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Natural distribution of the genus *Dacrydium* Lamb. (Podocarpaceae) in Central Kalimantan, Indonesia

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Abstract. *Maimunah S, Kessler PJA, Indrioko S, Naiem M. 2022. Natural distribution of the genus* Dacrydium *Lamb.* (*Podocarpaceae*) *in Central Kalimantan, Indonesia. Biodiversitas 23: 2816-2822.* The tropical coniferous genus *Dacrydium* is widespread in Kalimantan, Indonesia. It is estimated that four species still exist in Borneo, locally known as *Alau.* This genus thrives in a range of habitats, from heath to deep-peat forests in Central Kalimantan. This genus is currently threatened by logging, fire, and forest conversion to plantations. The objectives of this study were: 1) to know the distribution and abundance of *Dacrydium*, and 2) to describe the Dacrydium's habitat. The research was conducted in a heath forest located in PT. Taiyoung Engreen (PTTE) in Gunung Mas District and PT. Dasa Intiga (PTDI) in Kapuas and North Barito District, and in deep-peat swamp forest located in Sebangau National Park (SNP) in Palangka Raya and Pulang Pisau District. Data were collected in plots, each measuring 50 x 80 m, and the collected data were analyzed using a biodiversity calculator device created by MSU in USAID Lestari 2019. The identified specimens of *alau* found were sent to Herbarium Bogoriense for validation. The results of the analysis showed that we could identify three species of *alau* from the four species that are suspected to exist in Kalimantan. namely *Dacrydium beccarii* Parl. (*alau Bakam* (B)); *Dacrydium pectinatum* de Laub. (*alau Kelangkang* (K)), and *Dacrydium elatum* (Roxb.) Wall. ex Hook. (*alau Tombak* (T)) with various abundance. Depending on the conditions of habitat, *Alau* could be found only in some parts of heath to deep-peat swamp forest. The finding of *D. pectinatum* in the study areas is a new discovery because it was previously reported that this species was not found in Central Kalimantan.

Keywords: *Dacrydium,* deep-peat swamp forest, distribution, heath forest, Indonesia, Kalimantan, natural distribution, Podocarpaceae

INTRODUCTION

Alau is a group of plants of the conifer group that grows in the tropics belonging to the genus *Dacrydium*, the family Podocarapceae, and the division Spermatophyta (seed plants). Four species of *Dacrydium* grow in northern Sumatra and Kalimantan, namely *Dacrydium beccarrii* Parl., *D. elatum* (Roxb.) Wall. ex Hook., *D. pectinanum* de Laub., and *D. xanthandrum* Pilg. (Farjon & Filer 2013). Outside these two islands, seven other species are still found, especially in West Papua.

The result of the earlier analysis with the dendrology expert of the Faculty of Forestry, Gadjah Mada University Dr. Adriyanti, that a species of *Alau* found in Central was *Dacrydium beccarii* Parl. It is possible that several other species of *Dacrydium* exist around the habitat of *D. beccarii*, as Farjon and Filer (2013) stated that in Central Kalimantan, two species of *Dacrydium* were found. *Alau* is related to the genera *Falcatifolium* de Laub. and *Dacrycarpus* (Endlicher) de Laub. of the same family with sympodial branching type. In contrast to *Araucaria* (Araucariaceae), another conifer is generally monopodial and the fruit is similar to that of *Podocarpus*.

Alau has beautiful timber sought by the wood and craft industry. This genus is increasingly threatened mainly due to damage to its natural habitat by human activities, forest fires, and internal factors of the species. Research on the identification of *Alau* in the forest's native habitat in Kalimantan aims to reveal the system of relationships between individuals in a community to know the supporting and inhibiting factors of the sustainability of natural growth.

The whole genus *Dacrydium* is endangered because of the exploitation due to their beautiful timber known as *melur/cemantan*. Plant propagation efforts are difficult because the plant seeding system is complicated and the survival rate is low. The record derives from WCSP (data supplied on 2012-03-23), which reports it as an accepted name (record 383545) with original publication details: Bot. Jahrb. Syst. 69: 252 1938. Farjon. A. 2013.

