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RESEARCH PAPER

Brief Documentation of Basidiomycota and Ascomycota Diversity in Gunung Gading National Park, Sarawak

Mohamad Fhaizal Mohamad Bukhori*, Besar Ketol, Khairil Rizadh Razali, Azizi Hussain and Mohd Faizullah Rohmon

Biology Unit, Centre for Pre-University Studies, Universiti Malaysia Sarawak,
94300 Kota Samarahan, Sarawak, Malaysia

*Corresponding author: mbmfhaizal@unimas.my

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Abstract

To facilitate the learning objectives of ecology, biodiversity and environment course, *in situ* activities remain the finest key to complement by conducting real fieldwork and hands on study. The specific objectives of the study are to promote sustainable learning, adopting effective practice in academic and scientific documentation, and implementing holistic and blended learning approach in the course by introducing a comprehensive learning experience in biodiversity-related discipline. Therefore, Basidiomycota and Ascomycota study based on diversity, host association and community structure in Gunung Gading National Park was chosen and resulted with the following attributes, where, four different species of macrofungi were identified and classified including *Ganoderma*, *Coprinellus* and *Cookeina*. Information on Basidiomycota and Ascomycota diversity species present in the parks is useful for educational and research purposes such as in Malaysian fungal diversity, climate change marker and Malaysian fungal monograph, developing a conservation education and attitude towards scientific reporting and also helps in promoting ecotourism.

Keywords: Biodiversity; *Cookeina*; *Coprinellus*; *Ganoderma*; macrofungi

Abstrak

Untuk membantu mencapai objektif pembelajaran berkaitan kursus ekologi, biodiversiti dan alam sekitar, aktiviti di luar kelas adalah elemen terbaik bagi melengkapkan matlamat ini dengan cara pengendalian kerja lapangan secara lansung. Objektif khusus kajian ini adalah untuk mempromosikan pembelajaran secara mampan, mempraktikkan kaedah yang berkesan dalam membuat dokumentasi akademik dan saintifik, dan juga mengaplikasikan pendekatan pembelajaran secara menyeluruh dalam kursus secara memperkenalkan pengalaman pembelajaran berkaitan bidang biodiversiti secara bersepadu. Oleh itu, kajian Basidiomycota dan Ascomycota berdasarkan kepelbagaian, perhubungan dengan perumah dan struktur habitat di Taman Negara Gunung Gading telah dipilih dan menghasilkan beberapa dapatan berikut iaitu empat jenis spesis kulat telah dikenal pasti dan dikelaskan termasuk *Ganoderma*, *Coprinellus* dan *Cookeina*. Maklumat mengenai kepelbagaian spesis Basidiomycota dan Ascomycota yang terdapat di taman negara ini amat bermanfaat untuk tujuan pendidikan dan penyelidikan seperti kepelbagaian kulat di Malaysia, penanda-biologi perubahan iklim dan monograf kulat Malaysia, termasuk juga pembangunan pendidikan pemuliharaan, kaedah penulisan saintifik dan membantu dalam mempromosikan ekopelancongan.

Kata kunci: Biodiversiti; *Cookeina*; *Coprinellus*; *Ganoderma*; makrofungi

INTRODUCTION

Malaysia is well known as a mega diversity country particularly in East Malaysia encompass of Sarawak and Sabah. One of the reference hotspot is Gunung Gading National Park which caters the tourists and researchers with the perfect place to explore (Abu Bakar et al., 2016; DE, 2012; Kamri, 2013). Ironically, the country is in ongoing transition becoming a developed nation and has exerted various pressures on local biodiversity, leaving many valuable heritages vulnerable with some even facing threats of extinction and habitats that are degrading problems (Abu Bakar et al., 2016; Demies et al., 2008; Kamri, 2013). As reported by the MNRE (2015), nearly half of the nation's plant diversity is facing various levels of threat.

Therefore, in order to introduce, nurture and preserve awareness of the importance of ecology, biodiversity and environments to the students, among the action taken was by introducing the relevant topic and issues in the academic syllabus. On that note, further measures need to be adopted and practice towards the sustainable utilisation of the nature resource on dissemination of ecology, biodiversity and environment education such as habitat, interaction, potential, and species of invertebrates, vertebrates, insect, forest, plant, animal, fungi, ecosystem, and ecotourism.

