.1)	4.5(1.7)	4.15(1.9)c	0.83(0.38)
9	*Shorea curtisii*	4.8(2)	3.5(1.2)	4.15(1.6)c	0.83(0.32)
10	*Cananga odorata*	3.5(1.1)	4.7(1.9)	4.1(1.5)c	0.82(0.3)
11	*Hopea pubescens*	4.4(1.4)	3.5(0.9)	3.95(1.2)c	0.79(0.23)
12	*Palaquium gutta*	2.2(1.1)	4.4(1.2)	3.3(1.15)cd	0.66(0.23)
13	*Garcinia homobroniana*	3.1(1.1)	3.2(1.1)	3.15(1.1)cd	0.63(0.22)
14	*Neobalanocarpus heimii*	2.8(1.1)	3(1.2)	2.9(2)d	0.58(0.23)
15	*Agathis borneensis*	2.7(1.1)	3(0.8)	2.85(0.95)cd	0.57(0.19)
16	*Aquilaria malaccensis*	2.2(1.1)	2.8(1.1)	2.5(1.1)d	0.5(0.22)
17	*Pentaspadon motleyi*	2.2(0.8)	2.8(1)	2.5(0.9)d	0.5(0.18)
18	*Careya arborea*	1.6(0.57)	1.6(0.7)	1.6(0.63)de	0.32(0.12)
19	*Sindora coriacea*	2.9(1.2)	2.97(1.3)	1.2(1.2)e	0.24(0.25)
20	*Melaleuca cajuputi*		3.4		0.68

Values in parenthesis denote standard deviation and different alphabetical letters denote significant difference by t-test at 0.05 level.

Mean top height and mean annual height increment

The mean top height and mean annual height increment of 20 rainforest tree species could be seperated into four groups. The first group consists of *Aquilaria malacensis, S. parvifolia, S. platyclados, D. aromatica* and *S. accuminata,* which are relatively fast growers and have their range of top height from 6.9–8.1 m (Table 5). The second group of rainforest species had mean top height of 5.8–6.4 m including *S. ovalis, S. macroptera, S. curtisii, Hopea pubescens* and *P. motleyi*. The third group of tree species namely *S. assamica, N. heimii, S. roxburghii, C. odorata, Palaquium gutta, A. borneensis, Sindora coriacea* and *Garcinia homobroniana* had a range of top height from 3.65–4.85 m. Lastly, *Careya arborea* was identified as the slowest grower due to reasons stated earlier. A single remaining tree of *M. cajuputi* was excluded from the ranking. Similarly, mean annual height increment follows the same trend as the mean top height.

Table 5. Mean top height and mean annual height increment of 20 tree species

No	Species	Jalan Biodiversiti	Jalan Pasir	Mean Height (m)	Mean Annual Increment (m/year)
1	*Shorea parvifolia*	8.7(3.2)	7.5(2.5)	8.1(2.8)a	1.6 (0.6)
2	*Shorea platyclados*	7.9(2.3)	6.6(2.2)	7.25(2.2)a	1.45(0.45)
3	*Aquilaria malaccensis*	7.2(1.9)	6.9(1.8)	7.05(1.8)a	1.41(0.37)
4	*Dryobalanops aromatica*	7.4(1.9)	7.1(2.1)	7.25(2)a	1.4(0.4)
5	*Shorea acuminata*	7.9(2.5)	5.9(1.4)	6.9(1.9)ab	1.38(0.45)
6	*Shorea ovalis*	7(1.6)	5.8(1.9)	6.4(1.8)b	1.28(0.35)
7	*Shorea macroptera*	6.4(1.9)	6.2(2.2)	6.3(2.0)b	1.26(0.41)
8	*Shorea curtisii*	6.8(2.6)	5.4(1.7)	6.1(2.2)b	1.22(0.43)
9	*Pentaspadon motleyi*	4.4(2.3)	7.2(2.8)	5.8(2.6)bc	1.16(0.51)
10	*Hopea pubescens*	6.5(1.1)	5(1.4)	5.8(1.6)bc	1.15(0.25)
11	*Cananga odorata*	4.1(1.8)	5.6(1.6)	4.8(1.7)c	0.97(0.34)
12	*Shorea assamica*	3.6(1.9)	6(1.4)	4.8(1.6)c	0.96(0.33)
13	*Shorea roxburghii*	3.8(2.1)	5.7(2.3)	4.75(2.2)c	0.95(0.44)
14	*Palaquium gutta*	4.3(1.1)	4.4(1.2)	4.35(1.2)c	0.87(0.23)
15	*Agathis borneensis*	3.4(1.5)	4.4(0.9)	3.9(1.2)c	0.78(0.24)
16	*Neobalanocarpus heimii*	3.7(1.8)	3.8(1.4)	3.75(1.6)c	0.75(0.32)
17	*Sindora coriacea*	3.6(1.2)	3.9(1.3)	3.75(1.2)c	0.75(0.25)
18	*Garcinia homobroniana*	3.5(1)	3.8(1.3)	3.65(1.12)c	0.73(0.23)
19	*Careya arborea*	1.9(1.2)	1.4(1.2)	1.65(1.2)d	0.33(0.24)
20	*Melaleuca cajuputi*		6.6	6.6	1.32

CONCLUSION

The early survival and mean top height growth show promising results for some climax rainforest tree species but tending programme must be continued. Some of them are classified as IUCN Red List species. Methods to prevent further damage by wild boars or feral pigs on the seedlings are being developed.

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DOMESTICATION OF TEN ENDEMIC, ENDANGERED AND THREATENED TREE SPECIES IN A DEGRADED TERRESTRIAL ECOSYSTEM IN PENINSULAR MALAYSIA

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ABSTRACT

The importance of domestication of tree species in Red List of a nation and International Union for Conservation of Nature (IUCN) cannot be over-empathized. Asian Forest Cooperation Project (AFoCo) has sponsored a six-year joint project between Malaysia and Thailand for domestication of Red List tree species from 2016 to 2022. A 3-ha plot comprising 1,500 seedlings and saplings of 10 Red List tree species were planted under a mixed stand of secondary regrowth interspersed with *Khaya ivorensis* and *Acacia mangium* stands in an ex-tin mine. The research and development plot was established in the first year period of the project (2016–2017) in Tin Tailings Afforestation Centre. This paper describes the establishment method and tending regime of the 3-month-old mixed stand comprising *Aquilaria malaccensis, Dipterocarpus charteus, Dryobalanops oblongifolia, Hopea ferruginea, Lagerstroemia langkawiensis, Neobalanocarpus heimii, Palaquium maingiyi, Hopea helfri, Shorea glauca* and *Shorea sumatrana.* Early survival of the ten species at three months after planting was also reported.

INTRODUCTION

Asian Forest Cooperation Project (AFoCo) has funded a collaborative project between Malaysia–Thailand on ‘Domestication of Endangered, Endemic and Threatened Tree Species (EETs) on Degraded Terrestrial Ecosystem’. The project planted some EETs classified by IUCN Red List and/or species identified as endangered, endemic and threatened nationally (Chen 2004, Chua *et al*. 2010). The research and development project started from 2016 and will be completed in 2022 with an estimated cost of USD1.2 million for both countries. This paper only focuses on the planting component of the project carried out in Malaysia from 2016–2017. The planting component of the project is with the objective of producing a model plot for domestication of EETs especially on problematic sites. Planting of problematic sites such as ex-mining lands is preferred other than replanting them in their disturbed habitats. Normally, lowland forests would have to be converted to other land use in a developing country like Malaysia. Losing of natural habitat is one of the classifying factors for IUCN Red List species. Hence, commercially important timber species from lowland forest in Malaysia are normally also Red List species classified by IUCN, e.g. *Shorea sumatrana*. The project aims to domesticate 10 to 15 species of EETs during the six years period in Malaysia alone. The species selection of the EETs would depend on the availability of the planting stock in the market. Hence, the ten species selected to be planted in the Phase I of the project are *Aquilaria malaccensis, Dipterocarpus chartaceus, Dryobalanops oblongifolia, Hopea ferruginea, Lagerstroemia langkawiensis, Neobalanocarpus heimii, Palaquium maingayi, H. helferi, Shorea glauca* and *S. sumatrana*. This paper aims to share the plot establishment experiences including site amelioration technique, planting and tending experiences. In addition, early survival of the mixed stand at three months after planting is also reported.

The objectives of this study is to share the establishment technique and early survival of the planting of 10 selected species of endangered, endemic and threatened tree species at slime tailings.

MATERIALS AND METHODS

Study site

A 3-ha mixed stand of *Khaya ivorensis* and *Acacia mangium* located in Tin Tailings Afforestation Centre, SPF Bidor, Perak was selected as the study site. The mixed stand with size 150 m x 200 m was dominantly covered with naturally regenerated tree species such as *Euodia glabra, Eleocarpus petiolatus* and *Macaranga gigantea.*

Site preparation

The 3-ha plot has 30 planting lines of size 5 x 200 m, and the undergrowth of the planting line was cleared except for trees with diameter at breast height > 20 cm are retained to provide shade. The planting line was loosened to the depth of 1.5 m using a back-hoe (Plate 1). Planting point is distributed at 5 x 4 m spacing. Each planting hole of sizes 0.5 m depth x 0.5 m radius to 0.7 m depth x 0.5 m radius was added with enriched soils of a mixed soil conditioner comprising of coconut-peat with burnt-rice husk (biochar) at a ratio of 1:2 or 5 kg coconut-peat with 10 kg burnt-rice husk. The slime was well-mixed with the soil conditioner and refilled back into the planting hole at a depth of 20 cm.

Planting stock

The planting stock was sourced from several nurseries throughout Peninsular Malaysia and the planting was transported to site one month before planting. The site conditioning of the planting stock helps them to adapt to heat stress in the field. Table 1 lists the conservation value, size and quantity of planting stock for each species. Eight out of the 10 tree species are from lowland forest and which produce high quality timber except *A. malaccensis* and *L. langkawiensis*. Of the eight timber species from the lowland forests, five of them are classified as IUCN Red List species. Two species are not being assessed in IUCN and one is assessed as a lower risk in IUCN but they are important timber species from lowland forest which produce highly demanded *keruing* and *kapur* timbers for trade. The project included them in the list for domestication as their planting stocks are still available in the market. *Aquilaria malaccensis* in the lowland forest which produces expensive agarwood resin has been illegally over-exploited, and *L. langkawiensis* is an endemic species which suffers from the loss of their natural habitat in the northern region of the Malay Peninsula.

