Pertanika J. Trop. Agri. Sci. 45 (3): 663 - 675 (2022)

TROPICAL AGRICULTURAL SCIENCE

Journal homepage: http://www.pertanika.upm.edu.my/

# *Shorea macrophylla*: Overview of Illipe Nut Producing Tree

**Ivy Yee Yen Chew, Hung Hui Chung*, Melinda Mei Lin Lau, Boon Siong Wee and Siong Fong Sim**

*Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia*

## ABSTRACT

*Shorea macrophylla* is also named as 'Engkabang' (Iban), 'Kawang' (Brunei), and 'Tengkawang' (Indonesia). It belongs to the Dipterocarpaceae family and is categorised under the genus *Shorea*, which can be found in the tropical rainforests in Southeast Asia. It prefers wet habitats, such as in periodically flooded alluvium and riverbanks. The tree size of *S. macrophylla* is medium or large; however, some researchers in Kalimantan claim it is a small tree. The flowering and fruiting systems of most Dipterocarps, including *S. macrophylla*, are irregular, but there is a massive flowering event once every few years. Its genetic structure is characterised by moderate genetic diversity within species and populations, as well as high genetic differentiation within local populations. *Shorea macrophylla*, also known as the Light Red Meranti, is a suitable timber supply for light construction work. It produces illipe nuts that are widely used as cocoa butter replacer fat. Wildlife eats the ripe illipe nuts, which contain a high oil content with mostly beneficial unsaturated triglycerides. The fat extracted from the nut are suitable for cosmetic application as it provides a good moisturising effect. Future investigation into the illipe nuts' composition and other potential uses should be carried out.

*Keywords*: Dipterocarpaceae, Engkabang, illipe nut, *Shorea macrophylla*, timber

ARTICLE INFO

*Article history:*
Received: 15 February 2022
Accepted: 30 March 2022
Published: 28 July 2022

DOI: https://doi.org/10.47836/pjtas.45.3.08

*E-mail addresses*:
ivychewyeeyen97@hotmail.com (Ivy Yee Yen Chew)
hhchung@unimas.my (Hung Hui Chung)
mlaumeilin@gmail.com (Melinda Mei Lin Lau)
swboon@unimas.my (Boon Siong Wee)
sfsim@unimas.my (Siong Fong Sim)
*Corresponding author

ISSN: 1511-3701
e-ISSN: 2231-8542

## INTRODUCTION

*Shorea macrophylla*, also known as Engkabang tree by the locals, are grouped under the Dipterocarpaceae family. Dipterocarpaceae, including *S. macrophylla*, is mainly distributed in Southeast Asia, and they favoured the periodically flooded alluvium and grew wild by the riverbank. Its fruit, the 'illipe nut', is rich in oil content, and thus *S. macrophylla* is also named the 'butter in the forest' by the locals. The illipe nut is one of the foods consumed by wild animals such as fish. Interestingly, *Tor tambroides* preferred high protein-energy content, including Engkabang fruit, which could be the main contributor to its sweetness-enriched flesh (Rahman & Basri, 2013). However, the flowering and fruiting of all the dipterocarps, including *S. macrophylla*, is irregular (Mathiesen, 1994). There is a mass flowering occurrence once every few years, and the locals would collect the illipe nuts and dry it for a prolonged storage purpose for other uses later (Chai, 1998). According to Chai (1998) as well as Sulistyawati and Widyatmoko (2018), *Shorea gysbertsiana* Burck, a species from the same genus, is another name for *Shorea macrophylla*. However, Nurtjahjaningsih et al. (2012) found that the allele frequencies of these two species are different, indicating that they are closely related but not the same.

## DISTRIBUTION OF *SHOREA* SPP.

The tropical rainforests of Borneo, Malaysia, Indonesia, and the Philippines are abundant in *Shorea macrophylla* and other Dipterocarp species (Chai, 1998; Ng et al., 2002). It prefers the wet habitats, which can be found in periodically flooded alluvium and along some riverbanks up to 1,500 metres above sea level, but with rare and scattered distributions across hillsides below 600 metres (Kanzaki et al., 1996; Lee et al., 1997; Ng et al., 2002). *Shorea macrophylla* is flood-tolerant, and according to Kenzo et al. (2007), *S. macrophylla* is a drought intolerant species and should be planted in high soil moisture or clay-rich conditions to avoid drought. According to USDA Soil Taxonomy, the soil type of *S. macrophylla* area consists of sand, silt, clay, and loam texture, is also known as the Grey-White Podzolic soil group (Adanan et al., 2020; Perumal et al., 2015). Although the Grey-White Podzolic soil is not suitable for most agricultural activities since it is developed through intense weathering and has a friable structure that could promote the occurrence of soil erosion, *Shorea* species are adaptable in extreme conditions, and they can grow well in this soil type as well (Leysia, 2012; Perumal et al., 2013). Grey-White Podzolic soils are pale in colour with weak to strong subangular blocky texture (Adanan et al., 2020). According to an analysis conducted by Adanan et al. (2020) at Sabal Forest Reserve (Sarawak), they found out the Grey-White Podzolic soils are strongly acidic with high contents of exchangeable aluminium and low contents of exchangeable bases, with a clay content of 9.3% to 27.9% in different plots. Clay deposition adds to limited water retention, which may be linked to the occurrence of large floods in the habitat of *S. macrophylla* (Perumal et al., 2015).