The park covers an area of 4,196 hectares, was gazetted in 1983 and launched in 1994 to create a conservation zone for the endangered plant including some of the fungal (Demies et al., 2008; Sarawak Government Gazette, 1998; SF, 2003). Apart from the Rafflesia (*Rafflesia tuan-mudae*) which is endemic to the park region, Gunung Gading National Park is also home to other rare plant and animal species, including the corpse flower, Blue-eyed Angle-headed lizard and yellow-horned spider (DE, 2012; Kamri, 2013; Shoparwe, 2013; Wahab, 2012).

Tropical forests were postulated as putative biodiversity hotspots for endophytic fungi such as Basidiomycota and Ascomycota (Cummings et al., 2016). On the other hands, specificity of host–fungus associations in species-rich tropical forests such as Gunung Gading National Park has invaluable implications for the documentation and understanding of fungal biodiversity (Ahmad Ali et al., 2016). Therefore, the study was conducted to comprehend the needs.

Recent discoveries have revealed that there are over about 300 species of fungi in Sarawak and Sabah, and the 26 species of macrofungal were identified at Gunung Gading National Park alone as reported by Eyssartier et al., (2009); Kerfahi et al., (2014); Su See & Watling, (2005). However, it was estimated that up to about 70% of the fungi in Malaysia have yet to be discovered (Su See & Watling, 2005). Among them is Basidiomycota, which are a subkingdom of fungi including jelly and shelf fungi; mushrooms, stinkhorns and puffballs (Eyssartier et al., 2009; Kerfahi et al., 2014; Nakasone et al., 2017; Sato et al., 2015; Tan et al., 2007). Ascomycota is another subkingdom of fungi that is characterised by a saclike structure such as Ascus, which compresses four to eight ascopores in the sexual stage (Haelewaters et al., 2014; Sato et al., 2015).

The diversity of Basidiomycota is strongly correlated with the diversity of plants in the habitats where they inhabit, with a higher diversity in tropical areas such as Gunung Gading National Park and fewer species in temperate location. This is certainly the species are performing saprotrophic nutrition where they serve many important ecological roles in litter decomposition, nutrient cycling, soil genesis and providing a food source for numerous molluscs, arthropods and small vertebrates in surrounding (Tan et al., 2007). Meanwhile, the diversity of Ascomycota is highly correlated with the non-forest soil such as peat area as reported by Ahmad Ali et al., (2016) in various plantation area in Sri Aman and Sibu, and Maludam National Park. The phylum are attributed with lignin-poor and nutrient rich character of most of the organic matter they reach in the habitat which commonly grows under the big trees (Haelewaters et al., 2014).

Macrofungi including Basidiomycota and Ascomycota are also known as macromycetes or larger fungi, which possess large (macroscopic) sporocarps or fruiting bodies and visible to the naked eye (Nakasone et al., 2017; Su See & Watling, 2005). Therefore, the distinct diversity of

these phylum may attributed by the fungal size. Many macrofungi are important as sources of food and medicine, and some are symbionts in ectomycorrhizal associations with trees while others cause diseases and decay (Kerfahi et al., 2014; Sato et al., 2015). Generally, Basidiomycetes make up the bulk of the collections described by many researchers as compared to Ascomycota, with the earliest records being the collections of Beccari between 1865 and 1879 in Sarawak itself (Tan et al., 2007).

The study was conducted in order to ensure the understanding towards the concept of biodiversity, ecology and environment by observing the natural ecosystems of the various species diversity of Basidiomycota and Ascomycota in Gunung Gading National Park, to understand the significant contributions of macrofungi in scientific studies, and to promote attentiveness towards the sustainable conservation approaches in Sarawak specifically.

MATERIALS AND METHODS

Study Site

The study area was located in Gunung Gading National Park (1.6905° N, 109.8458° E) (Figure 1), around 85 kilometres from Kuching city centre. The park is undisturbed natural forest includes four mountain peaks Gunung Gading, Gunung Perigi, Gunung Sebuloh and Gunung Lundu. The study area along the Waterfall Trail has variety of rugged surface with criss-crosses a pretty little creek up through some attractive vine-draped rainforest as well as steep and scrambling in some parts (Figure 1) (Mohamad Arif, 2012; SF, 2003; Teo et al., 2013).

