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The mortality factor of rafflesia buds (*Rafflesia tuan-mudae*) in Sungai Betung Distric, Bengkayang Regency

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ABSTRACT
The mortality of the *Rafflesia tuan-mudae* buds can be caused by the environmental conditions of the growing place and the host *R. tuan-mudae*. The purpose of this study is to describe the habitat conditions of *R. tuan-mudae* and found the cause of the death of Bud *R. tuan-mudae*. The study used a survey method with data collection techniques in the form of a double plot that is placed purposively where *R. tuan-mudae* is found with a size of 20 m × 20 m. Based on the result of the study *R. tuan mudae* was found in 3 observation plots, the first is found in Bukit Salapar, and the other plot is in Gunung Bawang Raya. The results of measurements of the environmental conditions of the *R. tuan-mudae* habitat show that *R. tuan-mudae* is often found in conditions of air humidity 87.4 – 91 %, air temperature 25.7 – 26.7 °C, soil pH 4.1 – 4.2, soil moisture 69 – 70 %, soil temperature 25 – 26 °C, light intensity 542 – 1782 lux, land slope 52.8 – 64.0% and altitude 292-537 MASL. The condition of *R. tuan-mudae* population has a percentage of 32% live buds, 60% of dead buds and 8% die after blooming. The death of *R. tuan-mudae* buds is caused by high air humidity 91%, host death, a very steep land slope 64.0% and buried by litter.
Keyword: Cause of Death, Habitat, Rafflesia.

1. Introduction

Rafflesia tuan-mudae is one of the Rafflesia species that can be found in Peninsular Malaysia, Southern Thailand, Sumatra, Java, and Kalimantan [1]. Sungai Betung sub-district is a sub-district in Bengkayang Regency, West Kalimantan. This sub-district has an area of approximately 205.95 km² and consists of 4 villages: Cipta Karya Village, Karya Bhakti Village, Suka Bangun Village, and Suka Maju Village. Cipta Karya Village and Suka Bangun Village are two villages that are the primary habitat of *R. tuan-mudae*, precisely in Bukit Salapar (Limited Production Forest Area) and Gunung Bawang Raya (Protected Forest Area).

Rafflesia is a holoparasitic plant that attaches and lives on its host, Tetrastigma spp [1-2]. Holoparasites are defined as plants that do not have chlorophyll, leaves, or stems, and their lives depend on the host [3]. Tetrastigma is a Rafflesia liana or host plant that usually climbs tall trees. Tetrastigma root system has a lot of branching with the growth and development of roots that tend to be horizontal and are generally on the surface of the topsoil [4].

According to the International Union for the Conservation of Nature and Natural Resources (IUCN), *Rafflesia tuan-mudae* is critically endangered [5]. The small population and endemic species make this plant a priority in its conservation. Presidential Decree of the Republic of Indonesia Number 4 of 1993 concerning National Animals and Flowers states that Rafflesia is known as a protected rare puspa. This rare flower is known for its unique shape and distinctive smell when it blooms. In addition, forest destruction in Rafflesia's natural habitat and the difficulty of finding flowers pose a serious threat to Rafflesia's sustainability.

Previous research shows that there are 3 types of rafflesia found on the island of Kalimantan is *Rafflesia hasselti*[6], *Rafflesia pricei Meijer* [7] *and Rafflesia tuan-mudae* [8]. The increase and decrease in population caused by the death of rafllesia in various phases of its life has a close relationship with the surrounding environmental conditions. The conversion of forest land into agriculture and plantations, and a decrease in habitat quality such as changes in temperature, rainfall, and soil quality further suppresses the survival of young and old Rafflesia. Favorable environmental conditions are one aspect that needs to be considered to preserve Rafflesia and ensure the number of existing Rafflesia populations to avoid extinction [9]. According to [10], if the rate of new shoots that appear is lower than the death rate, it is inevitable that a population will experience a decline and extinction. This indicates that the existence of new shoots is essential for future conservation purposes. This study aims to describe the habitat conditions of R. tuan-mudae and find the cause of death in R. tuan-mudae saplings an effort that can be done so that later it can be used as a study material to maintain the existence of this plant.