## MORPHOLOGICAL CHARACTERISTICS OF *SHOREA MACROPHYLLA*

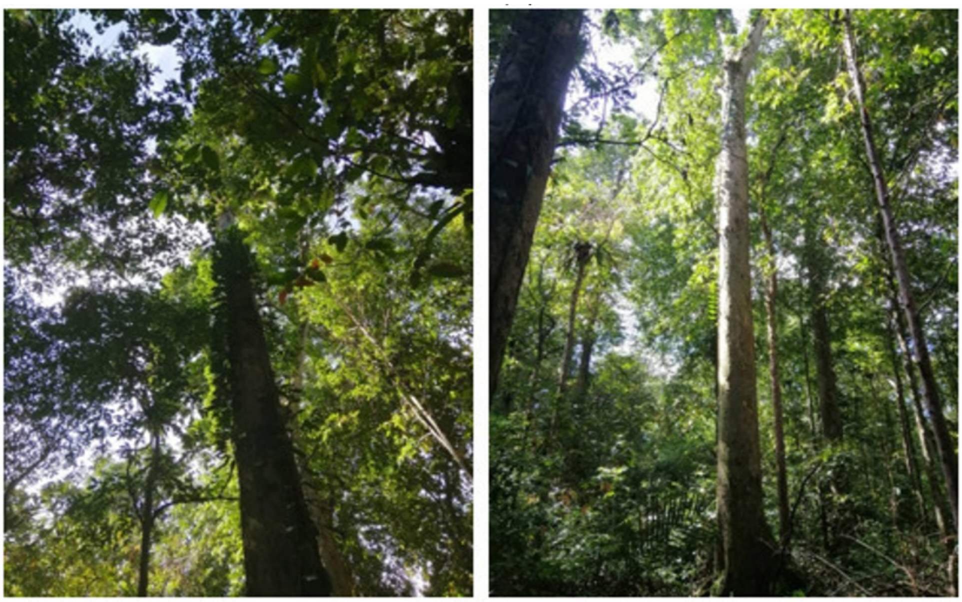
*Shorea* is the largest member of the Dipterocarpaceae family, and it is the emergent or main canopy of the forest. The genus *Shorea* is classified into 11 sections, each with its androecium characteristics (Ashton, 1982). The species within sections are defined principally by their leaf morphology and tomentum (Ashton et al., 1984). However, identifying species morphologically is challenging for *Shorea* species as the appearances of the species grouped under this genus are relatively similar (Rosdayanti et al., 2019). Several studies on the morphology of *S. macrophylla* have been carried out. However, there are differences in the identification of morphological characteristics among researchers in Malaysia and Indonesia. According to Hotta (1997), who conducted his research in West Kalimantan, *S. macrophylla* is a small tree with sub-persistent stipules, outside tomentose, with leaf midribs that are usually pubescence and a mature tree height of 15 to 20 metres. However, the tree size of *S. macrophylla* in Sarawak, Malaysia, according to Lee et al. (1997), is medium or large, reaching up to 50 metres in height, four metres in stem girth at breast height, and two metres in buttress height. The description of Lee et al. (1997) is consistent with the *S. macrophylla* species observed in the planted plot at Semenggoh Wildlife Centre under Sarawak Forestry Corporation. It has large leaves, elliptic-oblong, base obtuse or subcordate, 13 to 18 pairs of prominent, well-spaced nerves and hairy midrib above, petiole stout, bark smooth or shallowly scaly, bole short (Ng et al., 2002). They are arranged in alternate forms, with secondary and tertiary veins visible or a three-centimetre long leaf stalk with leaves around 40 centimetres long (Riska & Manurung, 2018).

*Shorea macrophylla* had a smooth and brownish-green bark in its early stages of growth, which progressively evolved into an elderly tree with cracking and flaking (Chai, 1998; Riska & Manurung, 2018). Windyarini and Hasnah (2015) describe the stipule shape of *S. macrophylla* as spear-shaped, blunt, or elliptic, with a length of 5 cm and a width of 1.3 cm. They also discovered that a ten months-old *Shorea* plant might grow to a height range of 67.19 to 88.79 cm with a diameter of 9.65 to 10.33 mm and sturdiness of 7.0 to 9.21 (Windyarini & Hasnah, 2015). Figures 1(A) and 1(B) show the images of adult *S. macrophylla* tree and their canopy view. According to Sidi et al. (2021)'s research on insect pest studies on *S. macrophylla*, foliage damage was primarily caused by hairy caterpillars from the Lymantriidae in the early stages of tree development, where the most prevalent foliage was 'hole damage.'

Researchers met difficulties in classifying *Shorea* species due to their large sizes, unpredictable flowering season, and the absence of reproductive structures most of the time. Furthermore, several closely related and morphologically similar species may co-occur, making it confusing to identify their species without using any molecular approach (Moura et al., 2019).