Dacrydium beccarii is categorized as least concern in the IUCN Red List of Threatened species in 2013. *Dacrydium pectinatum* de Laub. (family Podocarpaceae) record is from WCSP (data supplied on 2012-03-23), which reported it as an accepted name (record 383536) with original publication details: J. Arnold Arbor. 50: 289 1969. Full publication details for this name can be found in IPNI: http://ipni.org/urn:lsid:ipni.org:names:687961-1.

Dacrydium elatum has most recently been assessed for The IUCN Red List of Threatened Species in 2011 (Thomas 2013). *Dacrydium elatum* is categorized as least concern in the IUCN Red List of Threatened Species 2013.

Alau grows in heath forest or *kerangas* in Dayak term which grows on soil with a thin layer of peat and has sand

content. Richards (1996) in Hilmawan (2015) created the term heath forest for special vegetation in Sarawak. Heath forest is one of the important types of forests in Indonesia that grows on podsol soil, a nested quartz sand land, nutrient-poor and low pH (sour) (Whitmore 1984; Kusmana 1995; Richards 1996; Hilwan 1996) and is prone to burning.

Heath forests are extremely vulnerable or very sensitive to disturbances such as fires because it impacts species richness (Sakai et al. 2022). MacKinnon et al. (1996) stated that heath forests are special and easily recognizable ecosystems in all lowland rainforest formations. Kalimantan has the most extensive area of heath forest in Indonesia.

The purposes of the study were: (i) to know the distribution and abundance of *alau* in its natural habitat and (ii) to describe the *alau*'s habitat.

MATERIALS AND METHODS

Study sites

The research was conducted in three different locations in Central Kalimantan Province, Indonesia, namely PT. Dasa Intiga (PTDI) in Kapuas and North Barito Districts, PT. Taiyoung Engreen (PTTE) in Gunung Mas District, and Sebangau National Park (SNP) of Pulang Pisau and Palangka Raya Districts of by determining the dominance area in three areas (Figure 1).