2. Method

2.1. Research Location

This research was conducted in Cipta Karya Village and Suka Bangun Village, Bengkayang Regency in October - November 2022. Plot 1 was located at Bukit Salapar, Cipta karya Village and Plot 2-3 at Gunung Bawang Raya, Suka Bangun Village (Figure 1).

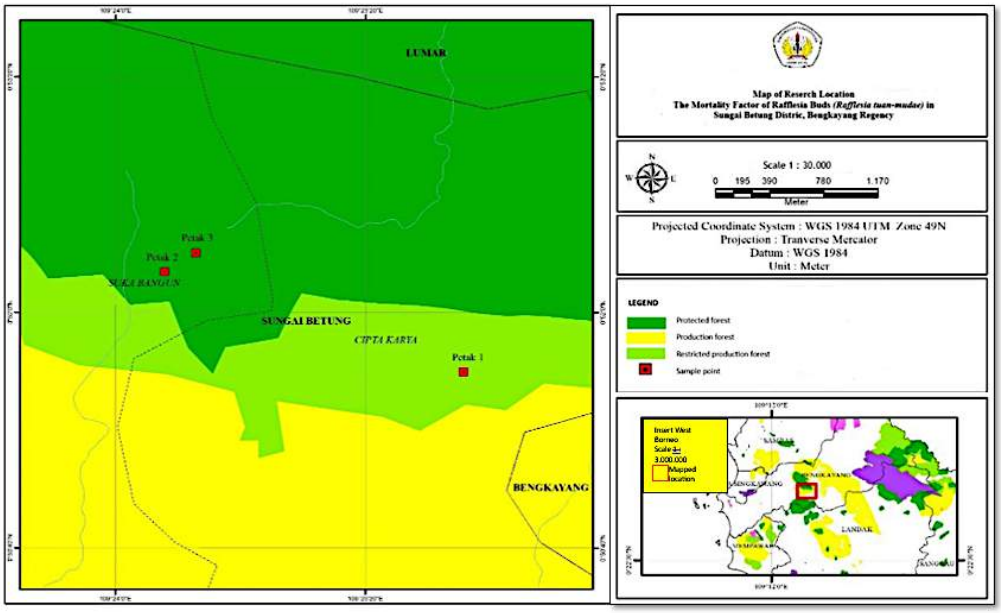

Figure 1. Map of Research Location

2.2. Data Collection

The implementation of this research was carried out using a survey method with data collection techniques in the form of double plots placed purposively where *R. tuan-mudae* was found, namely as many as three measuring plots spread across Bukit Salapar (Plots 1) and Gunung Bawang Raya (plots 2 and 3). Each observation plot was made with a size of 20 m × 20 m, which was used to observe *R. tuan-mudae* individuals, vegetation, and habitat conditions (environmental factors). Determination of the size of the plot is based on the association of this plant with existing environmental factors, especially the testasigma and its host tree. Data collection on *R. tuan-mudae* included the number of *R. tuan-mudae* individuals, flower phase, and developmental status (bud/blossom) with information on whether it was alive or dead, bud width, and cause of death. Data on vegetation browsed by *R. tuan-mudae* hosts include species name, number, and diameter of trees. Data on environmental factors such as temperature, air humidity, land slope, pH, soil temperature and humidity, and altitude were measured in situ in the field at the time of data collection. Data on animal or insect activity is collected by direct observation in the field, data taken in the form of species name, activity, number of individuals, and time of encounter.