## FLOWERING AND FRUITING OF *SHOREA MACROPHYLLA*

The flowering and fruiting systems of most Dipterocarps, including *S. macrophylla*, are irregular. However, according to Chai (1998) and Mathiesen (1994), *S. macrophylla*



(A) (B)

*Figure 1*. Diagram of the canopy of *Shorea macrophylla* (A) and adult *S. macrophylla* tree reaches a height of about 50 meters (B) taken from Engkabang plot in one of the natural reserve centres named Semenggoh Wildlife Center under Sarawak Forestry Corporation

flowering occurs between September and October, with fruit ripening between January and March. Flowering may begin around 15 to 16 years; however, it may take several years before the next flowering occurs (Chai, 1998). The Dipterocarp trees flower yearly, although the flowering and seed production is limited. However, once every few years, a massive flowering event yields many seeds (Chai, 1998). The mass flowering phenomenon might be due to the combination of an aseasonality forest and the flowering system of dipterocarps itself (Appanah, 1993). An aseasonal forest is defined as a forest that does not have a consistent annual dry season and receives an average annual rainfall of around 2,900 mm (Appanah, 1993; Chandler et al., 2021). Plant phenological patterns, such as flowering, fruiting, and leaf change, are always more regular in a seasonal area, such as tropical America, than in aseasonal zones of Southeast Asia (Appanah, 1993). According to Ng et al. (2002), a significant level of inbreeding revealed that mating occurs primarily among relatives or closely related species, possibly due to the bigger fruit of *S. macrophylla*. As evidenced by their living environment, which is prone to continuous flooding, *S. macrophylla* is tolerant of soil acidity and well-adapted to harsh living conditions (Perumal et al., 2013). *Shorea macrophylla* grew well in canopy gaps, according to Grubb (1977).

Perumal et al. (2021) conducted a study on the growth performance of different seedling ages of *S. macrophylla* and found that the survival rate decreased with increasing seedling age, with the three months old seedlings outperforming the six-, nine-, and twenty-four-month-old seedlings throughout the experiment. Therefore, they recommend keeping the three-, six-, and nine-month-old seedlings as planting material while keeping the twenty-four-month-old seedlings planted during the unpredictable fruiting interval (Perumal et al., 2021). Due to the inconsistent flowering of *S. macrophylla*, various studies have been conducted to determine the optimum way for its plantation. For example, Lo (1985) used a cutting technique in which single-node leafy cuttings from node two with 1,200 ppm and 3,600 ppm indole-3-butyric acid (IBA) were found to root better than the control plant samples.

In a fertilizer study conducted by Perumal et al. (2019), all types of fertilizers are advantageous in raising the seedlings in a nursery; however, jellyfish fertilizer with nitrogen: phosphorus: potassium ratio of 13.1: 1.7: 0.03 was the best for all morphological quality features compared to two others fertilizers tested, which are the chemical fertilizer (control) and controlled-instant release fertilizer, except for the root to shoot ratio which it still reached the average root to shoot ratio values (Perumal et al., 2019). Furthermore, the jellyfish fertilizer, which has a high percentage of organic matter (approximately 81%), is important for enhancing the physical structure of soil and, as a result, increasing soil moisture (Perumal et al., 2019).

## GENETIC DIVERSITY AND DIFFERENTIATION OF *SHOREA MACROPHYLLA*

According to Kanzaki et al. (1996), *S. macrophylla*'s genetic structure is characterised by moderate genetic diversity within species and populations, as well as high genetic differentiation within local populations. Their moderate genetic diversity may be due to their limited dispersion in their environment and the immovability of their heavy fruit. These ecological features are most likely to contribute to the low gene flow among the local population (Kanzaki et al., 1996). The measured population genetics statistics of the plantation population were lower than those of the other populations, according to Utomo et al. (2018). Nurtjahjaningsih et al. (2012) developed microsatellite markers for four species of *Shorea* plants using the microsatellite primer of *Shorea curtisii*. Their findings revealed that the genetic diversity of all the plants, including *S. macrophylla*, had high genetic diversity and the inbreeding coefficient fit the Hardy-Weinberg equilibrium. Besides, among the *Shorea* species, *S. macrophylla* is closely related to *S. gysbertsiana* (Nurtjahjaningsih et al., 2012).

## USES OF *SHOREA MACROPHYLLA*

### Timber or Reforestation Sources

*Shorea macrophylla*, also known as the Light Red Meranti, is a suitable timber supply commonly utilised for light construction work (Ng et al., 2002; Yunanta et al., 2014). However, this timber is not resistant to exposed conditions and cannot be treated with preservatives, so it is only suitable for interior wall boarding in construction (Chai, 1998; Wong, 2009). Furthermore, Ismaili et al. (2016) showed that Engkabang was classified under-strength group SG6, which is close to *Acacia mangium*, which was grouped in SG5, and concluded that Engkabang is suitable for furniture making and other non-structural applications.