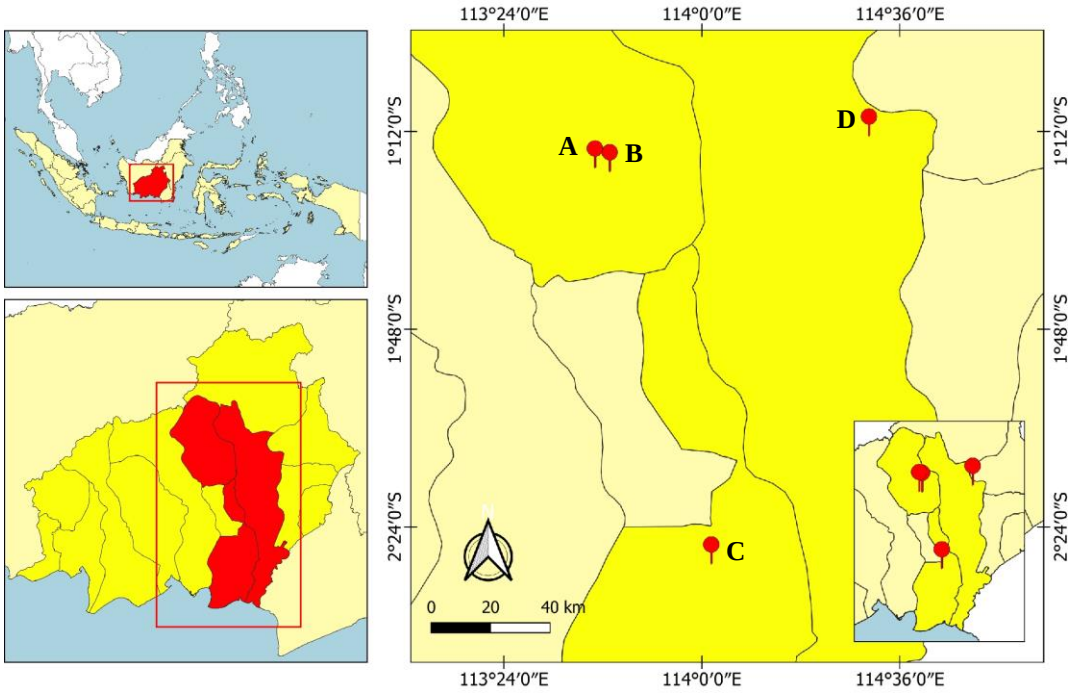
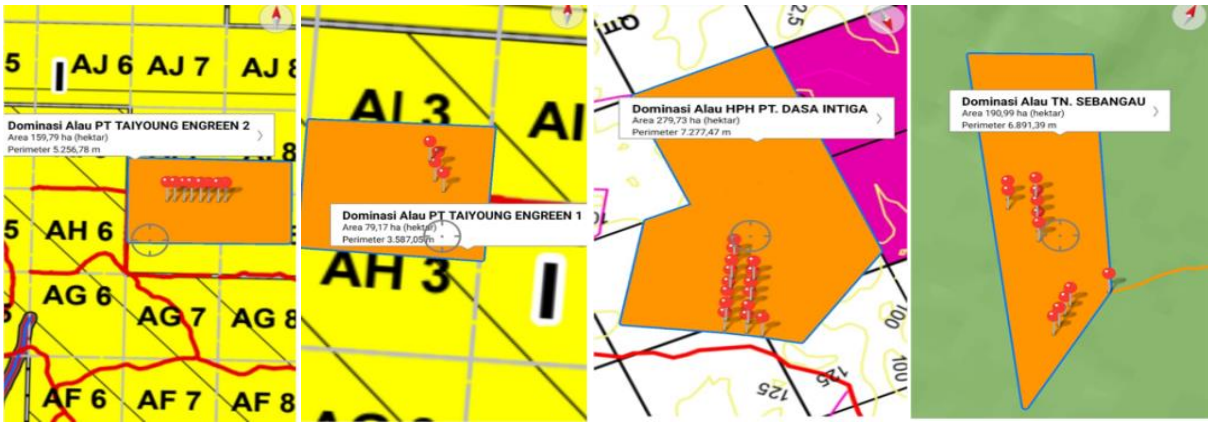


Figure 1. Location of study area in Central Kalimantan, Indonesia (Maimunah et al. 2021). A. PTTE-1, B. PTTE-2, C. PTDI, D. SNP



A **B** **C** **D**

Figure 2. Plot map in Central Kalimantan, Indonesia. A. PTTE-1, B. PTTE-2, C. PTDI, D. SNP

Table 1. Plot information in Central Kalimantan, Indonesia

Study site	The area where *Alau*'s Dominant			
	PTTE-1	**PTTE-2**	**PTDI**	**SNP**
Extent (ha)	159.79	79.17	279.73	190.99
Sampling Intensity (SI)	1.001	1.010	1.001	1.047
Number of Plots	4.00	2.00	7.00	5.00
Plot size (ha)	0.40	0.40	0.40	0.40
Extent of Plot (ha)	1.60	0..80	2.80	2.00
Starting Coordinate in first plot	S 01.325038 E. 113.721327	S 01.313704 E 113.676631	S 01.216722 E 114.506997	S. 02.51493 E 114.02885

Data collection

Based on the preliminary observation, plots were made in the area where *Dacrydium* was found dominant. Sampling with 1% intensity was done in plots, each measuring 50 x 80 m^2, with a distance of 100 m between plots. Table 1 is the information of plots in three areas of research, i.e. in PTTE for pure heath forest with sandy soil dominant in two separate locations, one area for natural habitat and one area for disturbed area. PTDI for the mineral to shallow peat area sampling and Sebangau National Park (SNP) for deep peat area sampling. Figure 2 is the map of plot in four locations. The identified specimens of *alau* were sent to Herbarium Bogoriense for verification.