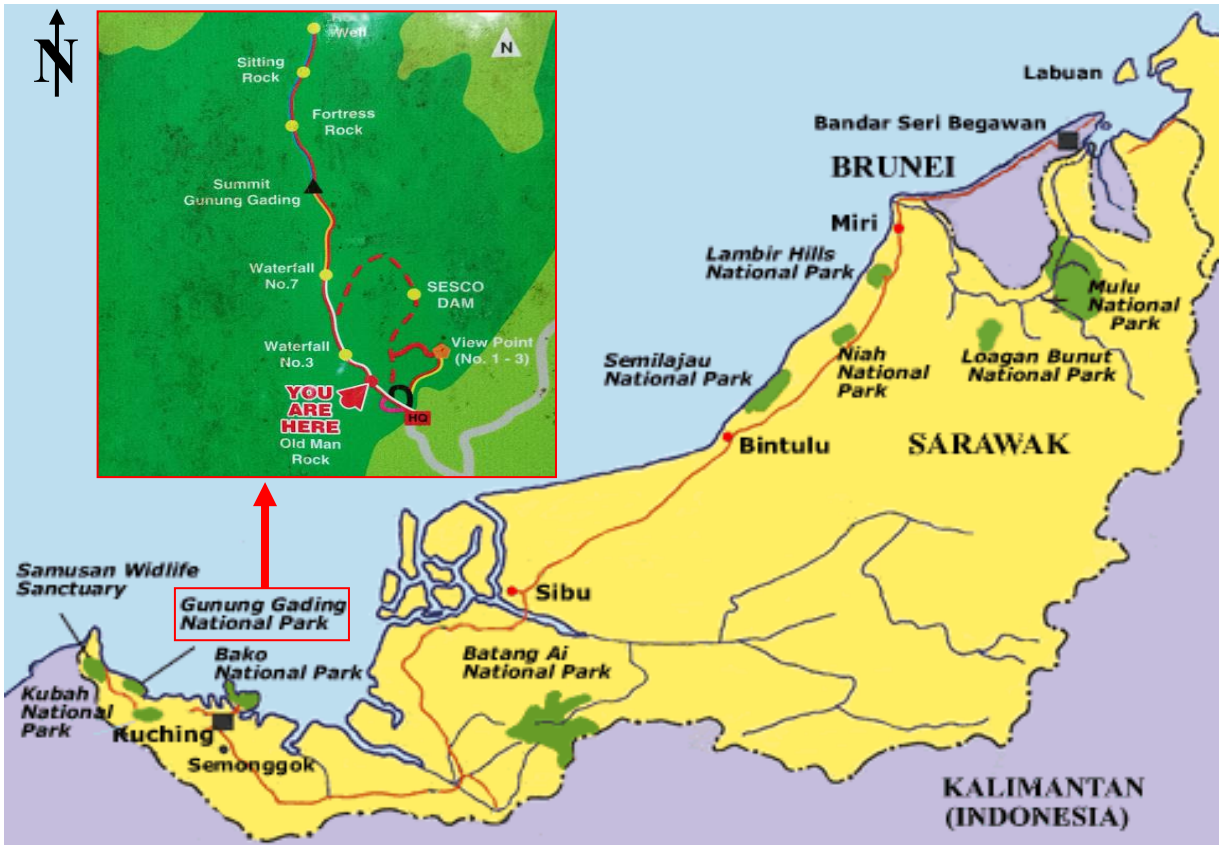

Figure 1. Map of Gunung Gading National Park and trail of the study area (SF, 2003).

The park is also consisting a series of waterfalls in the upper reaches of Sungai Lundu with abundance of fig trees in the forest (Mohamad Arif, 2012). There are five main vegetation types of forest in Gunung Gading National Park namely lowland mixed dipterocarp (with the family Dipterocarpaceae dominating the plant species), kerangas, alluvial, submontane and high mixed dipterocarp forest (Abang Bohari, 2015; Lateef et al., 2016; SF, 2003; Soepadmo et al., 1995; Su See & Watling, 2005), and are characterised by a tropical climate with an average annual temperature of 27 °C and an average annual rainfall of 4095 mm.