Its fast-growing ability is due to its soft to medium texture timber structure, so this species is ideal for reforestation. The tree can reach a diameter of 50 to 60 cm at breast height (dbh) in about 20 to 30 years and continue regenerating after 15 to 16 years on the plantation (Ng et al., 2002). According to Lee et al. (1997), the average height of *S. macrophylla* was 19 metres after 21 years of planting, beginning in May 1973 with the first evaluation.

Besides being fast-growing, *S. macrophylla* has other beneficial characteristics for reforestation, such as its ability to adapt to harsh conditions (for example, flooding) (Indriani et al., 2019). Furthermore, fast-growing trees are important for changing the microclimate and soil's physical and chemical qualities, reducing understory temperature and humidity fluctuations, and providing better light for seedling development (Nawar, 2012). Therefore, *S. macrophylla* is an excellent candidate for reforestation purposes. The only problem with using *S. macrophylla* as a reforestation subject is the difficulty in obtaining a huge amount of readily available seeds because their viability is limited and they are mainly found in forests, and sampling is more difficult than those available in nurseries (Chai, 1998). Based to Tsumura et al. (2011), the amount of tax paid for imported wood is determined by their classified group, with *S. macrophylla* belonging to the Red Meranti group being among the highest tax timber. However, some *Shorea* species have been misclassified, resulting in a lower tax rate paid than it should be. Although identifying *Shorea* wood can be done by those well-trained and experienced in a few days, DNA analysis is recommended for a more accurate and convenient identification among species (Tsumura et al., 2011).

**Illipe Nut**

*Shorea* species such as *S. macrophylla* produce illipe nuts, known as 'butter' in the forest, and are widely used as cocoa butter replacer fat (Nesaretnam & Ali, 1992). The term 'illipe' came from South India to describe the nuts of *Bassia* species of the Sapotaceae family, as well as the Mowrah nuts of *B. latifolia* (Nesaretnam & Ali, 1992). Since then, the name 'illipe' has come to be used to refer to any oil-bearing nut with similar characteristics (Nesaretnam & Ali, 1992). The illipe nuts are large and have long calyx, which looks like a badminton shuttlecock, and they have a high oil content of 45% to 70% (Chai, 1998; Nesaretnam & Ali, 1992). Therefore, they are cultivated by the locals for their daily needs and as raw materials for other commercialised products (Nesaretnam & Ali, 1992). However, locals do not plant this plant in large quantities;

instead, they are mostly found in the forest, primarily for local use, and some are for exportation.

Their size and oil content governed the value of nuts; a bigger nut with more oil content is more valuable (Chai, 1998). The oil is yellow in colour and solid in nature (Roslan et al., 2019). Illipe nuts have a fat level of 52% to 53.9%, and they are high in C16, C18, and C18:1, making them a viable substitute for cocoa butter (Nesaretnam & Ali, 1992). Because the seed is recalcitrant and has a short viability period (Lo, 1985; Tompsett, 1998), it must be collected as soon as it falls and immediately placed in water (temporarily stored) to avoid direct germination, or else the fat will be utilised for seed germination and the oil content of nuts will be reduced (Chai, 1998). Submersion of the nuts in water can cause the seed coat to crack, yet it can also protect the seed against insect attack (Chai, 1998). Therefore, the seeds are removed from their coatings and dried under the sun to reduce moisture content (Chai, 1998; Nesaretnam & Ali, 1992). The dried seed can be stored longer than usual and is usually used for oil extraction (Lo, 1985).

Several studies have been conducted to determine the suitability of the oil derived from illipe nuts, also known as 'Engkabang fat', for use in the food industry. According to a study by Nesaretnam and Ali (1992), Engkabang fat has properties similar to cocoa butter fat. They also made chocolate using Engkabang fat and palm-mid fraction (PMF), which is a fraction from a palm that is rich in palm olein (POP), which is also known as desaturated triacylglyceride, proving that it is a suitable alternative to cocoa butter equivalent (CBE) fat, which is useful to substitute with cocoa butter that has a high demand in the market. The liquid fraction of Engkabang fat was more enriched with unsaturated triacylglyceride (TAG), suggesting that it might be used to make margarine or as a raw material for cosmetic products (Yanty et al., 2013). Canola-Engkabang fat blends have thermophysical qualities similar to lard, according to Illiyin et al. (2013). The proportion of palmitic and stearic acids increases as Engkabang fat (EF) is added to canola oil (CaO), whereas the amount of oleic and linoleic acids drop, and this makes their blending to be similar to lard (Illiyin et al., 2013). Roslan et al. (2019) conducted a continuing study to determine the composition. Physical features of Engkabang fat and canola oil blending before and after transesterification with *Mucor miehei* lipase; and they concluded that the slip melting point (SMP) value of the blended canola oil with Engkabang fat that has been interesterified for six hours is most closely related to lard (Roslan et al., 2019). Since the illipe nuts have high commercial value as they are suitable to be used in the food industry, the only problem is the limited seed production due to the unpredictable flowering and fruiting season of the Dipterocarpaceae family. More research can be done to understand the flowering and fruiting system of dipterocarp, as well as the long-term storage of the nuts for future analysis or use.

