

Research Article

Rafflesia patma Blume in Pananjung Pangandaran Nature Reserve, West Java: Population Structure, Distribution Patterns, and Environmental Influences

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ABSTRACT

Rafflesia patma is an endemic plant of Pangandaran, West Java which is protected because of its rare status. The purpose of this research is to study the population structure, distribution patterns, and the effect of the physical environment of abundance *R. patma* in Pananjung Pangandaran Nature Reserve, West Java. The method used in this research was a survey method with a purposive sampling technique. Sampling was conducted using quadrat plots. The population pattern distribution was defined by a standardized Morisita index, and the analysis of abiotic environmental factors was determined by Principal Component Analysis (PCA) using PAST3. The results showed that there were 114 *R. patma* individuals scattered in several research areas in Pananjung Pangandaran Nature Reserve, they were Gua Parat (3 individuals), Cilegon (13 individuals), Pasir Putih (12 individuals), Badeto (48 individuals), and Curug Leutik (38 individuals). The distribution pattern of *R. patma* in Pananjung Pangandaran Nature Reserve was clustered with the Morisita index value (I_d) > 1. Based on the PCA analysis, results that support the classification of the cluster analysis were obtained. Based on four abiotic environmental conditions analyzed, the most dominant character in influencing the distribution patterns and population structure of *R. patma* is light intensity.

Keywords: distribution pattern, habitat, nature reserve, population structure, *R. patma* Blume

INTRODUCTION

Rafflesia patma is a unique plant that lives in the tropical rainforest ecosystem of Malesiana. The plants do not have any stem, leaves, roots, or photosynthetic organs (Wicaksono et al. 2016). *R. patma* is a parasitic plant on the tree as the host in its habitat. The nutritional needs in its life cycle are taken from the host plant. The intake of nutrients from the host plant is carried out using suction roots to absorb photosynthate into the body organs of *R. patma*. The characteristic of *Rafflesia* is a rare plant species must receive a priority for conservation because the population in nature is small (rare) and is an endemic species. Scarcity of this species is caused by *Rafflesia* having different biological characteristics from other plants, namely having an annual life cycle, being a parasite in certain liana species, and breeding

difficult. This leads to the notion that *Rafflesia* chose certain environmental conditions to support its breeding and growth (Hidayati & Walck 2016; Priatna et al. 1989).

The population of *Rafflesia* in nature is very small. The small number coupled with the sporadic and inconsistent flowering seasons causes the scarcity of male and female flowers to bloom at the same time. In the case of *R. Patma*, in Pangandaran (West Java) the population is dominated by male flowers (Hidayati et al. 2000), which means that the chances of pollination between male and female flowers are reduced. This opportunity is further reduced by the short bloom period, around 4-5 days. Consequently, the pollen viability of male flowers will be very limited. Nais (2001) stated that the viability of *R. keithii* pollen was only 72 hours after being separated from the flower. This means that during this time the pollinating insects must find the female flowers in bloom and pollinate them. It is not yet known how long the viability of *R. patma* pollen is.

Rafflesia has specific life characteristics so that it requires suitable habitat to support its growth, distribution, and sustainability. Anthropogenic factors that contribute to declining populations of *Rafflesia* are deforestation and harvesting by locals due to their perceived medicinal properties (Nais 2001; Yahya et al. 2010). The current human influence tends to be negative and leads to their extinction. This is shown by *Rafflesia* and its habitat which are disposed to disturbance and extinction caused by humans. Protection to avoid the extinction of *Rafflesia* and its habitat must be done. Basic data is needed as a reference for the efforts to preserve *Rafflesia*, both in terms of numbers and in terms of preserving its intact habitat.

The purpose of this study is to analyze the population structure, distribution patterns, and the effect of the physical environment of abundance *R. Patma* in Pananjung Pangandaran Nature Reserve, West Java. It is hoped that the data obtained from this study can be an adequate source of information so that it can be used as a policy basis for the conservation of *R. Patma* and its habitat in Pananjung Pangandaran Nature Reserve, West Java.

MATERIALS AND METHODS

Study Area

This research was conducted from January to April 2020 in Pananjung Pangandaran Nature Reserve, Pangandaran Regency, West Java, which is divided into 5 locations, namely Gua Parat, Badeto, Cilegon, Curug Leutik, and Pasir Putih. Pananjung Pangandaran is a peninsula on the South Coast of West Java, bordering Central Java. The location of the Pananjung Pangandaran Nature Reserve is located between 108°50' to 109°55' E and 7°40' to 7°45' S. This area is bordered by the Indian Ocean to the south, Ciamis Regency to the north, Teluk Pangandaran or Pananjung in the east, and Parigi Bay to the west (Figure 1).