Field Observation

The researchers conducted the observation and documentation activities on Basidiomycota and Ascomycota species diversity by trekking (1.5 km); beginning from the Park Headquarters at 0 m up to the Waterfall Trail at 800 m, with the details documentation and records was done in every 100 m (Figure 1). The trekking passes through from the Summit Trail and Rafflesia Loop Trail. The trail is follows the Lundu River with a crystal-clear mountain stream and passes through stately dense dipterocarp primary forest.

Known and unknown Basidiomycota and Ascomycota species observed along the trekking journey were recorded at 200, 300, 400, 500, 600 and 700 m of trail. The observation and documentation were made by written reports, taking photographs and videos. Preliminary identification was made during the visit, and the detailed analysis was made once the researchers have returned to laboratory.

Species Identification

Records of Basidiomycota and Ascomycota species in Gunung Gading National Park which were initially recorded were further categorized according to the scientific name. A brief analysis of the collected data was done based on reference metadata, scientific and academic books, articles, journals and official-related website to finalize the obtained results.

Each Basidiomycota and Ascomycota species were identified using keys including macrofungi form or shape, size, the area or habitat of growing, and area or habitat characteristics. The samples were also compared with Sarawak Herbarium, Sarawak Forestry (Demies et al., 2008; Lateef et al., 2016; Mohamad Arif, 2012; Nakasone et al., 2017; Sarawak Government Gazette, 1998; SF, 2003; Soepadmo et al., 1995; Teo et al., 2013; Vincent, 2002).

Basidiomycota species is characterised by lacking long dextrinoid hairs; lacking strongly gelatinized tissues; pileipellis lacking a trichodermial palisade of smooth, elongated cells and white-spored (Cummings et al., 2016). The texture is usually tough and persistent (Tan et al., 2007).

The pileus shape varies from obtusely conical to convex or campanulate when young, and in age expands to broadly convex or plane and may have a central papilla, umbo or umbilicus. The majority of pilei are striate to plicate but some are smooth or venose. Mostly, the surface ornamentation ranges from glabrous to subvelutinous, or rarely hispidulous from the presence of erect setae. Pilei are often rather brightly coloured, ranging from yellow to orange, red or brilliant purple, although the majority of species range from white or cream-coloured to various shades of brown (Eyssartier et al., 2009; Nakasone et al., 2017; Tan et al., 2007). The lamellae are either attached directly to the stipe or attached to a free collar of tissue called a collarium. The lamellae range in colour from white to cream with an edge that is concolourous with the sides or concolourous with the pileus surface (Eyssartier et al., 2009; Tan et al., 2007). The species are also

have well-developed central stipes. The stipe base is inserted cleanly at the substrate without obvious mycelium. Stipes is usually filiform to narrowly cylindrical with surface ornamentation ranging from glabrous to pruinose or hispidulous (Eyssartier et al., 2009; Tan et al., 2007).

Most of the Basidiomycota species are substrate generalists, whereas many others are apparently substrate specific, forming basidiocarps only on leaves of monocotyledons or dicotyledons, or only on wood (Tan et al., 2007). Basidiospores are white in deposit, although a few species have been reported to form cream-colored or even brown basidiospores (Nakasone et al., 2017). They range in shape and size from ellipsoid and relatively small (5 to 6 × 2.5 to 3 μm) to elongate-clavate and very large (30 to 40 × 4.5 to 5 μm) (Nakasone et al., 2017).

Ascomycota species do not form a mycelium but rather produce small thalli. In very young thalli appendage consisting of 3 to 5 superimposed cells, giving rise to short branchlets. Antheridia terminal on these branchlets. They attached to the host by a haustorium. The main axis of a thallus is formed by the receptacle, which supports all parts of the thallus (Haelewaters et al., 2014; Kistenich et al., 2018). The only spore-forming structure in Ascomycota is perithecium. Perithecium structurised in stout, elliptical to distinctly asymmetrical, straight, curved or flexed, the tip not particularly distinguished, bearing anteriorly a darkened finger-like projection directed outwards, the blunt apex consisting of four unequal, rounded lips (Haelewaters et al., 2014). The primary appendage system is a prolongation of the receptacle axis and bears antheridia, which produce spermatia (Haelewaters et al., 2014). Most of the species are very dark brown and some are irregularly olive brown, with much paler lower portions (Kistenich et al., 2018). The species exhibit 106 to 154 μm in total length from base of foot to perithecial tip and 110 to 125 μm in total length from foot to tip of appendages. They are also slender and elongate, regularly broadening upwards (Haelewaters et al., 2014; Kistenich et al., 2018).