Table 1. Planting stock of 10 selected tree species

Species	Conservation value	Size	Quantity
Aquilaria malaccensis	*Vulnerable A1cd	Sapling	300
Dipterocarpus chartaceus	#Lowland timber species	Seedling	140
Dryobalanops oblongifolia	#Lowland timber species	Sapling/seedling	50
Hopea ferruginea	*Critically Endangered	Seedling	56
Hopea helferi	*Critically Endangered	Seedling	179
Lagerstroemia langkawiensis	*Endangered	Sapling	301
Neobalanocarpus heimii	*Vulnerable	Sapling/seedling	164
Palaquium maingayi	*Lower Risk/ #nyatoh tree from lowland forest	Sapling/seedling	60
Shorea glauca	*Endangered	Seedling	200
Shorea sumatrana	*Critically Endangered	Sapling/seedling	50
Total			1,500

# denotes criteria classified as threatened timber species from lowland forest (Chen 2004);
* denotes classification using IUCN Red List species version 2.3

Distribution of planting stock and planting technique

The planting stock was transported from the road to the boundary of the plot and distributed using a wheel-barrow within the plot**.** The distribution of the planting points was mapped (Figure 1). Planting was carried out immediately, the poly-bag was removed using a pen-knife and the root-ball was carefully placed into the planting hole, the stem must be vertical to the ground level, and the enriched soil was filled back into the planting hole. The root ball must be at least 15 cm below the ground level. This would prevent direct water loss from the root-ball and thus reducing the effects of drought.

Figure 1. The distribution of the planting point using a GPS receptor

Tending regime

Watering for the planted seedlings was carried out immediately and continued daily until heavy rainfall, then, the seedlings were watered at two dry-day interval. The soil of 50 cm radius of the planting point was loosened, climbers were removed monthly. Fertilizer application was carried out quarterly. The last application of a mixture of 60 g compound fertilizer NPK (17:17:17) + trace elements with chicken manure at 80% maturity per planting was carried out in June 2017.

RESULTS AND DISCUSSION

The survival count at three months after planting showed that only *L. langkawiensis* has not suffered from any mortality even subjected to the dry period from mid May till early July 2017 (Figure 2). *Hopea ferruginea* suffered the most during the dry period (Table 2). The mortality of the saplings and seedlings of EETs are mainly due to drought and heat stresses during mid May till mid June 2017. Even though watering was being carried out, some of them still could not survive the heat load and dryness of the air which created high ambient vapour pressure demand (VPD). High VPD would increase the loss of water during photosynthesis and eventually dry up the plants if there were no leaf shedding. *Lagestroemia langkawiensis* and *A. malaccensis* shed their leaves at the onset of drought and heat stresses, and they survived through the dry period.

Low VPD is expected under the shade created by crowns of the existing trees. Hence, this produces a moist microsite which promotes better water use efficiency of the plants and subsequently promotes higher survival during the drought. This observation is supported as most of the mortality of all the tree species occurred in the open microsites. Those saplings and seedlings planted in shady microsites under the existing big trees suffered no mortality during and after the dry period (Figure 2).

Table 2. The survival count of 10 tree species at three months after planting

Tree species	Quantity	April	May	June	July
Dryobalanops oblongifolia	50	50	50	50	49
Shorea sumatrana	50	50	49	49	47
Hopea ferruginea	56	56	36	26	24
Palaquium maingayi	60	60	60	59	59
Dipterocarpus chartaceus	140	140	140	138	138
Neobalanocarpus heimii	164	164	164	154	154
Hopea helferi	179	179	179	179	177
Shorea glauca	200	200	191	190	190
Aquilaria malaccensis	300	300	299	268	268
Lagerstroemia langkawiensis	301	301	301	301	301

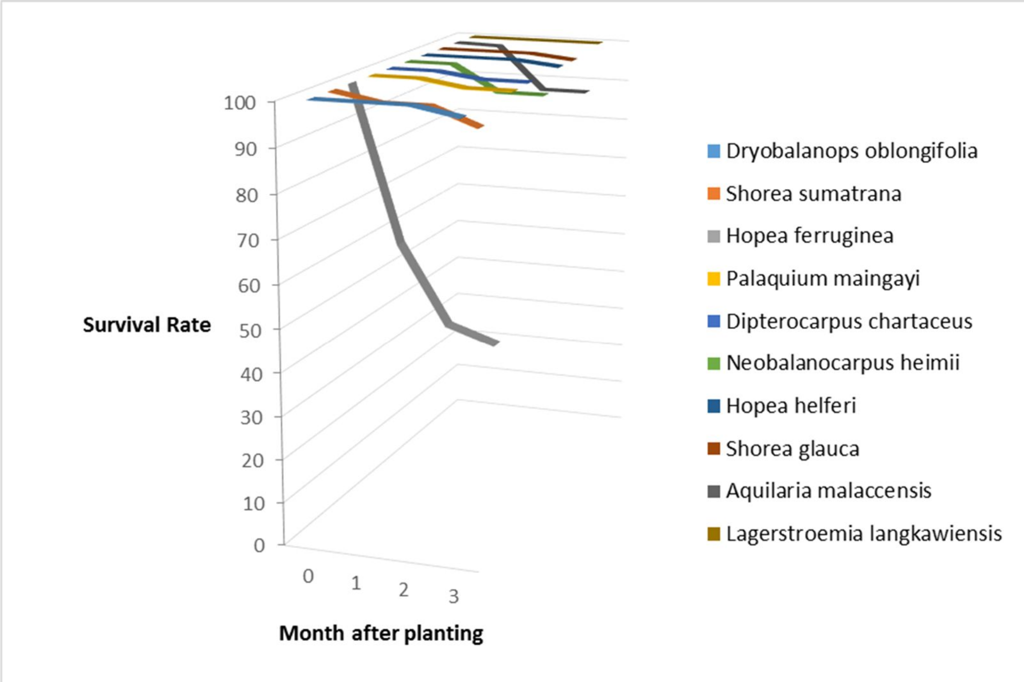

Figure 2. Survival rate of the 10 tree species at three months after planting

CONCLUSION

The 3-ha domestication plot of 10 EETs was established in the project site and the site improvement technique and tending regime were documented. The early survival of the EETs shows that *Lagerstroemia langkawiensis* is more adaptable to the site condition of the slime tailings and had 100% survival through the mid-year short dry period in Bidor. Most of the EETs in the seedlings and sapling stages required shady microsites which are provided by the existing big trees.

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CAN EX-TIN MINE BE A DEPOSITORY FOR INDIGENOUS AND RED LIST SPECIES?

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ABSTRACT

Ex-tin mines have always been associated with harsh microclimate and infertile soils that usually allows the growth of grasses, ferns, shrubs and few pioneer tree species. Despite these challenges, FRIM has put in efforts to rehabilitate an ex-tin mine with various indigenous and exotic species. Initial efforts using fast-growing exotic tree species were aimed at greening the barren area while establishing a demonstration site for cost-effective planting techniques. When adequate shade and suitable microclimate have been created by nurse tree stands, indigenous and threatened tree species were added to the ecosystem. This is an approach not only to enrich species diversity but also to conserve threatened tree species. Species from the Dipterocarpaceae Red List have been planted and some have shown encouraging growth and survival. These include *Dryobalanops aromatica*, *Shorea curtisii* and *Shorea roxburghii*. Among the non-Dipterocarp species planted are *Aquilaria malaccensis* and *Pentaspadon motleyii* which have also shown good growth and survival when established under tree stand. Although ash was used to increase the pH of soil as a means to ameliorate soil condition, no significant result on the growth and survival was observed. This finding is not conclusive as some trees have been killed and disturbed by the presence of wildlife.

INTRODUCTION

Since the late 19th century to early 20th century, tin mining had been the main industry that propelled the socio-economic growth of the country. The methods used for tin mining include dredging, gravel pump, open cast and *dulang* washing. Tin ore is recovered using gravity separation and tailings generated are considered as waste materials. The tin tailings produced consist of sand, slime or sandy slime. Mining activities had altered the landscape of the mining sites thoroughly. Ex-tin mines could be seen with long tracts of sand barns, slime retention areas interspersed with clear blue mining ponds. During the above-mentioned period, there were little or no rehabilitation efforts carried out on the affected areas. As a result, mined areas were left almost desolate of vegetation particularly tree species with economical values. Reclamation or rehabilitation of tin tailings is often difficult due to adverse physical and chemical characteristics of the tailings.

Establishment of both sand and slime tailings with tree species are inhibited by physical and chemical characteristics of these tailings. The former consist of more than 95% sand and are deficient of nutrients. When exposed to extreme hot weather during dry season, high temperatures in sand tailings can be detrimental to the growth and survival of seedlings. These porous tailings also have low water retention capacity and low nutrient content which hampers tree planting activities. On the other hand, slime tailings are mostly silt and clay, and are prone to inundation during monsoon season. Formation of iron pans in these tailings is common causing impedance to root growth and preventing root penetration. Tailings also have elevated potentially toxic elements which include lead, cadmium, arsenic and mercury. Plant uptake of these toxic elements and incorporation into food chain through translocation of metals may pose health risks. Therefore, conversion of ex-tin mines for agricultural purposes such as production of food crops is not recommended. On the other hand, rehabilitation of ex-tin mines by planting forest species provides an alternative to reduce harvesting pressure from natural forest and improve soil properties of these areas (Ho *et al.*, 2015) besides enhancing biodiversity through enrichment planting.

MATERIALS AND METHODS

A *Hopea odorata* stand was established in year 2000 on slime tailings of an ex-tin mine located in Bidor, a town about 120 km north of Kuala Lumpur. *Hopea odorata* trees were used as nurse trees providing shade for the establishment of indigenous rainforest species. A total of 10 Dipterocarp and another 10 non-Dipterocarp species with average height of 45–50 cm seedlings were planted at the end of 2011, supported by the ASEAN-ROK Forest Cooperation as part of a species enrichment project. Ash was added to the seedlings as a treatment and comparisons were made with control seedlings (no ash added). For ash treatment, 1 kg of ash was placed in each planting hole. Line weeding and circle weeding were carried out to improve the growth of seedlings.

Survey on the growth of selected planted species was carried out in May 2017 to determine the performance of those species at approximately five years after planting. Diameter at breast height (DBH) and total height were measured and analyzed for mean annual increment (MAI).

RESULTS AND DISCUSSION

Survival

Survival of the planted enrichment species were reported to decline from 91.8% in 2012 to 74.9% in 2013 (Ho *et al*., 2014). According to Ho *et al*. (2014), *Shorea roxburghii* and *S. ovalis* had the highest survival of over 90% in 2013 while *Pentaspadon motleyii* was the only non-Dipterocarp with over 90% survival. The survival of these plants further dropped in the current survey in 2017 (Table 1). High mortality was mainly caused by wild boar attacks. Plants given ash treatment showed lower survival initially but significantly higher survival in 2017.