Data analysis

Two Excel-based tools developed by Michigan State University under the USAID LESTARI Project (2015-2020) were used to compute biodiversity indices, wood volume (m^3 ha^{-1}), and stand density (trees ha^{-1}) from the collected field data. The tools compute species richness and dominance and several other biodiversity indicators. We used the output from these two tools to report species composition and stand habitat characteristics for the four study areas.

RESULTS AND DISCUSSION

Alau's habitat

The description of *Alau*'s habitat in the study areas is given in Table 2. The forest type in Sebangau National Park (SNP) is peat swamp, while the others are heat forests. Therefore, SNP area has many different characteristics than the other areas. The four locations of plots represent a gradient of ecological conditions.

The forest in SNP had a higher total volume and density of woody plants than the other areas (Table 3). The largest contribution of volume and density in SNP came from the poles.

The biodiversity analysis of the area for PT. Taiyoung Engreen is divided into 2 areas, namely PTTE 1 and PTTE 2. PT. Dasa Intiga (PTDI) and Sebangau National Park (SNP). Table 4 is the result of biodiversity analysis in four locations.

Distribution and abundance of alau

The results of data analysis showed that *alau* had a wide distribution from thin peat to deep peat. Simpson's diversity index was similar at all four locations (0.83-0.96), with the number of species ranging from 63 to 83 species. It is known that *alau* grows in the same habitat with different species at each different depth of peat. The abundance of *alau* at various growing stages varied among plots. The highest number was found in Sebangau National Park, with the dominant growth stage of the tree measuring 20-30 cm in diameter. The five most abundant species were different among the four plots. Only *jambu merah* and *jambu putih* were dominant in all of location. Only *pilau* (*Agathis borneensis* Warb.) could be found in PTTE; *supang* (*Shorea pachyphylla* Ridl.) in PTDI and *tumih* (*Combretocarpus rotundatus* (Miq.) Danser) in SNP.

Alau grows in the natural habitat mixed with many species and not in one colony. The presence of seedlings depends on the disturbance of forest, flood, and the number of adult *alau* present in the plot. PTDI had the most abundant seedling because the condition was good for seedlings to grow. PTTE is the disturbed area, and SNP is the flooded area.

Based on the characteristic-of the phenotype, the *alau* was distinguished into four species, namely *Alau Bakam* (*Dacrydium beccarii* Parl.), *alau Kelangkang* (*Dacrydium pectinatum* de Laub.), *alau Tombak* (*Dacrydium elatum* (Roxb.) Wall. ex Hook.) and alau te*mbaga* (*Dacrydium spp*.). In the observed plots, there were only three species of *alau*, while *tembaga* was not found. *Alau tembaga* has the best wood quality among the four species of *alau* that exist and has been widely exploited.

The distribution of *Dacrydium* seems to depend on certain forest types, which are inherent to soil conditions like thin peat /kerangas and deep peat. So far, we have observed not all deep peat or thin peat / *kerangas* soils are generally covered by *alau*, but it seems that the presence of alau also depends on the floristic association (Maimunah et al. 2021). The description of the shape of the different species is shown in Figures 3, 4 and 5.