**Natural Feed for Animals**

Wild boar, woodpeckers, foxes, rodents, freshwater fish, squirrels, and local reindeer eat the illipe nuts, which contain a high oil content with mostly beneficial unsaturated triglycerides (Chai, 1998). The *Shorea* fruit is commonly consumed by riverine carp species, such as the *Tor tambroides*, also known as mahseer or empurau, as part of their natural diet. *Tor tambroides* are riverine cyprinids classified as endangered (Kamarudin et al., 2017). They are in high demand and command a high market price of up to RM800 per kilogram, depending on their size, grade, and origin (Entri, 2013). The cooked empurau reached up to RM1,300 per dish (Harith & Hassan, 2011). The special taste of the *T. tambroides* might have been adapted from the consumption of Engkabang fruit (Redhwan & Komilus, 2021). Kamarudin et al. (2017) researched the performance of crude illipe oil extracted from *S. macrophylla* as a dietary lipid source for riverine cyprinid *T. tambroides*. Their findings revealed that increasing dietary illipe oil levels had no significant impact on survival, growth performance, feed utilisation, body indices, lean percentage of *T. tambroides* juveniles, or whole-body proximate composition of the fish. However, generally, saturated fatty acids (SFA) and monosaturated fatty acids (MUFA) in the fish were found to be significantly higher after the feeding, but polyunsaturated fatty acids (PUFA) in the fish were lower after the feeding compared to control groups (Kamarudin et al., 2017).

Because of its growing region in the forest near riverbanks, Engkabang fruit is mostly used as a feed for several fish species; however, the data on Engkabang fruit as the natural feed of other animals is limited. Since the Engkabang fruit might give the empurau a distinct flavour, a study can be done into the factors that might cause a special aroma or taste. In addition, the Engkabang fruit might be tested as a food source for other animals to determine whether it can cause changes or specific tastes, similar to the *T. tambroides*.

**Moisturising Agent for Lipstick**

Norazlin et al. (2015) researched using Engkabang as the softening agent that could improve lipstick formulation by promoting moisturising protection. The lipstick containing the Engkabang fat worked better than the control lipstick (that did not contain the Engkabang fat) in their study. Engkabang fat, which has a lower melting point, offers the lipstick a suitable hardness and better spread-ability. Furthermore, Engkabang fat can also prevent moisture loss twice better as the control lipstick formulations, comparable to commercially available lipstick.

Another research was done by Rahman et al. (2011), who compared the suitability of Engkabang fat and Engkabang fat ester as an ingredient for cosmetic applications. Based on the properties and characteristics of the fat, their findings showed that Engkabang fat is suitable for cosmetic use, while Engkabang fat esters outperformed Engkabang fat in terms of moistening impact (Rahman et al., 2011). Furthermore, the hydration values of the formulations, including Engkabang fat and esters, were higher than the control (Gani et al., 2010). All this could be due to a polar head group and the long hydrophobic tail of the Engkabang fat esters, which can act as a humectant and occlusive agent. The occlusive characteristics keep the skin moisture by reducing evaporation by forming a layer on the skin (Gani et al., 2010). Therefore, if the availability of Engkabang fruits can be increased, they might be proposed as the ingredient in cosmetic and healthcare products, as customers might prefer plant fat over animal fat.

## FUTURE PROSPECT

*Shorea macrophylla* is a versatile plant used as timber and reforestation sources. Its fruit, the illipe nuts, are high in fat, which can be used as cocoa butter replacer fat and as animal feed. However, the studies conducted on Engkabang are still quite limited regarding their flowering and fruiting cycle or the Engkabang fruit itself. Since the Engkabang can be used for reforestation purposes, more research on how to optimise their growth can be done to learn more about the reforestation of this plant species and their supplementary uses. Furthermore, the illipe nuts are believed to provide nutritious food sources for industrial or agricultural applications. They are still underexplored due to the difficulty in obtaining these nuts, as the bearing of the nuts occurs only once every few years. However, their uniqueness and potential commercial value are intriguing and worth exploring. The International Union for Conservation of Nature (IUCN) categorised *S. macrophylla* as vulnerable back in the year 1998; however, it is listed as the least concern after being revised in the year 2019, so more research and investigation such as composition and other potential uses of the illipe nuts should be done to understand *S. macrophylla* and the illipe nuts further.

## ACKNOWLEDGEMENTS

With grant number F07/TZC/2164/2021, Tun Zaidi Chair funded this research to Dr Chung Hung Hui. The authors acknowledged the guidance of the park warden, Mr Asraff Julaihi Khan, and the park rangers of Semenggoh Wildlife Center, which led us to the planting plot of *S. macrophylla* at Semenggoh Wildlife Centre.