Table 1. Survival of enrichment species according to treatments

Treatment	Survival (%)		
	June 2012	May 2013	May 2017
Control (no treatment)	98.33	75.14	50.00
Ash	91.81	74.86	68.75

The growth performance of selected enrichment species under *H. odorata* stand in slime tailings has been evaluated and shown in Figure1 and Figure 2. Generally, ash treatment improved the DBH and total height growth of only some species.

Species Performance

Non-Dipterocarp species such as *Aquilaria malaccensis* has shown considerable DBH and height in the slime tailings with 7.32±3.07 cm and 6.22±1.55 m, respectively. *Aquilaria malaccensis* has been listed as a vulnerable species in IUCN Red List due to harvesting for agarwood (IUCN, 2015). For Dipterocarps, *S. parvifolia* has recorded better DBH and height followed by *S. acuminata*. The former has DBH and height measuring at 6.18±2.39 cm and 6.36±2.20 m while the latter at 5.05±0.64 cm and 6.85±0.78 m, respectively.

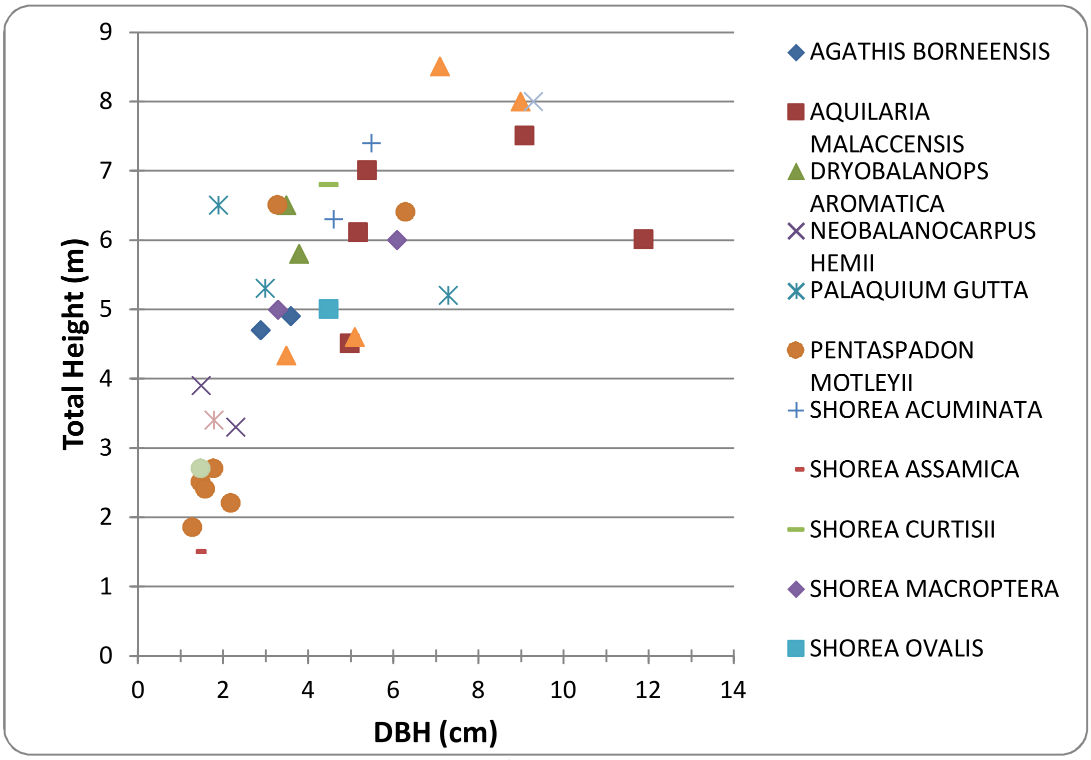

Figure 1. Total height and DBH of selected enrichment species in control plot (without treatment)

The 17-year-old *H. odorata* stand (nurse trees) has an average DBH of 5.50±0.87 cm and total height of 6.80±0.26 m. For non-Dipterocarps, we found that the growth of *P. motleyii* was comparable to the nurse trees with average DBH of 5.31±2.86 cm and total height

6.32±3.77 m (Figure 1). In control plots, however, poorer growth was recorded with DBH 2.57±1.77 cm and total height 3.51±2.03 m. For Dipterocarps, *D. aromatica* and *S. roxburghii* have shown good growth with average DBH of 4.89 cm and 4.90 cm, respectively while average height recorded were 5.91 m and 5.80 m, respectively.

<u>Mean Annual Increment</u>

Mean annual increment (MAI) of both DBH and total height for selected enrichment species were calculated. In control plots, *A. malaccensis* showed relatively better growth with MAI of DBH and height at 1.46 cm and 1.24 m, respectively (Figure 2). Ash treatment provided better growth for *S. roxburghii* and *P. motleyii*. Other species did not respond significantly to the application of ash. The effects of ash treatments were not conclusive as wild boar attacks were rampant in the site, impeding healthy growth of trees.

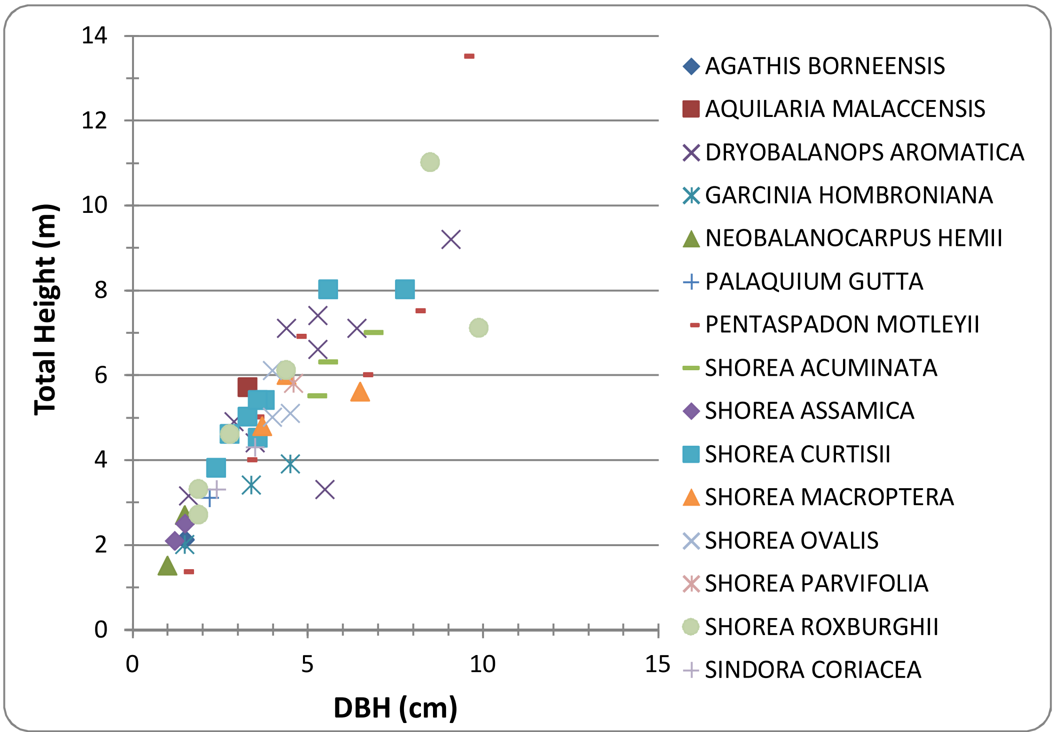

Figure 2. Total height and DBH of selected enrichment species with ash treatment

CONCLUSION

Enrichment planting in ex-tin mine using indigenous and red list species on slime tailings have shown to be considerably successful under tree stands with the survival of above 50% at five years after planting. The survival and growth of those species can be improved if strategies to control wild boar attacks were in place. This study indicates that degraded areas like ex-tin mine need can have great potentials as forest plantation as well as a depository of threatened species to restore both ecological and economical values.

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REHABILITATION TECHNIQUE DEVELOPED FOR DISTURBED FIREFLY HABITAT AT THE RIVERBANK OF SUNGAI SELANGOR

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ABSTRACT

The destruction of firefly habitat is one of the contributory factors to the reduction of firefly population in the tourist attraction site of Kuala Selangor. The State Government of Selangor and AEON Co. (M) Bhd. through the cooperation of Forest Research Institute Malaysia had successfully grown a mixed stand of riverbank species on a 2.5 ha ex-farmland located at Tanjung Beluntas, Kuala Selangor. The study site is part of the firefly sanctuary which occupies about 99 acres of open grassland interspersed with ex-farmland and ex-oil palm plantation. A total of 1,600 seedlings of riverbank species were planted. The survival of planted species included *Fagreae crenulata*, *Bredelia tomentosa*, *Metroxylon sagu*, *Macaranga gigantean* and *Ficus hispida*. High density of firefly larvae was found in the greened site compared to the 2 years old regrowth. Firefly Population Index of Abundance (PIA) behind the rehabilitated plot was monitored from 2011 till 2017. The PIA had shown an increasing trend for the last seven years.

Keywords: rehabilitation, riverbank species, firefly habitat, species-site-matching

INTRODUCTION

This is the first project on rehabilitation of firefly breeding habitat in the tropics. The project was recognized as the first in Malaysia by the Guinness Book of Record Malaysia on 11 February 2012. The project site is a 2.5 ha riverbank open space and is also part of the initial 99 acre-parcel of riverbank landmass acquired by the State Government of Selangor in 2010–2011 for the restoration of firefly habitat. Reduction in the size of the natural riverbank vegetation is the main contributing factor to the reduction of the firefly population as it is also the breeding ground of firefly (Nada & Kirton 2003). Fragmented stands of sago palm were found to have the highest larva counts compared to fruit orchard and oil palm plantation. Higher larva count under the sago palm stands could probably be due to a more conducive moist microclimate which favors the larva phase of the firefly (Hui *et al.* 2006). The finding was incorporated into a strategic move by the state government to acquire the riverbank landmass which was converted for various land uses prior to 2008. The State Government of Selangor is no longer allowing the riverbank of Sungai Selangor to be converted for other land uses. This project was undertaken to green the degraded riverbank landmass acquired by the State Government of Selangor. The developed technology of greening would be used for restoring the rest of the degraded firefly habitat. This paper aims to report 1) the early performance of some tree species planted and 2) the firefly larva count of the degraded site before planting and three years after planting as well as the seven-year population index of abundance count of firefly.

MATERIALS AND METHODS

Firefly larva and snail counts

A standard transact sampling method was employed to determine the number of firefly larva and snail. Each transact covers a length of 100 m but only 10 quadrates measuring 1 m x 1 m were employed to determine the density of the firefly larvae and the snails. Two sampling transacts of 200 m length were established respectively in the newly planted site, the secondary regrowth and the fragmented sago and nipah stands. The sampling lines were prepared during the daytime and sampling was done at night by the Entomology Unit. The counting was carried only for three years due to lack of manpower, as one of the lead researchers left for her post-graduate study in 2014.