2.3. Data Analysis

Data analysis was carried out descriptively and quantitatively. This analysis is used to describe the results of observations made so that later, it can describe the cause of the death of *R. tuan-mudae* buds. According to

[11], the descriptive method is a method used to analyze or describe a research result by not making conclusions more broadly. While quantitative research uses certain samples or populations, data collection uses research instruments and quantitative and statistical data analysis to test hypotheses that have been set. Density (D) and Relative Density (RD) on species composition such as tree-level vegetation in each observation plot, were calculated to describe land cover conditions in *R. tuan-mudae* habitat using the following formula :

$$\text{Density} = \frac{\text{Number of Individuals}}{\text{sample plot area}} \quad (1)$$

$$\text{Relative density} = \frac{\text{Density of species A}}{\text{total density of all species}} \text{ x } 100 \quad (2)$$

3. Results and Discussion

3.1. Species composition and density of plant vegetation R. tuan-mudae area

The analysis of tree-stages vegetation density is one of the components in the observation of *R. tuan-mudae* habitat. Based on the data obtained, the composition of tree-level vegetation in *R. tuan-mudae* habitat has six plant species with varying density values (Table 1).

Table 1. Tree Level Vegetation

No.	Site	Species	Total	Density	Relative Density (%)
Bukit Salapar (Plot 1)					
1.		Nyatoh (*Palaquium rostratum)*	5	125	83.33
2.		Ubah (*Eugenia sp)*	1	25	16.67
Gunung Bawang Raya 1 (Plot 2)					
1.		Kelampai (*Elateriospermum topos)*	2	50	66.67
2.		Damar (*Agathis dammara)*	1	25	33.33
Gunung Bawang Raya 2 (Plot 3)					
1.		Keruing (*Dipterocarpus retusus)*	1	25	25
2.		Meranti merah (*Shorea macrophylla)*	3	75	75

The types of trees found in the study site include *Palaquium rostratum*, *Eugenia* sp., *Elateriospermum topos*, *Agathis dammara*, *Dipterocarpus retusus*, and *Shorea macrophylla*. Based on the results of observations, there are two types of trees in each plot; this is because these types of trees are the dominating types in each observation plot and have a larger diameter. The density of tree-level vegetation in plot 1 is a relatively dense density of 150 individuals/ha compared to the density of tree-level vegetation in plots 2 and 3, which is 75 individuals/ha and 100 individuals/ha based on each observation plot. Tree density is related to canopy cover, which can affect light intensity. According to [8], tight canopy cover can keep the growth of *R. tuan-mudae* exposed to direct sunlight. In addition, the header cover is also able to maintain air humidity [12]. *R. tuan-mudae* at the research site is often found in high air humidity in 87.4 - 91%. This is not much different from [8] which states that Rafflesia Tuan-mudae is found in 86.25% humidity with an average temperature of 25.6 °C

3.2. Tree species associated with R. tuan-mudae host

Based on the results of observations, there are six species of plants spread across three observation plots (Table 1); of the six types of plants that exist, *Eugenia* sp., *Agathis dammara*, and *Shorea macrophylla* are tree species propagated by host *R. tuan-mudae* (Table 2).

Table 2. Types of trees propagated by host *R. tuan-mudae*

Site	Plot	Species	Diameter (cm)
Bukit Salapar	1	Ubah (*Eugenia* sp.)	22
Gunung Bawang Raya	2	Damar (*Agathis dammara)*	33
	3	Meranti merah (*Shorea macrophylla)*	25

Agathis dammara is a plant with the most prominent tree diameter with a size of 33 cm, and the minor tree diameter is the type Eugenia sp. with a diameter size of 22 cm. Support trees are one of the main determining factors in the process of Raflesia growth [13], large diameter trees are beneficial for *R. tuan-mudae* hosts to climb to the top of the tree canopy, which aims to get more sunlight compared to small diameter trees. According to [3], the activity of the Rafflesia host in climbing supporting trees does not depend on the species of a particular tree. However, it is influenced by its proximity and usually has a strong, tall trunk and header exposed to sunlight. The results of field research show that trees associated by the host *R. tuan-mudae* are taller than other trees and have a crown that is not too wide with a diameter of 22-33 cm. It is suspected that a canopy that is not too wide can make it easier for sunlight to penetrate the header, so the host *R. tuan-mudae*, chose the tree as a support tree to climb and get sunlight.