Table 2. Overview of *alau*'s habitat characteristics in the four plots

Ecological characteristics	PTTE-1	PTTE-2	PTDI	SNP
Peat depth	6.5 cm	10 cm	12 cm	> 3 m
Presence of sand under the peat layer	Present	Present	Present	Not Present
Sand color	Black	White	White	Not Present
Presence of hardpan layer	Present	Present	Not Present	Not Present
Forest type	Heath	Heath	Heath	Peat swamp
Light intensity	50 %	60 %	45 %	40 %
Presence of puddles	Not present	Not present	Present (some)	Present
Ground water depth	NA	NA	NA	11 cm
Species found only in this area	*Pilau* (*Agathis borneensis.* Warb.)	*Meranti kahiu* (*Shorea xanthophylla* Symington)	*Supang* (*Shorea pachyphylla* Ridl.)	*Mertibu* (*Dactylocladus stenotachys*), *Belangeran* (*Shorea balangeran* (Korth.) Burck) *Kapurnaga jangkar* (*Calophyllum sclerophyllum.* Vesq.)
Abundance of *Alau* seedlings in 2 x 2 m^2 plot	8	13	16	11
Relative abundance of liana (rattan, *bajakah*)	++	+++	+	-
Relative abundance of pandan	+++	+++	++	+

Tabel 3. Stand volume and density

Growth stage	Average volume (m^3 per ha) of woody plants from sapling to trees PTTE-1	PTTE-2	PTDI	SNP
Saplings	17.07	31.44	34.64	43.05
Pole	8.98	83.37	113.93	309.44
Trees	186.99	207.95	270.58	242.40
Total	292.04	322.75	419.16	594.89
	Average of forest density (trees per ha)			
	PTTE-1	**PTTE-2**	**PTDI**	**SNP**
Seedlings (> 20,000)	48,750	118,125	88,571	60,000
Saplings (> 1,600)	800	1,100	1,086	1,840
Pole (> 200)	650	550	700	1,680
Trees (> 25)	129	134	123	148

Table 4. Biodiversity Index

Biodiversity Index	Name of area PTTE-1		PTTE-2		PTDI		SNP	
	Trees	**Seedlings**	**Trees**	**Seedlings**	**Trees**	**Seedlings**	**Trees**	**Seedlings**
Species Richness	77	35	63	12	83	59	82	26
Richness Menhinick's	1.78	2.57	2.41	2.03	1.27	3.50	1.34	2.38
Richness Margalef	10.09	6.51	9.50	3.09	9.80	10.27	9.84	5.23
Species diversity Shannon	3.65	2.68	3.44	1.99	3.38	3.25	3.60	2.99
Diversity Simpson	0.96	0.88	0.95	0.83	0.94	0.92	0.96	0.95
Evenness	0.84	0.75	0.83	0.80	0.76	0.80	0.82	0.92
5 abundance rank of species	*Mahadingan jangkar*	*Mahadingan jangkar*	*Mahadingan jangkar*	*Jambu merah*	*Mahadingan jangkar*	*Jambu merah*	*Bintan*	*Tabati*
	Jambu putih	*Jambu merah*	*Jambu putih*	*Mahadingan jangkar*	*Jambu putih*	*Mahadingan jangkar*	*Geronggang*	*kambasira*
	Nyatoh puntik	*Jambu putih*	*Pilau*	*Kayu sapat*	*Jambu merah*	*Jinjit*	*Tumih*	*Jambu putih*
	Meranti bitik	*Aciw*	*Belawan merah*	*Meranti bitik*	*Nyatoh bawui*	*Jambu putih*	*Belawan merah*	*Jinjit*
	Gantalang	*Mangkinang*	*Jambu merah*	*Kambasira*	*Resak tembaga*	*Aciw*	*Aciw*	*Jambu merah*

Note: the plant names are local names.