Firefly population count

The firefly population count was done by the Entomology Unit using a night digital photography method as described by Veronica *et al.* (2014). The counting was carried out behind the perimeter of the plot facing Sungai Kuala Selangor which is known as Station 5 from 2011 till present.

RESULTS AND DISCUSSION

Survival of tree species

Five riverbank plant species were planted. They are sago palm (*Metroxylon sagu*), *Macaranga gigantea*, *Bridelia tomentosa*, *Ficus hispida* and malabera (*Fagraea crenulata*). Two planting periods were carried out; one planting in 23 December 2011 by Ecophysiology Unit, FRIM, and another in the drier season on 11 February 2012 by the public and young adults of various schools organized by AEON Co. (M) BHD, State Government of Selangor. The planting program was graced by Tan Sri Dato' Seri Abdul Khalid Ibrahim, the 14th and former Menteri Besar of the State Government of Selangor. Survival counts and vegetative measurements were carried out for the 0.5 ha sample plot from 28–29/1/2012, 23–25/4/2012, 23–26/3/2013 and 25–27/3/2015. Survival counts for sago palm after 2013 included the new palms grown from the suckers which had height >1.5 m. In 2016, the funding is only available for tending the plots and maintenance of the access road, hence there is no more enumeration of vegetative measurement.

Larvae and Snail Density

The degraded site of the riverbank had lower mean density of the larvae and snails compared to the existing remnant of sago-nipah stands (Table 1). Higher density of larvae was recorded at the rehabilitated site at 24 months after planting. The survey showed that firefly larvae were present in the newly planted site, the 2 year-old secondary vegetation, and a fragmented mixed sago-nipah stand in 2012 and 2013. One year later, more firefly larvae were found in the naturally regenerated site which is two years old after opening, and also the mixed sago-nipah stand.

More transacts would be required to ascertain a more representative population of firefly larvae and snail population, as sampling in the mixed sago-nipah stand can be a very difficult task especially in making the transact. However, the rehabilitated site had higher increase of firefly compared to the two-year-old secondary regrowth with sporadic trees covering with climbers in 2011. The percentage of firefly larvae increase is an infinity for the newly planted site, 240% for the secondary regrowth and 400% for the sago-nipah stand in 2012. In 2013, the percentage of increase for the newly planted site is 1300%, followed by secondary regrowth at 261% and lastly sago-nipah stand at 250%. The newly planted site in 2013 is the same age as the natural regrowth at 2011. Table 1 shows 2 year-old planting had higher firefly larvae count than the two-year old secondary regrowth. This shows that the planting that consists of riverbank species had created a better environment for the firefly larvae than the natural re-growth on the degraded site. Hence, rehabilitation should be carried out to capitalize the potential of the degraded habitat as firefly breeding ground.

Table 1: Firefly larvae and snail density

Type	Firefly larva 2011*	Firefly larva 2012	Firefly larva 2013	Snails 2011	Snails 2012	Snails 2013
Newly planted sites	0	500	6,500	0	500	0
Secondary regrowth	1,250	3,000	7,857	1,625	2,000	2,000
Fragmented sago-nipah stand	500	2,000	5,000	6,500	9,000	9,000

*denotes the presence of firefly larvae just after the site preparation, and the secondary regrowth was at 2-year-old. The original habitat was completely destroyed in 2010 for farming vegetables and banana.

Based on the latest data of firefly PIA collected by the FRIM Entomology Team, the steady increase of the firefly population at riverbank just at the back of the rehabilitated plot (Figure 1) reflects a steady increase in the firefly population index of abundance trend from <5 in 2011 to >100. Hence, it is observed to have an increase of 2,000% or 20-fold increase in the index magnitude since after the site is rehabilitated.

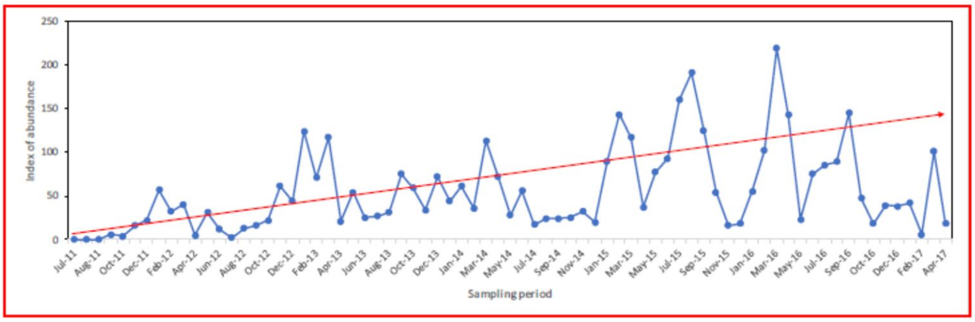

Figure 1. Firefly Population Index of Abundance at Station 5 from July 2011 till April 2017

Species Performance

The five riverbank species planted in December 2011 during the wet season had average survival of 86.3%. However, higher mortality was observed after the second planting because of the onset of dry season and also planted by untrained public at a difficult terrain. The latest survival of the mixed stand dropped to only 60.8% (Table 2).

Fagraea crenulata and *B. tomentosa* both had high mortality as these were smaller planting stocks and easily succumbed to stress during transplanting, distributing and planting on the difficult terrain. Sago palm had the highest survival amongst the five riverbank species planted and had survival of 133.3% at four years after planting (Table 2). The increase in survival for the sago is due to the increase of number of sucker production from each planting point which grew into young palms. Sago palms have distinctly increased in number and also occupied more space in the planting through expansion of its clump size.

The means of height for the five species were measured and calculated (Table 3). The planting is growing on a fertile site as shown in its soil chemical properties documented. Three tree species, namely *B. tomentosa*, *Macaranga gigantea* and *Ficus hispida* that required well drained soils, showed better growth in the early stage as they were planted on raised islands, whereas, malabera had the slowest growth in comparison to the three species at 12 months after planting but it was the tallest in 2015 (Table 3). Sago palm grew slower than the three species at 12 months after planting but attained similar height with the three species at 2015.

Table 2. Survival of five riverbank species

Species	Planted on 23/12/2011	Survival (%) on 28/1/ 2012	Planted on 11/2/ 2012	Total number planted	Overall Survival counted on 23/3/2012	Survival (%)		
						2012	2013	2015
Macaranga gigantea	30	100	20	50	39	78	56	50
Ficus hispida	100	90	180	280	225	80.4	71.8	64.6
Fagraea crenulata	122	82	200	322	140	43.5	46.2	42.9
Bridelia tomentosa	150	73.3	98	248	148	59.7	58.1	56.5
Metroxylon sagu	Nil	Nil	150	150	131	87.3	72.7	133.3

Table 3: Mean height with standard deviation of the species

Species	2012	2013	2015
Macaranga gigantea	0.4(0.1)a	2.2(1.4)a	5.4(1.0)a
Ficus hispida	0.3(0.2)a	2.8(0.9)a	5.3(1.0)a
Fagraea crenulata	0.1(0.1)b	1.3(0.6)b	5.8(1.9)b
Bridelia tomentosa	0.5(0.2)a	2.4(0.7)a	5.1(1.1)a
Metroxylon sagu	0.5(0.2)a	1.4(0.3)b	5.2(0.9)a

a & b denote significant differences by t-test at 0.05 level

CONCLUSION

The planting was successfully carried out. The tree species had closed their canopies at 18 months after planting and more firefly larvae were sighted in the stand compared to the initial stage. At three years after planting, the firefly Population Index of Abundance increases steadily along the riverbank behind the perimeter of the rehabilitated plot. The findings of this study demonstrate that rehabilitation of the degraded firefly habitat is the right strategy for promoting the increase of the firefly population at Sungai Kuala Selangor.

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POTENTIAL WOOD RESOURCES FROM *HOPEA ODORATA* GROWN ON TIN TAILINGS

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ABSTRACT

Marginal sites have been transformed for the establishment of timber plantation, including ex-tin mine areas. *Hopea odorata* stands were established on ex-tin tailings for greening purposes as well as to improve the economic value of the site. The site, a research station of Forest Research Institute Malaysia in Bidor, is about 10 km south west of the Bidor town in Perak. Periodical evaluation was performed on the growth performance and mortality assessment of the relatively young *H. odorata* stand, established in 2004. The current 13-year-old *H. odorata* stand in Bidor recorded a relatively high survival rate of 91.5%, despite a drop from 98%, measured when the stand was about seven-year-old. The 13-year-old stand showed an average DBH (diameter at breast height) of 19.81±7.52 cm while average height recorded was 10.56±4.35 m. The *H. odorata* stand in Bidor established more than 13 years ago, has showed great resilient with high survival rates and relatively good growth performance even on unfavourable soil conditions and harsh microclimates. This shows that besides serving the purpose of greening marginal site, *H. odorata* is also a potential wood source to substitute the depleting timber resources from natural forests.

Keywords: ex-tin tailings, timber plantation, survival, growth performance, mean annual increment

INTRODUCTION

The increasing demand for wood and pulp is posing a threat to natural forests. Forest plantations have thus been established to supply such demand and also to alleviate the pressure on natural forests. The scarcity of suitable and economical areas for establishment of forest plantations, however, has diverted plantations to marginal or degraded sites such as ex-mining areas and logged-over areas.

Ex-tin mines are notoriously known for their harsh microclimate and infertile soil, particularly sand tailings. It is recommended that if dipterocarp species are to be planted directly on marginal sites, light-demanding and drought-tolerant species should be selected for reforestation of degraded area such as grassland and shrub forest. Thus, *Shorea leprosula* and *Hopea odorata* are deemed good candidates for planting on open land (Mori, 1999).

Hopea odorata is one of the major species of *Hopea* spp. It has been identified and selected as one of the plantation species for establishment of forest plantations in Malaysia based on its excellent growth, ease of management, potential uses and promising financial returns (Ab. Rasip *et al.*, 2004). *Hopea odorata* or locally known as '*merawan siput jantan'* has been planted on sand tailings of an ex-tin mine. This species is amenable towards establishment and survival in open conditions, hardy and relatively easy to manage (Mohd Noor *et al.*, 2002).

Hopea odorata is classified as light hardwood, yellowish to yellow-brown with air-dry density of 785 kg/m^3. It has generally good working properties and has been used for flooring of pedestrian traffic and light industrial floors (Burgess, 1979). The moisture content of seven-year-old *H. odorata* ranged from 51.31 to 68.83%, with a mean of 58.78%. The density of the wood grown on tin tailings ranged from 559 to 792 kg/m^3, with a mean of 684 kg/m^3, and is comparatively higher than that of 10-year old *A. mangium* trees with a mean density of 588 kg/m^3, grown on same planting site (Ho *et al.*, 2012).