RESULTS AND DISCUSSION

Basidiomycota and Ascomycota Species

Basidiomycota is best known as filamentous fungi and produce large fruit bodies such as the mushrooms, puffballs, and brackets. The species commonly grows on dead or decaying woods, warm and moist environment which exhibit temperature range from 20 to 31°C. The propagation were recorded on average of 50 to 260 inches in normal rainfall per year are perfectly suitable for optimal species growth. Growth of species does not fully dependent on the moisture; however, it is also dependent on surrounding amount of nutrients available.

Basidiomycota species are usually decomposer fungi that colonize leaf litter, twigs, trapped debris, lianas and dead wood (Tan et al., 2007) which commonly inhabit at lower elevation. High abundance of Basidiomycota in tropical areas such as in Gunung Gading National Park is probably because the species are performing saprotrophic nutrition which feed on dead and decaying organic matter, and they serve many important ecological roles in litter decomposition, nutrient cycling, soil genesis and as a food source for myriad molluscs, arthropods and small vertebrates in the habitat of dipterocarp forest (Tan et al., 2007).

Meanwhile, Ascomycota is characterised by a saclike structure such as Ascus. The species also known as root-associated or root-endophytic species are usually interacting with surrounding plants as commensalistic, parasitic and mutualistic symbionts, however, indistinct host association patterns (Haelewaters et al., 2014). The species facilitate plant growth and health, maintenance of plant diversity, nutrient cycling, and ecosystem productivity in the habitat. Ascomycota can be seen associated with the relatively lignin-poor and nutrient-rich character of most of the organic

matter reaching the soil from roots and leaves of the hosts (Sato et al., 2015) which commonly inhabit at lower to middle elevation.

The distinct difference between these two phylum are the way their microscopic spores are produced. Basidiomycota produced it externally at its basidia while Ascomycota produced it internally inside its ascus. The localisation of Basidiomycota and Ascomycota species has decreased as the elevation increased based on the line transect observation estimation along the study area (Table 1). The occurrence is probably due to the increasing of mountain's altitude in which directly contributed to the increase of humidity and decrease the temperature (Adam et al., 1992; Lee, 2002) (Table 1). The higher the altitude, the lesser the environment's moisture, hence, the macrofungi are unable to inhabit due to the unfavourable condition (Kerfahi et al., 2014; Lee, 2002; Meekiong et al., 2012; Pearce, 1992). Besides, the macrofungi are also require moderate temperature to live, for example Basidiomycota the species requires warmth and humid environment to grow and survive (Kerfahi et al., 2014; Simarmata et al., 2007; Tan et al., 2007).

Table 1. Day time temperature, relative humidity recorded and number of macrofungal community structural observed along the study elevation in Gunung Gading National Park.

Elevation (m)	Day Time Temperature (°C)	Relative Humidity (%)	Number of Community Structural Observed
0 – 100	32	81	0
100 – 200	32	82	0
200 – 300	32	83	6
300 – 400	31	84	8
400 – 500	31	85	3
500 – 600	31	86	4
600 - 700	30	87	2
700 - 800	30	88	0

In addition, the size of macrofungi is also decreases as the increasing of habitat altitude based on the line transect observation estimation along the study area as also reported by Appanah et al., (1998), Manshor et al., (2012) and MNRE, (2006). This is probably because, in nature, macrofungi live as a parasite, mutual and sometimes as commensal, the species requires host to attach on such as live or died plants (Kerfahi et al., 2014), however, most of the plants and trees are having low tolerated of survival at high altitude because of the unsuitable soil and ecological structure (Adam et al., 1992; Kerfahi et al., 2014). Therefore, fewer inhabitants for these macrofungi species to the available host as the altitude increase.

Apart from that, other external factors such as living space, climate change and ecotourism effect may have also contributed to the habitat disturbance (Abang Bohari, 2015; Demies et al., 2008; Lateef et al., 2016; Sarawak Government Gazette, 1998; SCMP, 2017; Soepadmo et al., 1995; Vermeulen & Lamb, 2011; Vincent, 2002). As of this happened, the species richness are also affected. Figure 1 shows some of the macrofungi under Basidiomycota and Ascomycota which was observed and documented during the study. Table 2 presents brief description of the documented Basidiomycota and Ascomycota (Eyssartier et al., 2009; Kerfahi et al., 2014; Mohamad Arif, 2012; Nakasone et al., 2017; Sato et al., 2015; SF, 2003; Soepadmo et al., 1995; Tan et al., 2007; Vincent, 2002).