3.3. Betung Analysis of R. tuan-mudae Growing Places in Sungai Betung District

Based on the results of the study *R. tuan-mudae* in 3 observation plots. Environmental conditions where *R. tuan-mudae* grows can be measured from abiotic components: air humidity, air temperature, soil pH, soil moisture, soil temperature, light intensity, land slope, and altitude. The results of measuring environmental conditions (Table 3).

Table 3. Abiotic Environmental Conditions

Site	Plot	Abiotic Environmental Conditions							
		KU (%)	SU (℃)	pH Tanah	KT (%)	ST (℃)	IC (LUX)	KL (%)	K (masl)
Bukit Salapar	1	91	26.7	4.2	70	25	542	52.8	292
Gunung Bawang	2	87.4	26.1	4.1	69	26	1782	63.5	533
Raya	3	89.9	25.7	4.1	69	26	868	64.0	537

Description: KU: Air humidity; SU: Temperature; pH: Soil pH; KT: Soil Moisture; ST: Soil Temperature; IC: Light Intensity; KL: Slope; K: Altitude

The results showed that the air humidity in Bukit Salapar where *R. tuan-mudae* was found, reached 90% with an air temperature of 26.7 °C. In comparison, the air humidity in Bawang Raya ranged from 87.4 – 89.9 %, with air temperatures ranging from 25.7 – 26.1 °C. This study was conducted during the rainy season in October, which had a rainfall of 306 mm/month. High rainfall is thought to affect the level of air humidity. Research *R. tuan-mudae* conducted by [8], at Gunung Poteng Nature Reserve Raya Pasi has air humidity ranging from 83 – 89% with air temperatures ranging from 25.3 – 26.1 °C. High rainfall is thought to affect the level of air humidity. Research *R. tuan-mudae* conducted by [8], at Gunung Poteng Nature Reserve Raya Pasi has air humidity ranging from 83 – 89% with air temperatures ranging from 25.3 – 26.1 °C. The results of measuring air humidity and air temperature at the research location and the results of research in Mount Poteng Pasi Nature Reserve show relatively the same humidity and air temperature. The growing location of R. tuan-mudae in Bukit Salapar is at an altitude of 292 masl, and in Gunung Bawang Raya, it ranges from 533 - 537 masl. The altitude of the place has a close relationship to differences in temperature and humidity, the higher an area will reduce temperature and increase humidity. The land slope in both locations ranges from 52.8 - 64.0%. This land slope is included in the very steep category of >40% [14]. Steep land will result in high erosion rates and cover tiny R. Tuan-mudae buds, thus increasing the percentage of mortality.

In addition, at the time of observation in the field *R. tuan-mudae* can be found at an altitude of 292 meters above sea level in Bukit Salapar and on Gunung Bawang Raya ranging from 533 - 537 meters above sea level, while *R. tuan-mudae* in Mount Poteng Pasi Nature Reserve can be found at an altitude of 431 - 503 masl. The results of slope measurements at the study location ranged from 52.8 – 64% in contrast to the slope measurement results at Mount Poteng Pasi Nature Reserve, which was 18.25%. This shows that the slope at the study location is very steep compared to the slope on Mount Poteng Pasi Nature Reserve, which is included in the rather steep category. According to [14], a slope of 15 – 25% belongs to the relatively steep category, while a slope of >40% belongs to the very steep category.