The growth performance of *H. odorata* from this marginal site is not thoroughly explored. Thus, the objective of this study was to evaluate and compare the growth performance of 13-year-old *H. odorata* stand with its initial growth at seven years of age stands. This will provide as a good indicator to assess the viability of planting *H. odorata* on ex-tin mine areas, both for the purpose of greening the marginal site as well as obtaining potential wood resources to supplement the shortage of raw material faced by the timber industry.

MATERIALS AND METHODS

The site is located at 4° 06'N and 101° 16'E which was previously mined for tin ores. The study plot adopted a 4 m x 4 m planting regime. A 13-year-old *H. odorata* stand on sand tailings, initially established for improvement of site quality, was selected for the study. The stand was measured for height and diameter at breast height (DBH). The *H. odorata* stand has been previously assessed about six years ago, when it was at seven years of age.

The growth performance of the *H. odorata* stand at 13-year-old was compared with the seven-year-old stand. The mean annual increment (MAI) for both height and DBH was calculated using the seven-year-old stand as the basis of growth rate comparison.

RESULTS AND DISCUSSION

Survival

The *H. odorata* stand was initially established with a density of 650 trees/ha. Generally, *H. odorata* stands recorded high survival rates since they were established in 2004. The mortality of young *H. odorata* trees was relatively low and this species recorded a very high survival rate of 98% when the stand was seven years old. The following survey was conducted six years later, when the stands were 13 years old. The *H. odorata* stand continues to achieve high survival rate of 91.5%, despite a slight decline compared to the seven-year-old stands (Table 1). This continued high survival rates showed that *H. odorata* are able to adapt well even in harsh environmental condition and on problematic soils such as the tin tailings. This species showed better adaptability on tin-tailings compared to *Acacia mangium*, another selected demonstration species established on the sites, which recorded an 80% survival (Ho *et al.*, 2012).

Table 1. Survival of *Hopea odorata* on tin tailings

Survival (%)	
7-year-old stand	13-year-old stand
98.00	91.50

The growth performance of seven-year-old and 13-year-old *H. odorata* stand is shown in Table 2.

Stand Performance

The *H. odorata* stand in Bidor was established in 2004. Preliminary assessment was carried out when the stand was at seven-year-old and subsequent evaluation was carried out when the stand was at 13 years of age.

At seven-year-old, *H. odorata* showed good growth with an average diameter at breast height (DBH) of 13.49±4.23 cm while average height recorded was 6.47±2.11 m. Whereas, subsequent survey carried out in 2016 on the 13-year-old stand showed an average DBH of 19.81±7.52 cm while average height recorded was 10.56±4.35 m. Based on the lower range height and DBH values at seven- and 13-year-old, some trees showed stunted growth in height and recorded insignificant growth in DBH. However, these under-performing trees are still in healthy condition and will be under continuous monitored and assessed periodically.

Mean Annual Increment

Mean annual increment (MAI) of both DBH and total height for *Hopea odorata* was calculated. This is a mid-term MAI, calculated based on early to medium growth stage of the *H. odorata* from age seven to age 13. The MAI of the total height of respective *H. odorata* trees ranged from 0 to 2.28 m, while MAI of DBH of these trees ranged from 0 to 1.41 cm.

Other experiment carried out on planting of *H. odorata* on problematic sites also recorded relatively good growth height. Wan Razali and Ang (1993) reported an annual height increment ranging from 0.95 to 1.3 m for two-year-old *H. odorata* planted on decking sites, road shoulder and skid trails of logged-over forest in Pasoh Forest Reserve.

Table 2. Mean annual increment (MAI) of height and diameter at breast height (DBH) of *Hopea odorata* grown on tin tailings

Stand Age	7-yr-old	13-yr-old	MAI
Height (m)	3.40 – 13.45	3.40 – 21.30	0 – 2.28
Mean Height (m)	6.47 (2.11)	10.56 (4.35)	0.67 (0.44)
DBH (cm)	5.30 – 23.80	6.10 – 36.70	0 – 1.41
Mean DBH (cm)	13.49 (4.23)	19.84 (7.52)	1.05 (0.72)

Note: Figures in parentheses are standard deviation values

CONCLUSION

At 13 years of age, *Hopea odorata* grown on tin-tailings exhibited a promising outlook for the concerted effort of greening this marginal site and the prospect of timber production for economic returns. The trees survived a crucial infancy stage with minimal mortality and recorded high survival rates despite a slight decline in survival compared to the younger stand at seven-years of age. In general, the stand demonstrated relatively good growth performance. Hence, continuous monitoring and periodical assessments of the stand will further strengthen the viability of establishing more marginal sites such as the tin tailings with *H. odorata.*

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EFFECT OF DIFFERENT PLANTING METHODS TO THE GROWTH PERFORMANCE OF *NYPA FRUTICANS*

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ABSTRACT

Nypa fruticans (Aracaceae) or locally known as nipah tree is the only palm tree that is also considered as a mangrove tree. Nipah trees play essential roles in the ecosystem such as providing protection against strong wind, as wave damper zone and help in reducing risk of erosion. However, limited information is available on the suitable cultivation method of this species. Acknowledging this, a study on the growth performance of nipah trees was conducted in Kuala Sungai Muda, Kedah where trees were planted in (a) areas that were not exposed to tides, (b) areas that were vulnerable to high tides (c) areas which were constantly exposed to tides (fully submerged in water). Height of nipah trees was measured to identify areas with the best growth performance. The results indicated that planting in areas which were constantly exposed to tides (full submerged in the water) gave the best growth performance of the nipah trees.

Keywords: planting method, growth performance, erosion, pollution filter, ecosystem

INTRODUCTION

Nypa fruticans or locally known in Malaysia as “nipah” is from the family of Aracaceae. It is also the only palm tree that is considered as a mangrove species. The nipah fronds are commonly used to make roof (usually found in houses of indigenous people in Malaysia), basketry and the nipah palm sap or also known as *nira* which is drank as a sweet drink and also used in the food industries as flavoring.

Instead of mangroves trees, nipah also plays important role as a wave damper zone to the storm, in reducing the impact of erosion, in providing a habitat to small aquatic life such as fishes, shrimps and crabs, as a filter from pollution in a river, and in providing basic nutrients in the food web of small aquatic life (Mukherjee 1984, Roberston & Alongi 1992, Li & Lee 1997, Duke 1998, Abdul Hayat *et al*. 2009, Eswani *et al*. 2009).

Previously, FRIM had been the appointed as a consultant manager to replant nipah at the riverside of Kuala Sungai Muda, Kedah. The re-establishment of nipah was to minimize the impact of flood due to a project on widening the river. However, the original population of nipah in that area was cleared during the construction.

Subsequently, a small scale study on the effects of different planting methods on the growth performance of nipah was carried out. The study aimed to identify the most suitable planting method that provides the best growth rate for nipah. Findings in this study will provide a basic guideline for the cultivation of nipah in the future.

MATERIALS AND METHODS

The location of the study was at Kuala Sungai Muda, Kedah. Planting materials were seeds collected from natural populations in an adjacent area. The seedlings were grown in 20.32 x 25.40 cm (8 x 10 inch) polybags. The growing media used was soil obtained from the study site. The seeds were sown at the nursery of FRIM and seedlings were grown to a minimum height of 45 cm before being planted. A total of 300 trees were planted at a distance of 8 m x 4 m.

Three planting methods were tested: (a) planting in areas that were not exposed to tides, (b) planting in areas that were vulnerable to high tides and (c) planting in the areas that were constantly exposed to tides (full submerged in the water).

A total of 100 trees were tested for each planting methods. Growth data was collected at three months interval. The data were descriptively analyzed using SAS software (Statistical Analysis Systems Institute, Inc. 2008) to determine the growth performance of the nipah.

RESULTS AND DISCUSSION

Findings in this study can be used as guidelines for planting nipa in appropriate zones/areas in the future. The growth performance of the nipa (based on the trait of height) indicated that the planting method which the nipa trees were constantly submerged in water recorded the highest mean height at all ages (Table 1). Thus, the drainage system should be provided to ensure that the trees are constantly submerged if the area is located away from the river.

Table 1: Mean height of *Nypa fruticans* with different planting methods at different ages
Note: SE denotes Standard Error

Planting methods	Mean height (m) ± SE				
	Age: 3 months	Age: 7 months	Age: 10 months	Age: 13 months	Age: 16 months
(a) planting in the areas that were not exposed to tides	0.44 m ± 0.11	0.51 m ± 0.11	0.63 m ± 0.13	0.74 m ± 0.16	0.85 m ± 0.23
(b) planting in the areas that were vulnerable to high tides	0.47 m ± 0.12	0.60 m ± 0.15	0.73 m ± 0.18	0.86 m ± 0.22	0.92 m ± 0.34
(c) planting in the areas that were constantly exposed to tides (full submerged in the water)	0.60 m ± 0.11	1.03 m ± 0.17	1.24 m ± 0.17	1.45 m ± 0.20	1.78 m ± 0.22

CONCLUSION

Large-scale plantation of nipah can be done using on areas where the tree will be constantly exposed to the tides (full submerged in the water). This is to ensure the optimal performance of the tree growth. In addition, the competition between trees and weeds can be reduced as the tree canopy can cover the exposed area quickly. This method also reduces maintenance cost due to weeds.

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EDIBLE FRUITS FROM THE FOREST AND THEIR CHARACTERISTICS

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ABSTRACT

Fruit trees from the forest are seldom planted in commercial scale and are rarely found. These fruits from the forests usually have their own distinct and unique tastes. They can be eaten in various ways depending on the purpose including as fresh fruits, medicines, pickles or as salad. The objectives of this study are i) to collect edible fruits from the forest as germplasm collection, and ii) to introduce edible fruits from the forest to the public. Among the conservation efforts that should be recommended are i) collection of herbarium specimens for reference, ii) collection of seeds/ wildlings to be planted in arboreta, iii) promotion of these trees as commercial fruit trees and iv) record of their uses and other related information.

INTRODUCTION

Fruit trees from the forest can usually be found in the forest. They can occasionally be found among weeds, in abandoned areas and by riverside. Most of these trees grew from seeds spread animals or discarded by human. However, these trees are also facing increasing threat due to logging and conversion of forest areas. Nonetheless, some of these trees are planted among common fruit trees or as shade-providing trees. It is important to conserve the genetic resources of these trees for future generations.

MATERIALS AND METHODS

This study surveyed and recorded fruit species from the forest that are found in forest reserve, local villages near forests and riverside.