## REFERENCES

Adanan, I. C., Wasli, M. E., Perumal, M., & Ho, S. Y. (2020). Characterization of soil properties in relation to *Shorea macrophylla* growth performance under sandy soils at Sabal Forest Reserve, Sarawak, Malaysia. *Biodiversitas Journal of Biological Diversity*, *21*(4), 1467–1475. https://doi.org/10.13057/biodiv/d210426

Appanah, S. (1993). Mass flowering of dipterocarp forests in the aseasonal tropics. *Journal of Biosciences*, *18*(4), 457–474. https://doi.org/10.1007/BF02703079

Ashton, P. S. (1982). Dipterocarpaceae. *Flora Malesiana*, *9*(1), 237–552.

Ashton, P. S., Gan, Y. Y., & Robertson, F. W. (1984). Electrophoretic and morphological comparisons in ten rain forest species of *Shorea*

(Dipterocarpaceae). *Botanical Journal of the Linnean Society*, *89*(4), 293–304. https://doi.org/10.1111/j.1095-8339.1984.tb02561.x

Chai, E. O. K. (1998). *Aspects of a tree improvement programme for* Shorea macrophylla *(de Vriese) Ashton in Sarawak, Malaysia* [Master's thesis, University of Edinburgh]. GeoSciences PhD Thesis and Dissertation Collection. https://www.era.lib.ed.ac.uk/bitstream/handle/1842/13343/Chai1998.Pdf?sequence=1&isAllowed=y

Chandler, C. J., Heijden, G. M. F. V. D., Boyd, D. S., Cutler, M. E. J., Costa, H., Nilus, R., & Foody, G. M. (2021). Remote sensing liana infestation in an aseasonal tropical forest: Addressing mismatch in spatial units of analyses. *Remote Sensing in Ecology and Conservation*, *7*(3), 397–410. https://doi.org/10.1002/rse2.197

Entri, D. A. (2013). *Determination of* Tor tambroides *(empurau) growth rate using different feed system* [Unpublished undergraduate's thesis]. Universiti Malaysia Sarawak.

Gani, S. S. A., Basri, M., Rahman, M. B. A., Kassim, A., Rahman, R. N. Z. R. A., Salleh, A. B., & Ismail, Z. (2010). Characterization and effect on skin hydration of engkabang-based emulsions. *Bioscience, Biotechnology and Biochemistry*, *74*(6), 1188–1193. https://doi.org/10.1271/bbb.90915

Grubb, P. J. (1977). The maintenance of species-richness in plant communities: The importance of the regeneration niche. *Biological Reviews*, *52*(1), 107–145. https://doi.org/10.1111/j.1469-185X.1977.tb01347.x

Harith, M. N., & Hassan, R. (2011). Blue-green algae and nutrient concentrations in two *Tor tambroides* aquaculture ponds differing in construction. *Journal of Tropical Biology and Conservation*, *8*, 51–61. https://doi.org/10.13140/2.1.4820.5440

Hotta, M. (1997). A taxonomic note of *Shorea macrophylla* group (Tengkawang) in West Kalimantan. *Tropics*, *7*(1/2), 54–56. https://doi.org/10.3759/tropics.7.54

Illiyin, M. R. N., Marikkar, J. M. N., Shuhaimi, M., Mahiran, B., & Miskandar, M. S. (2013). A comparison of the thermo-physical behavior of Engkabang (*Shorea macrophylla*) seed fat - Canola oil blends and lard. *Journal of the American Oil Chemists' Society*, *90*(10), 1485–1493. https://doi.org/10.1007/s11746-013-2307-z

Indriani, F., Siregar, U. J., Matra, D. D., & Siregar, I. Z. (2019). Ecological aspects and genetic diversity of *Shorea balangeran* in two forest types of Muara Kendawangan Nature Reserve, West Kalimantan, Indonesia. *Biodiversitas*, *20*(2), 482–488. https://doi.org/10.13057/biodiv/d200226

Ismaili, G., Rahim, K. K. A., & Ismaili, Z. (2016). Strength group of Engkabang jantong as fast growing indigenous species timber in Sarawak. *Journal of Scientific Research and Development*, *3*(2), 28–32.

Kamarudin, M. S., Bami, M. L., Arshad, A., Saad, C. R., & Ebrahimi, M. (2017). Preliminary study of the performance of crude illipe oil (*Shorea macrophylla*) as a dietary lipid source for riverine cyprinid *Tor tambroides*. *Fisheries Science*, *84*(2), 385–397. https://doi.org/10.1007/s12562-017-1160-7

Kanzaki, M., Watanabe, M., Kuwahara, J., Kendawang, J. J., Lee, H. S., Serizawa, S., & Yamakura, T. (1996). Genetic structure of *Shorea macrophylla* in Sarawak, Malaysia. *Tropics*, *6*(1/2), 153–160. https://doi.org/10.3759/tropics.6.153

Kenzo, T., Ichie, T., Ozawa, T., Kashimura, S., Hattori, D., Irino, K. O., Kendawang, J. J., Sakurai, K., & Ninomiya, I. (2007). Leaf physiological and morphological responses of seven dipterocarp seedlings to degraded forest environments in Sarawak, Malaysia: A case study of forest rehabilitation practice. *Tropics*, *17*(1), 1-16. https://doi.org/10.3759/tropics.17.1