Table 5. *Alau* dominance

Parameters	Site of *Alau*							
	PT Taiyoung Engreen (1)		PT Taiyoung Engreen (2)		PT Dasa Intiga		Sebangau National Park	
Number of *Alau* trees in all plots	27 trees (4 plots)		5 trees (2 plots)		54 trees (7 plots)		102 trees (5 plots)	
Number of seedlings	84		65		468		178	
Number of *Alau Bakam* (*Dacrydium beccarii* Parl.)	3		1		10		35	
Number of *Alau Kelangkang* (*Dacrydium pectinatum* de Laub.)	15		4		35		57	
Number of *Alau Tombak* (*Dacrydium elatum* (Roxb.) Wall. ex Hook.)	9		0		9		10	
Min DBH (cm)	14.01		43.61		10.50		10.98	
Max DBH (cm)	59.84		54.11		59.84		41.38	
Mean DBH (cm)	39.71		50.61		36.03		21.98	
DBH Size Class	N	%	N	%	N	%	N	%
0-10 cm	1	4%	0	0%	1	2%	0	0%
10-20 cm	0	0%	0	0%	2	4%	41	40%
20-30 cm	6	22%	0	0%	12	22%	53	52%
30-40 cm	6	22%	0	0%	23	43%	7	7%
40-50 cm	9	33%	2	40%	11	20%	1	1%
50-60 cm	5	19%	3	60%	5	9%	0	0%

Table 6. Morphology of *Dacrydium* species

Features	Morphology		
	1	2	3
Local name	*Bakam*	*Kelangkang*	*Tombak*
Scientific name	*Dacrydium beccarii* Parl.	*Dacrydium pectinatum* de Laub.	*Dacrydium elatum* (Roxb.) Wall. ex Hook.
Canopy /crown shape	Round and thick	Round and thin	Conical
Branching type	Semi plagiotropic	plagiotropic	orthotropic
Leaf composition and canopy shape	Weight down plagiotropic/dangling	Collecting on one axil to form a group at the top canopy	Orthotropic and thiny
Bark characters	Scaly with an inverted position with a very large number of dark scales	Scaly with an inverted position on part of the surface of the stem	Hardly scaly
Leaf length	1-1.5 cm	0.6-0.8 cm	0.5 cm

Alau Bakam (*Dacrydium beccarii* Parl.)

Alau Bakam (*D. beccarii* Parl.) is categorized as least concern on IUCN Red List (Farjon 2013). The results of field observations reveal that the genus is still widely distributed within Central Kalimantan and can even dominate special areas (Adriyanti and Soekotjo 2019 pers. comm.). *Alau Bakam* dominates the areas of deep peat and *kerangas*. Other families associated are Myrtaceae, Guttiferae and certain Dipterocarpaceae. In fact, *D. beccarii* is in the second rank in the field after *D. pectinatum.* The natural distribution of *D. beccarii* is arround Malaka Peninsula, North Sumatra, Phillipine, North Kalimantan, Central Sulawesi, Maluku until Papua. Only in west Kalimantan this species cannot be found (Farjon and Filer 2013). New Guinea: *netukuria*, New Britain, *mejoop*, Kebar valley; Taliabu: *kawau*; Borneo: *kayu embun*, Merurong Plateau, *sempilor*, Sarawak, Bintulu; Malaya: *ekor kuda*. Kedah; Sumatra: *sampinur tali*, Tapanuli (Parlatore 1867). Amalina and Slik (2019) said that *D. beccarii* is one species of Brunei Darussalam in near-threatened from 8% included in the new species being evaluated on the IUCN Red-List. Deforestation and logging are likely to affect subpopulations and stands at lower altitudes (*kerangas* forest in particular) (http://www.IUCNRedlist/Species/42447/2980953).

Alau Kelangkang (*Dacrydium pectinatum* de Laub.)

Alau Kelangkang (*D. pectinatum* de Laub.) according to Farjon and Filer (2013) is evenly distributed on Kalimantan, Bangka Belitung Islands and parts of Sumatra and is still present now although with a smaller number than *D. Beccarii.* Farjon and Filer 2013 said that this species is in Endangered (EN) status on the IUCN red list. This species is also found in the Philippines and Hainan Island (China). This species is easy to find in the field and it is the most abundant species of *alau* in Kalimantan. Liu et al. (2020) said that *D. pectinatum* has a natural pattern of distribution in rainforests on Hainan Island China, with a status of rare and endangered species. The declaration from Farjon and Filer (2013) about EN status has changed with the reality of the field. It is imperative to protect the last *D. pectinatum* in the field from extinction. *D. pectinatum*, first

described by David de Laubenfels in 1969, is commonly known as *malur* in the Mangar language, *melur* in Singkawang language, *tjemantan* in Sampit language, and *sempilor* in Serawak and Sabah language https://conifersociety.org/conifers.