RESULTS & DISCUSSION

Aglaia korthalsii / Sekiat

This species is locally known as sekiat. It is frequently visited by various types of insects which are attracted to the nectar produced in its flowers. This species has yellow and fragrant flowers and reddish trunk with a broad crown that is also suitable as an ornamental tree. The fruits are reddish orange in colour and are edible with a sweet and sour taste. The fruits have also been reported to be eaten by *orang utan* and lar gibbon.

Mangifera lagenifera / Lanjut
This tree grows to about 40 m tall. The fruits of *M. lagenifera*, locally known as lanjut, are seldom available except in the forest. Its fruit is green and turns pink when ripe. The fruit is very fibrous and tastes sour. The fruit is eaten fresh or pickled while the wood is used for making fences and staircase of village houses.

Mangifera griffithii/ Rawa
The ripe fruit of *M. griffithii* is orange in colour with purple edges. It gives a sweet and sour taste and can be eaten fresh. This species can grow up to 40 m tall.

Nephelium maingayi/ Redan
From the same genus as rambutan, *N. maingayi*. has fruits with red wrinkled skin with sweet and sour taste. This species is suitable as ornamental and shade tree which can be propagated by cuttings and cleft method.

Artocarpus lanceifolius/ Keledang
This species belongs to the family of Moraceae and can be found growing to a height about 30m. The fruit is sweet and tastes similar as local nangka (*Artocarpus heterophyllus*) and cempedak.

Alphonsea maingayi/ Pisang-pisang batu
Alphonsea maingayi is from the family of Annonaceae despite its local name that is similar to banana. The size of this tree is suitable as an ornamental plant in garden. Nonetheless, the fruit resembles and tastes like a banana with juicy flesh. This fruit is also a favourite of bats and squirrels.

Castanopsis schefferiana/ Berangan duri
This tree is known as chestnut tree and grows to about 30m tall. The fruit is a delicacy when roasted or fried. It is also used as an ingredient for making bread, cake, sauce and for thickening soup.

Baccaurea pubera/ Tampoi berunai and *Baccaurea brevipes/* Rambai tikus
Baccaurea pubera has fruit with red flesh that that is sweet. However, fruit of *B. brevipe*s has blue purplish flesh that can taste sweet or sweet and sour. Both species was found in Jerantut Forest Reserve, Pahang.

Lepishantes rubiginosa/ Mertajam
The leaf and fruit of *L. rubiginosa* are either used or consumed by locals. The fruit bunches are an attractive sight to behold with bright with red and black fruits that can be eaten fresh. The shoots are used as a local remedy for skin disease.

Elaeocarpus robustus var. megacarpus/ Buah piah

This fruit species is uncommon but is known to rural folks. Kedai Piah Village in Kelantan is named after this tree. The tree does not have attractive fruits. The fruits are hard with yellow fluffy flesh with a creamy taste when eaten fresh. The fruit has to be hit until soft before eaten.

Individuals and populations of some fruit trees from the forest are declining rapidly. Efforts to protect and to conserve these trees are thus important to ensure their viability in the wild. The fruits surveyed are not only consumed by locals especially the older generation but are also important food sources for wildlife like squirrels and birds.

Several of the fruit trees surveyed can be potentially commercialised for example *B. pubera, B. polyneura, B. pyriformis, B. parvifolia* and *B. ramiflora*. These trees are relatively small and are thus suitable as landscape or roadside trees.

CONCLUSION

The results from this study showed that some fruit trees are only found in the forest. Therefore, some recommendations are provided here to help protect and ensure the sustainability of these trees:

i) To identify species that are threatened or endangered
ii) To establish a fruit arboretum as germplasm collection
iii) To enrich the biodiversity of forest ecosystems by planting fruit trees from forest

DESICCATION SENSITIVITY AND STORAGE OF *HOPEA SUBALATA* SEEDS — A CRITICALLY ENDANGERED SPECIES OF PENINSULAR MALAYSIA

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ABSTRACT

Hopea subalata, an endemic dipterocarp species to Peninsular Malaysia, is categorized as critically endangered. Its storage behaviour and longevity in storage has not been investigated yet. In the first part of this work, desiccation sensitivity of *H. subalata* seeds was examined. It was evaluated based on germination percentage following desiccation. Results obtained show that reduction in moisture content from 47.7% to 35% was followed by decline in germination percentage from 91.5% to 23.3%. At 34.4% moisture, only 18.3% of seeds germinated. Further reduction to 23.1% of moisture resulted in total loss of seed viability, which indicated that critical moisture level was in the range of 33–34%. The results reveal that *H. subalata* seeds are sensitive to desiccation and indicate that it belongs to the recalcitrant seed storage behaviour. In the second part of the experiment, *H. subalata* seeds were exposed to different storage conditions. Results demonstrated that these seeds are able to withstand storage for four weeks at 20°C with 55% of seeds remain viable.

INTRODUCTION

Hopea subalata Symington is one of the species in the Dipterocarp family. This small tree, with maximum height of 12 m and 35 cm diameter at breast height (DBH), is also locally known as 'merawan kanching' or 'giam kanching'. This species is critically endangered by habitat conversion (Chua *et al.* 2010). It occurs naturally only in the Kanching Forest Reserve and is not found elsewhere. Thus, it is also being categorized as an endemic species to Peninsular Malaysia.

Seed is a main and important form of plant genetic resources for conservation as it is easy to handle, cheap and reduces storage space. More importantly, seeds are able to maintain their genetic stability during storage (Sivalingam 2011). In developing an *ex-situ* conservation strategy, the first step is to determine the seed storage behaviour. Seed storage behaviour refers to the capacity of seeds to survive desiccation. Sensitivity to desiccation may limit the conservation of some species, mainly seeds of trees from wet tropical habitats.

Seeds that are sensitive to desiccation are also known as recalcitrant seeds. It is well known that recalcitrant seeds are short-lived and is difficult to store (Roberts 1973). These seeds are very sensitive where they do not tolerant to drying and low temperatures. Viability loss is mostly observed when the moisture content falls below 20–30%.

The storage behaviour and longevity of *H. subalata* seeds has not been investigated. Thus, the main objective of this work was to identify the critical moisture content level that causes loss of seed viability of *H. subalata* seeds during desiccation. Investigation on the most suitable storage conditions was also conducted in determining the longevity of these seeds under different storage temperatures.

MATERIALS AND METHODS

Seeds collection

Mature seeds of *H. subalata* were collected from trees located in Forest Research Institute Malaysia (FRIM), Kepong in December. The seeds were immediately taken to the laboratory after collection.

Seed moisture content determination

Seed moisture content was determined following the ISTA (1999) rules. Seeds were cut into halves with secateurs and weighed for the fresh weight before being placed in an oven at 103±2°C for 17 hours. Then they were weighed again to obtain the dry weight (ISTA 1999). Seed moisture content was expressed on a fresh weight (FW) basis.

Each set of seeds were weighed until the desired moisture contents (40, 35, 30 and 20%) were obtained by storing the seeds in tight polyethylene bags containing silica gel (SG). Then, they were removed from the packaging and subjected to germination test. Control seed samples were mixed with vermiculite.

Seed germination

A total number of sixty seeds were used for germination test with each set of 15 seeds placed in one petri dish. A moist kitchen paper towel was used as the germination medium in which the seeds were arranged in lines and kept at a temperature of 30±2°C. Germination was assessed every two days and after 30 days, the germination test was concluded. The seeds were scored as germinated when the radical emerged about 2 mm long (ISTA 1999). Results were presented as percentage germination.

Seed storage

Stored seeds were kept in loosely folded polyethylene bags, at different temperatures (12°C, 20°C and room temperature); and maintained at initial moisture content upon collection. A set of seeds were retrieved every month for germination evaluation.

RESULTS AND DISCUSSION

Seed moisture content and desiccation

The moisture content of *H. subalata* whole seeds, determined immediately after collection, was 47.7%. Meanwhile germination percentage was 91.5% after 22 days. Seeds maintained in vermiculite had moisture content of 46.1% and germination percentage was 79.5%. Results of desiccation and germination test performed on *H. subalata* seeds are shown in Figure 1.

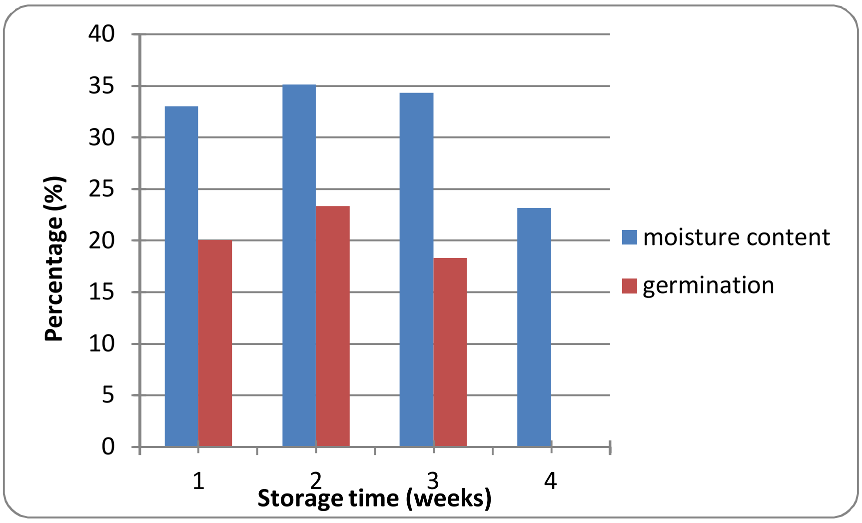

Figure 1. Desiccation and germination percentage of *H. subalata* seeds

When the seeds desiccated in SG, seed viability declined gradually with decreasing moisture content. At moisture content 35.0% (SG), germination percentage was 23.3%. As the moisture content was reduced to 33.0%, germination dropped to 20.0%. At 34.3% moisture content, seeds viability was only 18.3%. Further moisture reduction to 23.1% resulted in total loss of seed viability. Therefore, *H. subalata* seeds can be categorized as desiccation sensitive seeds with critical moisture level at slightly above 30% (33–34%).

Desiccation sensitive seeds or recalcitrant seeds do not undergo maturation drying and showed high moisture content even after shedding from the mother tree (Roberts 1973, Chin *et al.* 1984). Chin (1988) reported that critical levels of moisture content vary among species. King and Roberts (1979) found that seed lot/ batches also showed various critical levels of moisture. In addition, King and Roberts (1980) suggested that seed death resulting from desiccation occurs at or below a critical moisture content and is caused by membrane related physiological damages or an accumulation of by-products of biochemical enzymatic breakdown.