Based on the results of field observations, there were several pole and tree-level vegetation that had fallen, resulting in light intensity in the habitat of R. tuan-mudae on Mount Bawang being higher at 868 - 1782 lux compared to the light intensity in Bukit Salapar, which was 542 lux, high canopy closure will have an impact on growth for R. tuan-mudae because it can reduce direct exposure to sunlight. Light intensity that is too high can have a negative impact on the survival of R. tuan-mudae besides high and low light intensity will also affect the photosynthesis process that occurs in the growth of rafflesia host plants and will have an impact on

the process of nutrient cycling [15]. The condition of soil pH, soil moisture, and soil temperature in Bukit Salapar and Gunung Bawang Raya has a difference that is not so big. The results of soil pH measurements at both locations ranged from 4.1 to 4.2, which is acidic. In accordance with the research of [16], that the soil pH suitable for *R. tuan-mudae* tends to be somewhat acidic to neutral. Soil moisture at the study site ranged from 69 – 70% with a soil temperature of 25 – 26 °C. The existence of temperature differences both inside and on the ground surface in each place can be influenced by variations in vegetation on the ground surface and the level of depth of measurement [17].

3.4. Animals in the Habitat of R. tuan-mudae

During the study, five species of animals were found around the habitat of *R. tuan-mudae* (Table 4). Animals that were active around the habitat of *R. tuan-mudae* were black ants, spiders, dragonflies, fruit flies, and lizards. Fruit flies are one of the insects that interact directly with dead *R. tuan-mudae* flowers, especially on the diaphragm tube, which is almost decomposed. According to research by [9], at Rhino - Camp, fruit flies take material from decaying *R. patma* flowers and lay their eggs on the soft parts of the flower for larval growth. These and other insects play a role in decomposing decaying flowers as a food source for their young [18]. At the time of observation, there was not enough evidence to suggest that animals found around rafflesia buds were the cause of bud death.

Table 4. Family of animals in the habitat of *R. tuan-mudae*

No.	Family	Activity	∑
1.	*Formicidae*	Walk above ground level	>10
2.	*Diaspidae*	Perch on a twig	1
3.	*Libellulidae*	Perch on the leaves	1
4.	*Drosophilidae*	Perch on the dead flower *R. tuan-mudae*	7
5.	*Lacertidae*	Move to the bushes	1

3.5. Population of R. tuan-mudae in Sungai Betung District

The population of *R. tuan-mudae* in Bukit Salapar and Gunung Bawang Raya was found as many as 25 individuals in the form of live buds, dead buds, and dead blooms. This study's total number of live buds amounted to 8 live buds, 15 dead buds, and two rotting blooms. Data on its condition and development status (Table 5).

Table 5. Data on the condition and development status of R. tuan-mudae

Site	Plot	Live Buds	Dead Buds	Live Bloom	Dead Bloom
Bukit Salapar	1	5	14	-	-
Gunung Bawang Raya	2	3	-	-	1
	3	-	1	-	1
Sum		8	15	-	2
Percentage (%)		32	60		8

R. tuan-mudae found during this study had a percentage of 32% in the condition of live buds, 60% in the condition of dead buds, and 8% in the condition of dead after blooming (Table 5 and Figure 2). The population death rate of *R. tuan-mudae* buds in the Sungai Betung Sub-district is higher than that of live buds. The results of this study are directly proportional to the results of [8], regarding the high mortality of *R. tuan-mudae* buds in Mount Poteng, Raya Pasi Nature Reserve, which is 64% compared to the level of living buds. *R. tuan-mudae* was mostly found in Bukit Salapar with 19 individuals, while *R. tuan-mudae* in Gunung Bawang Raya had six individuals. The large number of *R. tuan-mudae* individuals in Bukit Salapar is influenced by the habitat distance of *R. tuan-mudae* to the very close water source, with a length of ±4 m. The same results also occur in R. patma in Penanjung Pangandaran Nature Reserve, near the river and Cikamal river tributaries [9].