Haodong Liu et al. (2020) said that conspecific negative density dependence and niche filtering as the general mechanisms of natural regeneration of *D. pectinatum* formations. Both biotic and abiotic factors might affect the survival and growth of seedlings and their relative importance varies with environmental gradients and species. This research can be used as a recommendation for protecting this species, recorded in Hainan, (China), Sabah and Serawak (Malaysia), Kalimantan (incl. Karimata & Natuna Islands), the island of Pulau Belitung off the coast of Sumatera (Indonesia) and a few isolated localities in the Philippines. The major part of its distribution is in the lowland forests of Sabah, Sarawak and Kalimantan Farjon and Filer (2013). Fragmentation of subpopulations is due naturally to their occurrence on several major islands, but is more recently exacerbated by conversion to other land uses, such as palm oil plantations. Massive conversion of lowland forest (*kerangas*) on the coastal plains of Sabah, Sarawak, and Kalimantan to oil palm plantations has reduced this species probably to 20% of its former area of occupancy. This threat is ongoing and may result in total disappearance in those areas making way for oil palm plantations (Curran et al. 2004). The species also occurs in low montane forests, where it is threatened by deforestation related to (shifting) agriculture. Logging affects the species, particularly in Hainan, where it can reach a greater size, but also in Kalimantan. http://www.IUCNRedlist/Species/42473/2981523).

Alau Tombak (*Dacrydium elatum* (Roxb.) Wall. ex Hook.)

Dacrydium elatum (Roxb.) Wall. ex Hook. so far was not yet been known in Central or South Kalimantan, but it was found in this study. *Dacrydium elatum* was first described by (Roxb.) Wall. ex Hook. in 1843. Sinonim of this species is *Dacrydium pierrei* Hickel. Farjon and Filer (2013) said that spread of *D. elatum* is from West Sumatra (Riau and Bengkulu), Malaysia, Cambodia, Thailand, Vietnam, North Kalimantan and Phillipine and Hainan Island (China). *D. elatum* cannot be found in south Kalimantan, but only in north Kalimantan (Sabah and Serawak) Malaysia. This species is native to Vietnam, Laos, Cambodia, Thailand, Malaysia where it is very common (Buchholz 1949). Farjon and Filer (2013) said that this species is categorized as Least concern (LC) on the IUCN Red List. Common names include in the Vietnamese language: Hoàng dàn giả; in Borneo: *ouk*, *kayan*, and *sempilor* (Buchholz 1949). *Dacrydium elatum* occurs in a number of protected areas throughout its range. In countries such as Viet Nam where it is listed as nationally threatened and it has been recorded from national parks such as Bi Doup Nui Ba in the south, Bach Ma in central Viet Nam and in the Hoang Lien NP in the north. In Lao PDR, it occurs in the Nakai Nam Theun NBA (*D. elatum* IUCN RedList).

A **B** **C**

Figure 3. *Alau Bakam* (*Dacrydium beccarii* Parl.)

A **B** **C**

Figure 4. *Alau Kelangkang* (*Dacrydium pectinatum* de Laub.)

A **B** **C**

Figure 5. *Alau Tombak* (*Dacrydium elatum* (Roxb.) Wall. ex Hook.

Figure 5 shows the morphology of *Dacrydium elatum* (Roxb). Kim et al. 2015 said that *Dacrydium elatum*, among the limited native gymnosperms of Sarawak, are highly fancied for decorative veneer and plywood manufacture because of the straight grain and the very fine texture their wood.

This study concludes that three species of *Dacrydium*, including *D. pectinatum*, were found in the study area. The finding of *D. pectinatum* is a new discovery because it was reported that this species was not found in Central Kalimantan.

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