Table 2. Four species of macrofungi observed and documented in Gunung Gading National Park.

	Nomenclature/classification	Morphology/characteristics	Ecology	Habitat	Edibility
Ganoderma philippii	Kingdom: Fungi Division: Basidiomycota Class: Agaricomycetes Order: Polyporales Family: Ganodermataceae Genus: *Ganoderma* Species: *Ganoderma philippii*	Blackish and brown in colour, thick and tough bracket-like cap in range of 2.5 to 3.0 cm.	Saprotrophic	Abundantly found growing on hardwoods of both living barks and dead barks.	Not edible
Coprinellus disseminatus	Kingdom: Fungi Phylum: Basidiomycota Class: Agaricomycetes Order: Agaricales Family: Psathyrellaceae Genus: *Coprinellus* Species: *Coprinellus disseminatus*	The diameter of the cap is commonly from 1 to 2 cm, has heavily ribbed and initially egg-shaped, then convex and finally flat. The species has distinctive tawny central 'eye' contrasts with the rest of pale grey cap. There are with gills under the cap. Thin and moderately spaced, the colour can turn to grey and black. Average high is 6 cm long, with slightly swollen base. Edible, tasteless and odourless.	Saprotrophic	Appears on most short grass on lawns and in parks and meadows but the habitat is in small group. In contrast, this species will produce an impressive troops on soil covered in leaf water and the woodchip.	Edible
Cookeina tricholoma	Kingdom: Fungi Phylum: Ascomycota Class: Pezizomycetes Order: Pezizales Family: Sarcoscyphaceae Genus: *Cookeina* Species: *Cookeina tricholoma*	This species has an ascocarp that has a shape of a goblet or deep-cup. The diameter of the ascocarp is 15 to 20 mm. The ascocarp is conspicuously hairy; hairs stiff, bristle-like, fasciculate, and usually 2 to 3 mm long. Inner surface of the cup is pink-orange	Saprobic	The typical habitat is on wood like twigs and rotten tree limbs, at low altitudes usually below 1000 m, and commonly located in wet tropical forest.	Edible

		to orange and has a smooth texture. Outer surface of the cup is very orange, ridged to smooth and finely roughened. The height is 25 mm and the stem is 5 mm long.			
Cookeina sulcipes	Kingdom: Fungi Phylum: Ascomycota Class: Pezizomycetes Order: Pezizales Family: Sarcoscyphaceae Genus: *Cookeina* Species:*Cookeina sulcipes*	This species has a deep, cup-shaped to funnel-shaped fruiting bodies, or apothecia. The diameter of the ascocarp is 3 to 5 cm. Stipitate apothecia and eccentrically, operculate asci.	Saprobic	Species may be found on fallen branches, trunks, and sometimes on fruits, at low altitudes usually below 1000 m, and commonly located in wet tropical forest.	Edible

Figure 1. Species of Basidiomycota and Ascomycota documented in various locations in Gunung Gading National Park. (A) *Ganoderma philippii*, (B) *Coprinellus disseminatus*, (C) *Cookeina tricholoma*, and (D) *Cookeina sulcipes*.

CONCLUSION

Gunung Gading National Parks provide an ideal platform for ecological-derived education, research and tourism including climate change effect, ecosystem degradation, habitat alteration, ecological function impairment, ethnomycology and economic mechanism. Generally, four different species of macrofungi such as *Ganoderma philippii* and *Coprinellus disseminates* of Basidiomycota and *Cookeina tricholoma* and *Cookeina sulcipes* of Ascomycota were observed and documented throughout the study area which was along the Waterfall Trail. Basidiomycota species was identified and spotted with high abundance in the park as compared to Ascomycota which may be due to favorable dry habitual environment and hardwood, and making it dominant species in the park.

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REFERENCES

Abang Bohari, D. N. A. (2015). *Structural Characteristics of a Regrowth Forest Stand*. Universiti Malaysia Sarawak.