Seed storage and germination

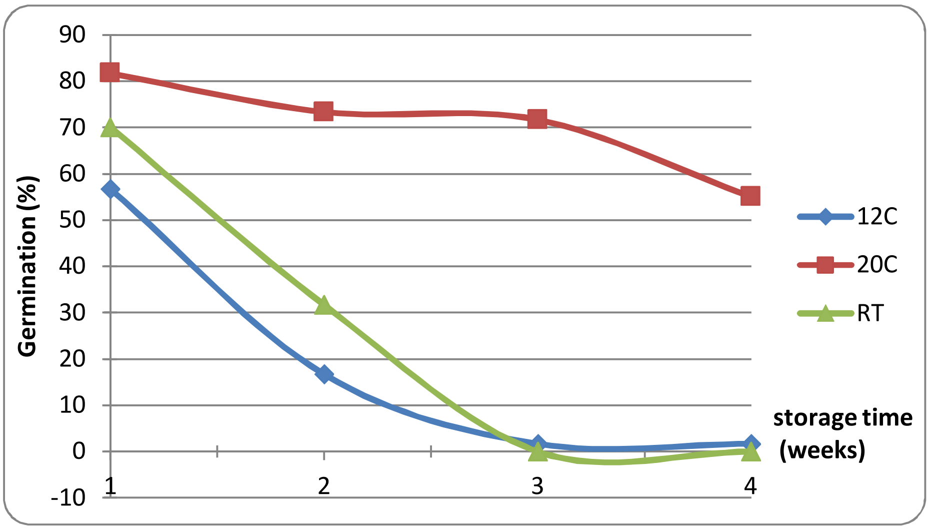

Figure 2. Changes in the percentage of germination of *H. subalata* seeds stored at different temperatures

Figure 2 shows the changing germination rate of *H. subalata* seeds stored at 12°C, 20°C and room temperature. The highest germination rate (81%) was observed in the storage condition of 20°C for the duration of one week. It reduced to 73%, then to 71% and maintained its viability at 55% after four weeks of storage.

Seed deterioration rate was higher for those stored at 12°C and under room temperature (26±2°C) as compared to seeds kept at 20°C. Under 12°C storage condition, germination rate reduced sharply from 56% to 16% (after 2 weeks) before declining to only 1% after three and four weeks of storage. In the other hand, after three weeks of storage, seeds stored under room temperature (26±2°C) failed to germinate although they showed high viability during the first and second week of storage with germination rate at 70% and 31%, respectively).

A study by Sivalingam *et al.* (2011) showed that *Embelia ribes* seed, with recalcitrant storage behaviour, stored well at 20°C compared to at 10°C. Lan *et al.* (2012) in their work found that *H. hainanensis* post-mature seeds can also be stored at 20°C when the seeds are partially dried. In addition, Umboh (1987 in Umarani *et al*. 2015) revealed that under 20°C air-conditioned room, germination rate of *Shorea javanica* was maintained above 80% after 30 days of storage.

CONCLUSION

Results from this work demonstrated that it is recommended to store *H. subalata* seeds with moisture content slightly above 40% (47%) at the temperature of 20°C. Under this condition, storage of viable seeds (55% germination) is possible even after four weeks. However, it is proposed that further investigation on storage of *H. subalata* seeds at reduced moisture content should be done when more seeds are available.

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GERMINATION OF *SHOREA ROXBURGHII* G. DON SEEDS FOR FUTURE *EX-SITU* CONSERVATION AND REFORESTATION PROGRAMMES

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ABSTRACT

Shorea roxburghii G. Don belongs to the family Dipterocarpaceace. It is a deciduous tree with simple alternate leaves and a very important timber and a source of resin. This species can be found in Cambodia, India, Laos, Malaysia, Burma, Thailand, and Vietnam. *Shorea* is an important timber genus with most of its species classified as Endangered in the IUCN Red List. Due to the importance of the genus, effort on the conservation of the species should be undertaken. The conservation of the superior genotype of *S. roxburghii* is necessary in order to preserve the gene source of superior genotype. The process for *ex-situ* conservation must follow scientific procedures to ensure that the materials obtained can survive in selected new environment. Therefore, researchers from Plant Improvement Programme of Forest Research Institute Malaysia (FRIM) have taken an effort to collect and germinate seeds of *S. roxburghii* for future production of quality planting materials. The seeds were taken from two selected mother trees located in the premise of FRIM's Research Station in Mata Ayer, Perlis. Effects of germination media was investigated in this study. The media treatments were i) 100% topsoil (T1), ii) 100% sand (T2) and iii) topsoil + sand (1:1) (T3). Results showed that T1 gave the highest rate of germination for seeds of *S. roxburghii* compared to other treatments. In conclusion, germination of *S. roxburghii* seeds can be done in the nursery based on the information provided in this study. In addition, seedlings produced from this study can also be used for future progeny trials. The trial plot can be converted to a seed production area (SPA) for the purpose of *ex-situ* conservation as well as to supply seeds for future reforestation programme.

Keywords: collection, tree selection, breeding program, genotype

INTRODUCTION

Shorea roxburghii G. Don is an important timber species and is classified as endangered species in the IUCN Red List. It is a deciduous tree with simple alternate leaves and a very important timber and resin source, stimulant and for fumigation (Ashton 1963, 1982). This species can be found in Cambodia, India, Laos, Malaysia, Burma, Thailand and Vietnam. In favourable conditions, the species can grow to a height of about 30 m and produce in excess of 200 cm in diameter at breast height (FIPI 1996). The species is adaptive to fire and the wood is hard and heavy with a density of 0.80–0.93 which makes it easy to saw and work on. Currently, rapid economic development and large scale deforestation have greatly increased timber consumption, resulting in the diminishing trends in the supply of high grade timber.

Due to the species importance, conservation effort on the species should be undertaken. Conservation of the superior genotype of *S. roxburghii* is necessary in order to preserve the gene source of superior genotype. It is important for *ex-situ* conservation to must follow scientific procedure to ensure the survival of collected materials in the new environment. Therefore, this study was conducted to determine the germination rate of *S. roxburghii* seeds in nursery using three different media. Information on various media types for germination can be utilized as guidelines for nursery operations especially in the production of quality planting materials. In addition, it can assist in ensuring the continuity of the species through *ex-situ* conservation as well as to supply seeds for future reforestation programmes.

MATERIALS AND METHODS

Seeds of *S. roxburghii* were collected from two selected mother trees (RTN39 and RTN51) located at FRIM's Research Station in Mata Ayer, Perlis. A total of 270 seeds trees were brought back to FRIM, Kepong, Selangor for determination of germination rates. Three sets of treatments were applied, i) 100% topsoil (T1), ii) 100% sand (T2) and iii) topsoil + sand (1:1) (T3) as sowing media. A total of 90 seeds were used in each treatment. The seeds were irrigated daily and the germination trays were labelled for easy identification of treatments and the replicates. The experiment was laid in a Completely Randomized Design (CRD). The criterion for germination was the emergence of plumule from the sowing media. Germination was recorded daily until no further germination was observed for 43 days.

RESULTS AND DISCUSSION

Effects of germination media

There were significant ($P \leq 0.05$) differences between germination of the three treatments at day 15 for seeds of RTN39 and RTN51 (Tables 1 & 2). Seed germination trends showed that seeds from RTN39 recorded higher than 70% germination in T1 at day 15 compared to other two treatments (Figure 1). However, seeds from RTN51 only recorded 30% germination in T2 at day 15 (Figure 2). Therefore, T1 (100% top soils) is recommended to boost the germination process at the initial stage. These findings concur with Bolanle-Ojo *et al.* (2014) where germination rate peaked at day 15 to 20.

Table 1. ANOVA results for the effects of treatment media on germination of RTN39 at day 15

Source of variation	df	SS	MS	F	Sig.
Treatments	2	122.88	61.44	69.12	.000*
Error	6	5.33	0.88		
Total	8	128.22			

Note: * significant (P≤0.05)

Table 2. ANOVA results for the effect of treatment media on germination of RTN51 at day 15

Source of variation	df	SS	MS	F	Sig.
Treatments	2	82.66	41.33	186.00	.000*
Error	6	1.33	0.22		
Total	8	84.00			

Note: * significant (P≤0.05)

At day 43, the germination rates for RTN39 and RTN51 showed no significant differences (P≤0.05) in all treatments (data not shown). Even though it has no significant differences, T1 recorded the highest percentage of *S. roxburghii* germination at 96% for RTN39 and 92% for RTN51, followed by T3 (93% for RTN39 and 84% for RTN51) and T2 (91% for RTN39 and 84% for RTN51) (Figures 1 & 2). Thus, 100% topsoil (T1) is suggested as the suitable germination media for *S. roxburghii* seeds.

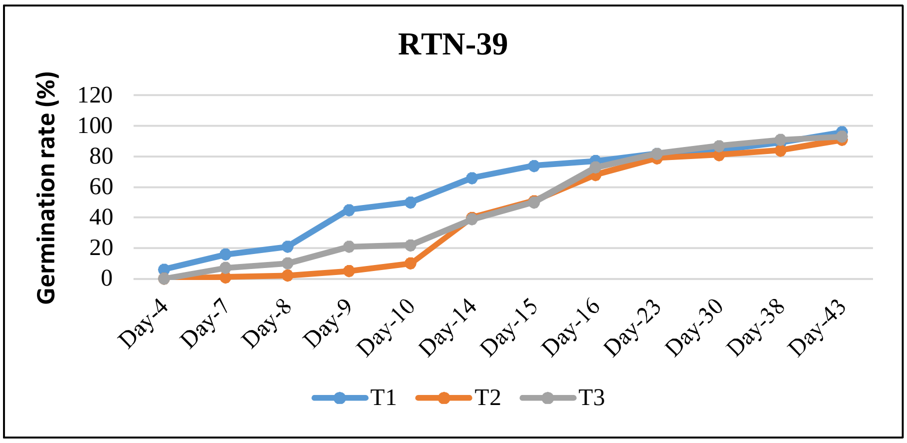

Figure 1. Germination rate (%) of *Shorea roxburghii* seeds (RTN39) in three different media, i) 100% topsoil (T1), ii) 100% sand (T2) and iii) topsoil + sand (1:1) (T3)

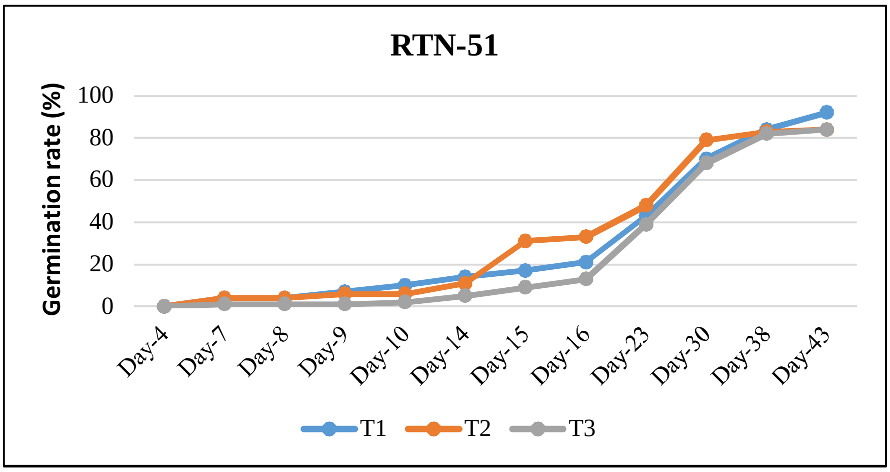

Figure 2. Germination rate (%) of *Shorea roxburghii* seeds (RTN51) in three different media, i)100% topsoil (T1), ii) 100% sand (T2) and iii) topsoil + sand (1:1) (T3)

At the end of the experiment, height of the seedlings from both sources of mother trees was measured. Overall, height of RTN39 seedlings from the three treatments showed higher value at 9.84 ± 0.12 cm and was significantly different compared to seedlings of RTN51 with 7.37 ± 0.13 cm (Table 3).