3.6. Identify the Cause of Death of R. tuan-mudae buds

According to [10] dead buds are characterized by black on the bud and small holes on the top surface of the bud. From the results of field research, the highest death of *R. tuan-mudae* buds occurred in Bukit Salapar, reaching 14 individuals with a diameter of 7-19 cm on plot 1 of the total *R. tuan-mudae* individuals, namely 19 individuals. While the mortality rate of *R. tuan-mudae* buds in Gunung Bawang Raya is that there is only one individual with a diameter of 12 cm from the total *R. tuan-mudae* individuals, which is two individuals on plot 3. The following buds of *R. tuan-mudae* at the study site can be seen in (Figure 2).

(a) (b) (c)

Figure 2. Live buds in the perigone phase (a), dead buds in the bract phase (b), and an internal view of dead buds (c) at Bukit Salapar

High humidity is influenced by high rainfall. This research was conducted during the rainy season, namely in October, when rainfall reached 306 mm/month. Based on the results of research in the field, there were 11 dead buds of R. tuan-mudae with a size of 7 - 19 cm; this was caused by the high humidity in Bukit Salapar, which reached 91%, which caused the buds to rot and be at risk of fungal infections and diseases. In addition, the size of tiny buds can increase the risk of death in plants; stated that the size of tiny rafflesia buds would increase the risk of death in rafflesia buds [19]. The results of this study are different from the results of research by [13] in Naha Jaley Sarawak Malaysia, which showed that the death of R. tuan-mudae buds in this location was caused by sandy soil conditions and poor humus that it had an impact on the supply of nutrients to the host tree.

In addition to the high air humidity factor, there are three dead *R. tuan-mudae* buds with a size of 11-14 cm caused by the death of the host *R. tuan-mudae*. A dead host can disrupt the distribution of nutrients from the host to the buds of *R. tuan-mudae*. Host death occurs due to the host weathering. This is in line with what [20], stated regarding the death of buds that also appeared in *Rafflesia zollingeriana* caused by the interruption of food supply from the host to the Rafflesia buds. Although some buds died due to the host's death, there were still some surviving *R. tuan-mudae* buds. This is proven by [3] that damage to the branch of the host *R. arnoldii* will not kill all buds; all *R. arnoldii* buds will die if damage occurs in the main stem of the host. The death of host *R. tuan-mudae* can be seen in (Figure 3).

Figure 3. View of *R. tuan-mudae* host damage in Bukit Salapar

The death of *R. tuan-mudae* buds also occurred on Gunung Bawang Raya. Bud death occurs due to buds growing on very steep land at a slope of 64.0%. This research was conducted during the rainy season so that the slope of the land makes it easier for rainwater to carry soil particles that can cover part of the surface of *R. tuan-mudae* buds. Factors that can cause soil erosion are rain, soil, slope, vegetation and humans [21]. Another cause of death, namely *R. tuan-mudae* buds, is buried by *R. tuan-mudae* flower litter and willows. The same research results also occurred on *R. patma* buds in Leuwung Cipeucang Geopark Ciletuh Sukabumi, which

suffered damage due to being buried by litter in diameters of 1-10 cm [16]. Rafflesia buds buried by litter make Rafflesia vulnerable to damage at a young age [22]. The death of the buds can be seen in (Figure 4).

Figure 4. Raya The death of buds on the steep slope of the land on Gunung Bawang Raya

4. Conclusion

Environmental conditions of *R. tuan-mudae* habitat show that *R. tuan-mudae* is often found in conditions of air humidity 87.4 - 91%, air temperature 25.7 - 26.7 ^{o}C, soil pH 4.1 - 4.2, soil moisture 69 - 70%, soil temperature 25 - 26 ^{o}C, light intensity 542 - 1782 lux, land slope 52.8 - 64.0 % and altitude 292 - 537 masl. The population condition of *R. tuan-mudae* has a percentage of 32% live buds, 60% dead buds, and 8% dead after blooming. The death of buds is caused by differences in light intensity, host mortality, altitude, and very steep slopes, which result in erosion and litter accumulation.

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