Abu Bakar, N. A., Radam, A., Samdin, Z., & Yacob, M. R. (2016). Willingness to pay in kubah national park and matang wildlife centre: A contingent valuation method. *International Journal of Business and Society*, 17(1), 131–144.

Adam, J. H., Wilcock, C. C., & Swaine, M. D. (1992). The Ecology and Distribution of Bornean Nepenthes. *Journal of Tropical Forest Science*, 5(1), 13–25.

Ahmad Ali, S. R., Safari, S., Thakib, M. S., Ahamed Bakeri, S., & Ab. Ghani, N. A. (2016). Soil fungal community with peat in Sarawak identified using 18S rDNA marker. *Journal of Oil Palm Research*, 28(2), 161–171.

Appanah, S., Maury-Lechon, G., Curtet, L., Bawa, K. S., Tompsett, P. B., Krishnapillay, B., Ashton, M. S., Lee, S. S., Elouard, C., Weinland, G., Shiva, M. P. & Jantan, I. (1998). *A Review of Dipterocarps: Taxonomy, ecology and silviculture*. (S. Appanah & J. M. Turnbull, Eds.). Bogor: Center for International Forestry Research and Forest Research Institute Malaysia.

Cummings, N. J., Ambrose, A., Braithwaite, M., Bissett, J., Roslan, H. A., Abdullah, J., Stewart, A., Agbayani, F. V., Steyaert, J. & Hill, R. A. (2016). Diversity of root-endophytic Trichoderma from Malaysian Borneo. *Mycological Progress*, 15, 50.

DE. (2012, June 28). Rafflesia with 10 petals. *Daily Express*, p. 8.

Demies, M., Lading, E., & Silang, S. (2008). Biodiversity Conservation in Sarawak. In R. Manurung, Z. C. Abdullah, F. B. AHmad, & C. Kuek (Eds.), *Biodiversity-Biotechnology: Gateway to Discoveries, Sustainable Utilization and Wealth Creation* (pp. 23–32). Kuching: Sarawak Biodiversity Centre.

Eyssartier, G., Stubbe, D., Walleyn, R., & Verbeken, A. (2009). New records of Cantharellus species (Basidiomycota, Cantharellaceae) from Malaysian dipterocarp rainforest. *Fungal Diversity*, 36, 57–67.

Haelewaters, D., Schilthuizen, M., & Pfister, D. H. (2014). On Diphymyces (Laboulbeniales, Ascomycota) in Malaysian Borneo. *Plant Ecology and Evolution*, 147(1), 93–100.

Jaafar, H. Z. E., Ibrahim, M. H., & Fakri, N. F. M. (2012). Impact of Soil Field Water Capacity on Secondary Metabolites, Phenylalanine Ammonia-lyase (PAL), Maliondialdehyde (MDA) and Photosynthetic Responses of Malaysian Kacip Fatimah (Labisia pumila Benth). *Molecules*, 17(6), 7305–7322.

Kamri, T. (2013). Willingness to Pay for Conservation of Natural Resources in the Gunung Gading National Park, Sarawak. *Procedia - Social and Behavioral Sciences*, 101, 506–515.

Kerfahi, D., Tripathi, B. M., Lee, J., Edwards, D. P., & Adams, J. M. (2014). The Impact of Selective-Logging and Forest Clearance for Oil Palm on Fungal Communities in Borneo. *PLoS ONE*, 9(11), 1–8.

Kistenich, S., Rikkinen, J. K., Thüs, H., Vairappan, C. S., Wolseley, P. A., & Timdal, E. (2018). Three new species of Krogia (Ramalinaceae, lichenised Ascomycota) from the Paleotropics. *MycoKeys*, 40, 69–88.

Lateef, A. A., Sepiah, M., & Bolhassan, M. H. (2016). Diversity and Distribution of Microfungi from Dipterocarp Forests in Sarawak, Borneo Island (Malaysia). *Malaysian Journal of Science*, 35(2), 290–303.

Lee, C. (2002). Nepenthes species of the Hose Mountains in Sarawak, Borneo. In K. Kondo (Ed.), *The 4th International Carnivorous Plant Conference* (pp. 25–30). Tok: International Carnivorous Plant Society.

Manshor, N., Rosli, H., Ismail, N. A., Salleh, B., & Zakaria, L. (2012). Diversity of Fusarium Species from Highland Areas in Malaysia. *Tropical Life Sciences Research*, 23(2), 1–15.