Table 3. Mean height (cm) of seedlings from RTN39 and RTN51 measured from three treatments

Tree number	Mean ± SEM (cm)
RTN-39	9.84 ± 0.12a
RTN-51	7.37 ± 0.13b

Means followed by the same letters in the same column are not significantly different at $P<0.05$
SEM: Standard error of means

CONCLUSION

The findings from this study show that seeds of *S. roxburghii* from both mother trees (RTN39 and RTN51) gave the highest rate of germination in T1 (100% topsoil). Overall, the germination rate and seedling height for RTN39 was better compared to RTN51. Maximum number of seedlings was achieved at 43 days. Therefore, the mother tree of RTN39 has the potential as superior mother genotypes in breeding programmes. Types of sowing media influence future production of high quantity and healthy vigorous seeds of *S. roxburghii* which will ensure the sustainable supply of seeds for future production of planting stocks used in conservation and reforestation programmes.

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DESICCATION AND STORAGE STUDIES OF *SHOREA ROXBURGHII* G. DON SEEDS

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ABSTRACT

Shorea is an important timber genus with most of its species classified as Endangered in the IUCN Red List (IUCN 2011). One of the species which is highly endangered in Malaysia is *Shorea roxburghii* G. Don which belongs to the family Dipterocarpaceace. Little has been studied on its reproduction especially using seeds. Therefore, a study has been conducted on its seed behaviour which is critical to save the species as well as for mass production of planting stock for future plantings. The relationship of seed moisture content and storage method of *S. roxburghii* seeds to germination was examined. Seeds of *S. roxburghii* were collected from Forest Research Institute Malaysia (FRIM) Research Station Mata Ayer located in the state of Perlis. This species has recalcitrant seed which affects its viability due to dehydration. Therefore, proper storage of the seed is vital for conserving its vigor and vitality. The findings from this studies revealed that germination rate of *S. roxburghii* seeds were 100% when seeds were dried from 45% initial moisture content to 35% but slightly reduced to 97.5% for seeds with 30% of moisture content. Storage trials showed that seeds of *S. roxburghii* are sensitive to desiccation. This study found that the viability of the seeds decreased to 60% when the seeds were stored at 27°C for one month. The output of this study provides useful information as a standard procedure for screening seeds for their tolerance towards desiccation and storage. Further studies on seed storage may also help to preserve and conserve genetic diversity of the seeds for future conservation purposes.

Keywords: *Shorea roxburghii*, recalcitrant, desiccation sensitivity, seed storage

INTRODUCTION

Shorea roxburghii or locally known as 'meranti temak nipis' is one of the many Shorea species found in Malaysian forest. The species, from Dipterocarpaceae family, is an important constituent of deciduous forests. *Shorea roxburghii* can be found in Cambodia, India, Laos, Malaysia, Burma, Thailand, and Vietnam. *Shorea* is an important timber genus with most of its species classified as Critically Endangered in the IUCN Red List (IUCN

2017). Seeds of *S. roxburghii* are not dormant and, as for many other tropical species (Come 1982), they germinate easily at high temperatures. However, seeds of this species are categorized as recalcitrant. Recalcitrant seeds are highly hydrated and they cannot withstand intensive desiccation. These seeds can only be stored in wet medium to avoid desiccation injury and at relatively warm temperature, since most of them are sensitive to chilling (King & Roberts 1979). Therefore, the aim of this study was to analyze the germination of *S. roxburghii* seeds and the effects of dry storage on their viability.

MATERIALS AND METHODS

Seed Collection and Initial Testing

Shorea roxburghii seeds were collected from adult trees at their peak maturity in Forest Research Institute Malaysia (FRIM) Research Station, Mata Ayer located in the state of Perlis (Figure 1). Purity of the seeds was 100%. Infected and infested seeds were removed. Only clean seeds were selected randomly for further experiments. There were three replicates of three seeds each for determination of seed moisture content (MC) and four replicates of ten seeds each for germination test. Initial germination tests were carried out in a growth room at 30°C and observation was conducted every two days for at least 30 days. Seeds were considered to be germinated when radicle grew to at least 2 mm in length.

Figure 1. *Shorea roxburghii* seeds collected from Perlis

Desiccation, Storage and Germination

Seeds were desiccated by mixing them with silica gel. The silica gel was frequently changed to ensure rapid drying. Seeds at two moisture contents (35% and 30%) were selected for storage at 27°C and 20°C for one and four weeks, respectively. Seeds that have been according to the previously mentioned temperatures and duration are removed for germination test and determination of moisture content. The survival of *S. roxburghii* seeds at different storage moisture content and temperature conditions was assessed.

RESULTS AND DISCUSSION

Seed of *S. roxburghii* was subjected to desiccation treatments and kept in two different temperatures (27 and 20°C) for one and four weeks. Freshly harvested seeds had no dormancy. Initially, the mean moisture content of *S. roxburghii* seeds was relatively high (45%) and germination percentage was 97.5%. For each rehydration procedure employed with moisture content of 35% and 30%, the percentages of seeds germinated recorded were 100% and 97.5%, respectively. Seeds stored at 35% of moisture content (fresh weight basis) in 20°C for one and four weeks showed reduction in germination percentage of 97.5% and 95%, respectively (Figure 2). The effects of reduction water content in *S. roxburghii* seeds to 30% and stored at 27°C for one and four weeks decreased the germination percentage to 92% and 60%, respectively (Figure 3).

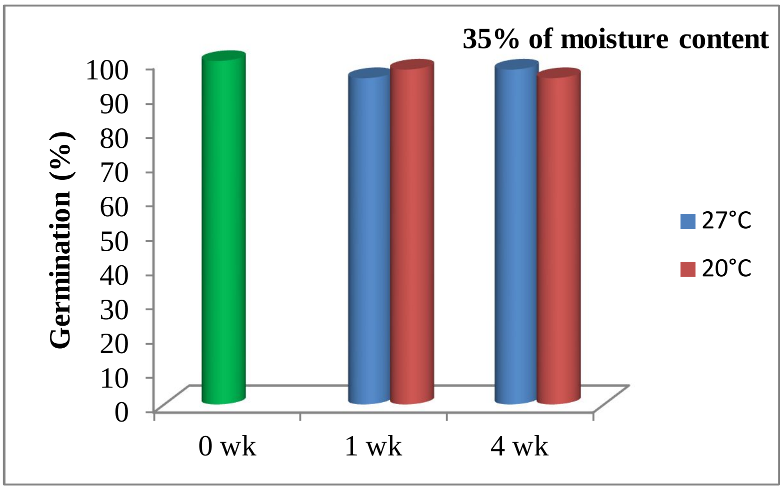

Figure 2. Germination of *Shorea roxburghii* seeds desiccated to 35% of moisture content and stored up to four weeks

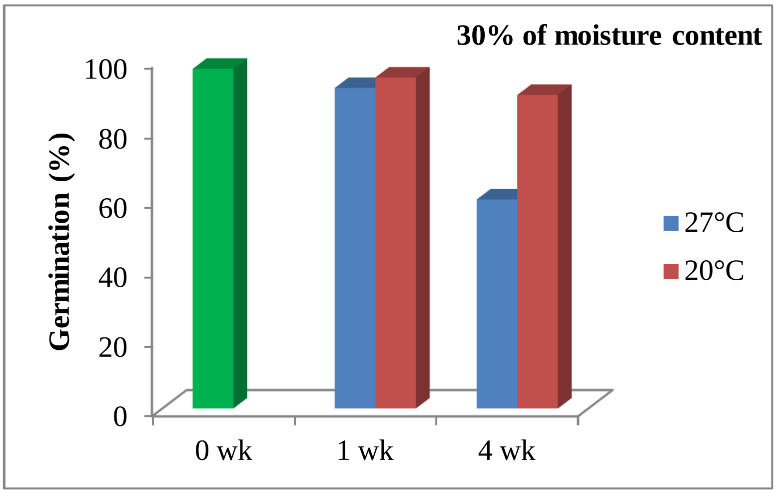

Figure 3. Germination of *Shorea roxburghii* seeds desiccated to 30% of moisture content and stored up to four weeks

Based on previous studies, several factors that may contribute to the high variability in desiccation and freezing tolerance among the non-orthodox plant species were identified. These factors include seed size and weight (Tompsett 1984, Hong & Ellis 1996), seed chemical composition, particularly, lipid content (Vertucci 1989, Dussert *et al*. 2001, Hor *et al*. 2005), drying conditions, particularly the drying rate (Pammenter & Berjak 1999). Further studies demonstrated that desiccation and freezing sensitivity in non-orthodox seeds is also dependent on the rehydration procedure under which seed germination is tested (Dussert *et al*. 2000, Sacande´ *et al*. 2001).

Germination ability declined when moisture contents were reduced approximately at 30% for *S. roxburghii* whereby a straight-line relationship was observed between the probit of germination and moisture content percentage. Storage at 35% moisture content in 20°C enabled survival of *S. roxburghii* seed for one month with over 90% viability. A sudden loss of viability was observed for seed of *S. roxburghii* stored for four weeks in 27°C at 30% of moisture content. This is probably due to the mechanical and structural damage on cell membrane structures, organelles and macromolecules inflicted by removal of water at very low water contents (Walters *et al*. 2002). It can also be due to dysfunctioning of the membranes suffering a desiccation-induced phase transition (Dussert *et al*. 2004).

CONCLUSION

In conclusion, the seeds of *S. roxburghii* can tolerate desiccation to 35% of moisture content (fresh weight basis). The seeds can be stored in 20°C for a few weeks without losing viability. This procedure enables *S. roxburghii* seeds to withstand low storage temperatures and perhaps possible approaches to increase storage life.

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