Lee, H. S., Itoh, A., Kanzaki, M., & Yamakura, T. (1997). Height growth of Engkabang Jantong, *Shorea macrophylla* (De Vr.) Ashton, in a plantation forest in Sarawak. *Tropics*, *7*(1/2), 67–80. https://doi.org/10.3759/tropics.7.67

Leysia, C. (2012). *Assessing soil characteristic under reforestation of indigenous tree species: A case study at Sampadi Forest Reserve , Lundu* [Master's thesis, Universiti Malaysia Sarawak]. UNIMAS Institutional Repository. https://ir.unimas.my/id/eprint/10140/

Lo, Y. N. (1985). Root initiation of *Shorea macrophylla* cuttings: Effects of node position, growth regulators and misting regime. *Forest Ecology and Management*, *12*(1), 43–52. https://doi.org/https://doi.org/10.1016/0378-1127(85)90135-5

Mathiesen, U. B. (1994). Borneo illipe, a fat product from different *Shorea* spp. (Dipterocarpaceae). *Economic Botany*, *48*(3), 231–242. https://doi.org/10.1007/bf02862321

Moura, C. C. D. M., Brambach, F., Bado, K. J. H., Krutovsky, K. V., Kreft, H., Tjitrosoedirdjo, S. S., Siregar, I. Z., & Gailing, O. (2019). Integrating DNA barcoding and traditional taxonomy for the identification of dipterocarps in remnant lowland forests of Sumatra. *Plants*, *8*(11). 461. https://doi.org/10.3390/plants8110461

Nawar, N. H. H. B. M. (2012). *Importance of topography and soil physical properties on the growth of* Shorea macrophylla *under reforestation at Sampadi Forest Reserve* [Unpublished undergraduate's thesis]. University Malaysia Sarawak.

Nesaretnam, K., & Ali, A. R. M. (1992). Engkabang (Illipe) - An excellent component for cocoa butter equivalent fat. *Journal of the Science of Food and Agriculture*, *60*(1), 15–20. https://doi.org/https://doi.org/10.1002/jsfa.2740600104

Ng, K. K. S., Ang, K. C., & Lee, S. L. (2002). Mating system in a planted population of *Shorea macrophylla* (Dipterocarpaceae). *Journal of Tropical Forest Science*, *14*(1), 145–149.

Norazlin, M. H., Mahiran, B., Puziah, H., & Salwa, A. G. S. (2015). Improved properties of lipstick formulation with engkabang fats. *Asian Journal of Pharmaceutics*, *9*(2), 125–128. https://doi.org/10.4103/0973-8398.154712

Nurtjahjaningsih, I. L. G., Widyatmoko, A. Y. P. B. C., Sulistyawati, P., & Rimbawanto, A. (2012). Screening penanda mikrosatelit *Shorea curtisii* terhadap jenis-jenis *Shorea* penghasil Tengkawang [Screening of microsatellite primers of *Shorea curtisii* for *Shorea* spp. producing Tengkawang oil]. *Jurnal Pemuliaan Tanaman Hutan*, *6*(1), 49-56. https://doi.org/10.20886/jpth.2012.6.1.49-56

Perumal, M., Wasli, M. E., & Ho, S. Y. (2019). Influences of inorganic and organic fertilizers to morphological quality attributes of *Shorea macrophylla* seedlings in a tropical nursery. *Biodiversitas Journal of Biological Diversity*, *20*(8), 2110–2118. https://doi.org/10.13057/biodiv/d200803

Perumal, M., Wasli, M. E., & Ho, S. Y. (2021). Outplanting performance of the bornean tropical indigenous species *Shorea macrophylla* (de Vriese) P. S. Ashton in relation to seedling age. *International Journal of Forestry Research*, *2021*, 8859205. https://doi.org/10.1155/2021/8859205

Perumal, M., Wasli, M. E., Sani, H., & Ho, S. Y. (2013). *Morphological and physicochemical properties of the soil planted with Shorea macrophylla at Sampadi Forest Reserve, Sarawak*. https://www.researchgate.net/publication/315116754_Morphological_and_Physicochemical_Properties_of_the_Soil_Planted_with_Shorea_macrophylla_at_Sampadi_Forest_Reserve_Sarawak

Perumal, M., Wasli, M. E., Ying, H. S., Lat, J., & Sani, H. (2015). Soil morphological and physicochemical properties at reforestation sites after enrichment planting of *Shorea macrophylla* in Sampadi Forest Reserve, Sarawak, Malaysia. *Borneo Journal of Resource*

*Science and Technology*, *5*(2), 28-43. https://doi.org/10.33736/bjrst.220.2015

Rahman, N. F. A., Basri, M., Rahman, M. B. A., Rahman, R. N. Z. R. A., & Salleh, A. B. (2011). High yield lipase-catalyzed synthesis of Engkabang fat esters for the cosmetic industry. *Bioresource Technology*, *102*(3), 2168–2176. https://doi.org/10.1016/j.biortech.2010.10.034

Rahman, N. F. A., & Basri, M. (2013). Interactive effects of impeller speed and substrate molar ratio on synthesis of Engkabang fat esters. *International Journal of Chemical, Environmental and Biological Sciences*, *1*(3), 528–530.