Meekiong, K., Latiff, A., Tawan, C. S., & Miraadila, M. I. (2012). Leaf micro-morphological characteristics of selected Vatica species (Dipterocarpaceae) from Kubah National Park, Sarawak. *Malaysian Applied Biology*, 41(2), 41–44.

MNRE. (2006). *Biodiversity in Malaysia*. *Ministery of Natural Resources and Envirnment*. Kuala Lumpur.

MNRE. (2015). *National Policy on Biological Diversity*. Putrajaya.

Mohamad Arif, N. A. (2012). *The Diversity of Understorey Birds at Gunung Gading National Park, Sarawak*. Universiti Malaysia Sarawak.

Nakasone, K. K., Draeger, K. R., & Ortiz-Santana, B. (2017). A Contribution to the Taxonomy of Rhizochaete (Polyporales, Basidiomycota). *Cryptogamie, Mycologie*, 38(1), 81–99.

Pearce, K. G. (1992). *The Palms of Kubah National Park, Matang, Kuching Division*. Kuala Lumpur.

Sarawak Government Gazette. Wild Life Protection Ordinance, 1998, Pub. L. No. Wild Life Protection Ordinance, 1998 (1998). Malaysia: Law of Sarawak.

Sato, H., Tanabe, A. S., & Toju, H. (2015). Contrasting Diversity and Host Association of Ectomycorrhizal Basidiomycetes versus Root-Associated Ascomycetes in a Dipterocarp Rainforest. *PLoS ONE*, 1–20.

SCMP. (2017, December 22). Timber Land to Revolutionise Sarawak Retail. *South China Morning Post*, p. S10.

SF. (2003). Innovative Tropical Rainforest Conservation. Kuching: Sarawak Forestry.

Shoparwe, N. I. (2013). *A Taxonomic Study on Rafflesia Tuan-Mudae (Rafflesiaceae) in Sarawak*. Universiti Malaysia Sarawak.

Simarmata, R., Lekatompessy, S., & Sukiman, H. (2007). Isolasi Mikroba Endofitik dari Tanaman Obat Sambung Nyawa (Gynura procumbens) dan Analisis Potensinya sebagai Antimikroba. *Journal of Biological Researches*, 13, 85–90.

Soepadmo, E., Mohamed, A. L., Kiew, R., Lee, H. S., Wong, K. M., Chung, R. C. K., Ashton, P. S., Dransfield, J., Kalkman, C. & Whitmore, T. C. (1995). *Tree Flora of Sabah and Sarawak*. (E. Soepadmo & K. M. Wong, Eds.), *Forest Research Institute Malaysia, Sarawak. Forestry Department, Kuching, Malaysia* (1st ed.). Kepong: Forest Research Institute Malaysia.

Su See, L., & Watling, R. (2005). Macrofungal Diversity in Malaysia. In L. S. L. Chua, L. G. Kirton, & L. G. Saw (Eds.), *Status of Biological Diversity in Malaysia and Threat Assessment of Plant Species in Malaysia* (pp. 169–180). Kuala Lumpur: Forest Research Institute Malaysia.

Tan, Y. S., Desjardin, D. E., Vikineswary, S., & Abdullah, N. (2007). Basidiomycota: The genus Marasmius in Peninsular Malaysia. *Malaysian Fungal Diversity*, 61–73.

Teo, S. P., Chai, P. P. K., & Phua, M. H. (2013). Conservation Gap Analysis of Dipterocarp Hotspots in Sarawak Using GIS, Remote Sensing and Herbarium Data. *Sains Malaysiana*, 42(9), 1237–1246.

Vermeulen, J. J., & Lamb, A. (2011). Endangered even before formally described: Bulbophyllum kubahense n.sp., a beautiful and assumedly narrowly endemic orchid from Borneo. *Plant Systematics and Evolution*, 292, 51–53.

Vincent, A. (2002). *Studies of native and exotic tree plantations in Sarawak*. Universiti Malaysia Sarawak.

Wahab, M. P. (2012). *Pitcher Plant (Nepenthes ampullaria) Choices by Frogs of the Microhyla nepenthicola and M. borneensis Complex for Breeding at Kunah National Park, Sarawak*. University Malaysia Sarawak.