Redhwan, A. I., & Komilus, C. F. (2021). *Mahseers in Malaysia: A review on feed for* Tor tambroides *(Empurau) cultured in captivity*. https://conference.upm.edu.my/PSAF2021

Riska., & Manurung, T. F. (2018). Morfologi vegetative jenis pohon Tengkawang (*Shorea* spp.) di Desa Mensiau Kecamatan Batang Lupar Kabupaten Kapuas Hulu [The vegetative morphology of Tengkawang tree species (*Shorea* spp.) in Mensiau Village, Batang Lupar Subdistrict, Kapuas Hulu Regency]. *Jurnal Tengkawang*, *8*(2), 110–121. https://doi.org/10.26418/jt.v8i2.31077

Rosdayanti, H., Siregar, U. J., & Siregar, I. Z. (2019). Karakter penciri morfologi daun Meranti (*Shorea* spp.) pada area Budidaya Ex-Situ KHDTK Haurbentes [Leaf morphology traits of *Shorea* spp. in Ex-Situ KHDTK Haurbentes]. *Media Konservasi*, *24*(2), 207–215. https://doi.org/10.29244/medkon.24.2.207-215

Roslan, N. I. M., Marikkar, J. M. N., Manaf, Y. N., Mustafa, S., & Miskandar, M. S. (2019). Effect of enzymatic transesterification using *Mucor miehei* lipase on physicochemical properties of Engkabang (*Shorea macrophylla*) fat-canola oil blends. *International Food Research Journal*, *26*(5), 1427–1435.

Sidi, M. B., Wasli, M. E., Polly, E., Nahrawi, H., Elias, H., & Omar, D. (2021). Short communication : Incidence of insect pest on planted *Shorea macrophylla* at reforestation sites in Gunung Apeng National Park, Sarawak, Malaysia. *Biodiversitas*, *22*(11), 5162–5168. https://doi.org/10.13057/biodiv/d221154

Sulistyawati, P., & Widyatmoko, A. (2018). Hubungan kekerabatan *Shorea gysbertsiana* dengan tiga jenis *Shorea* penghasil Tengkawang lainnya berdasarkan penanda RAPD. [Genetic relationship of *Shorea gysbertsiana* with other three *Shorea* species producing Tengkawang based on RAPD marker]. *Jurnal Pemuliaan Tanaman Hutan*, *12*(2), 85–94. https://doi.org/10.20886/jpth.2018.12.2.85-94

Tompsett, P. B. (1998). Seed physiology. In A. Simmathiri & J. M. Turnbull (Eds.), *A review of Dipterocarps*. Center for International Forestry Research (CIFOR). https://doi.org/10.17528/cifor/000463

Tsumura, Y., Kado, T., Yoshida, K., Abe, H., Ohtani, M., Taguchi, Y., Fukue, Y., Tani, N., Ueno, S., Yoshimura, K., Kamiya, K., Harada, K., Takeuchi, Y., Diway, B., Finkeldey, R., Na'iem, M., Indrioko, S., Ng, K. K. S., Muhammad, N., & Lee, S. L. (2011). Molecular database for classifying *Shorea* species (Dipterocarpaceae) and techniques for checking the legitimacy of timber and wood products. *Journal of Plant Research*, *124*(1), 35–48. https://doi.org/10.1007/s10265-010-0348-z

Utomo, S., Uchiyama, K., Ueno, S., & Matsumoto, A. (2018). Effects of Pleistocene climate change on genetic structure and diversity of *Shorea macrophylla* in Kalimantan Rainforest. *Tree Genetics and Genomes*, *14*, 44. https://doi.org/https://doi.org/10.1007/s11295-018-1261-1

Windyarini, E., & Hasnah, T. M. (2015). Identifikasi dan evaluasi pertumbuhan semai jenis-jenis *Shorea* penghasil Tengkawang [Identification and evaluation of the growth of seedlings of

Tengkawang-producing *Shorea* species]. *Jurnal Wasian*, *2*(1), 32–40. https://doi.org/10.20886/jwas.v2i1.868

Wong, S. L. (2009). *Comparison of physical and strength properties for different age group of* Shorea macrophylla [Unpublished undergraduate's thesis]. Universiti Malaysia Sarawak.

Yanty, N. A. M., Marikkar, J. M. N., & Shuhaimi, M. (2013). Effect of fractional crystallization on composition and thermal properties of engkabang (*Shorea macrophylla*) seed fat and cocoa butter. *Grasas y Aceites*, *64*(5), 546–553. https://doi.org/10.3989/gya.023213

Yunanta, R. R. K., Lukmandaru, G., & Fernandes, A. (2014). Sifat kimia dari kayu *Shorea retusa*, *Shorea macroptera*, dan *Shorea macrophylla* [Chemical properties of *Shorea retusa*, *Shorea macroptera*, and *Shorea macrophylla*]. *Jurnal Penelitian Dipterokarpa*, *8*(1), 15-24. https://doi.org/10.20886/jped.2014.8.1.15-24