Methods

The method used in this study was a survey method with purposive sampling technique and sampling using quadrat plots. The sampling area was determined based on different habitat types (coastal forest including Gua Parat and Pasir Putih; lowland forest including Curug Leutik, Badeto, and Cilegon). The quadrat used is 20 x 20 m in each location with five repetitions. The data collected were the number of living and dead buds, the number of flowers in live bloom, and dead flowers. Measurement of abiotic environmental factors includes temperature and humidity measured using a

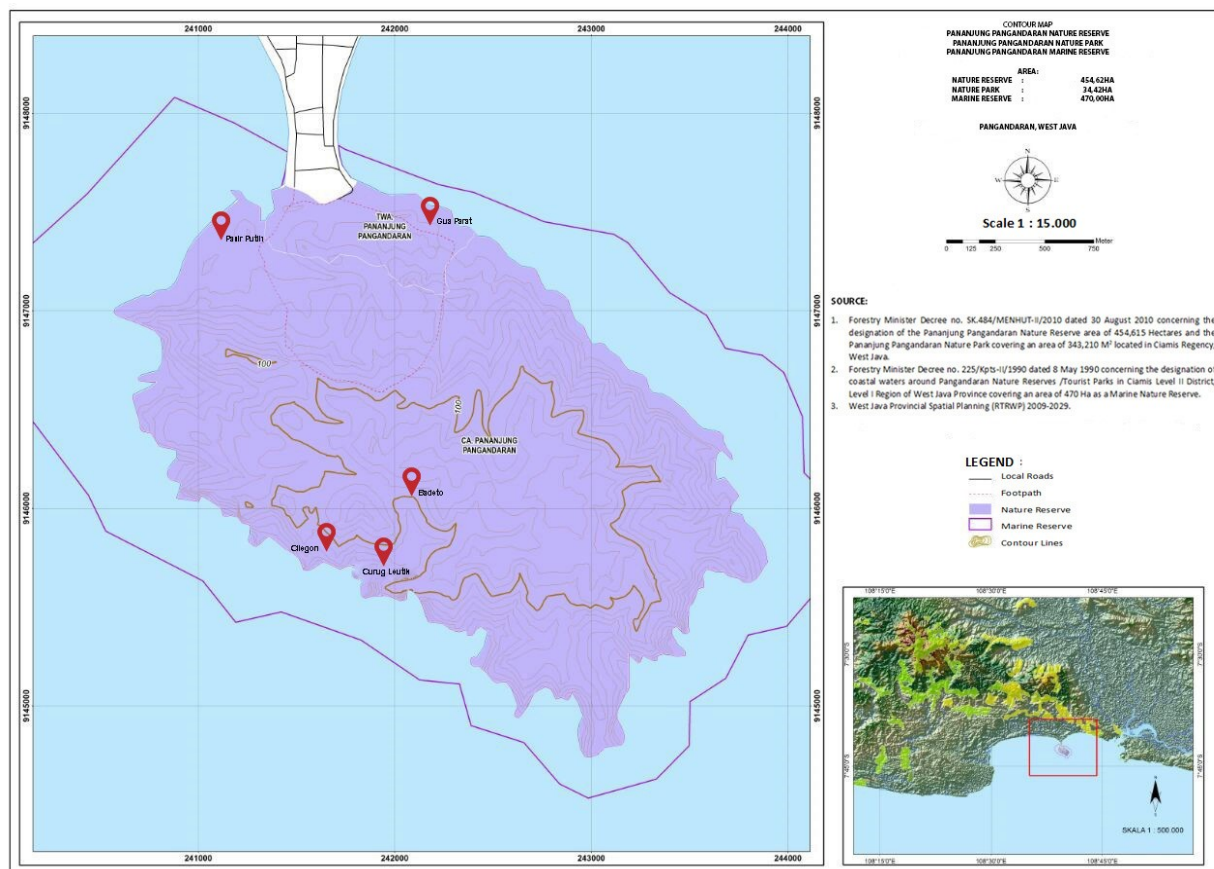


Figure 1. Map of Pananjung Pangandaran Nature Reserve, West Java, Indonesia.

thermo hygrometer, light intensity measured using a lux meter, and pH using a pH meter by measuring directly in the field on each sample plot.

Data analysis

Distribution pattern index

To find out the pattern of *R. patma* distribution, it can be calculated using the standardized Morisita Index (Krebs 1989). The standardized Morisita dispersion index (I_p) ranges from -1 to 1, with 95% confidence limits at 0.5 and -0.5.

Below was the formula used in this study:

$$I_d = n ((\sum x_i^2 - \sum x_i) / (\sum x_i)^2 - \sum x_i))$$

Information:

I_d : Morisita Index

n : Number of all plots

x_i : Number of individual species on i-th plot

Standardized of Morisita index calculated by equation:

$$I_p : 0.5 + 0.5 ((I_d - M_c) / (n - M_c)) \quad ; \text{ if } I_d \geq M_c > 1$$

$$I_p : 0.5 ((I_d - 1) - (M_c - 1)) \quad ; \text{ if } M_c > I_d \geq 1$$

$$I_p : 0.5 ((I_d - 1) / (M_u - 1)) \quad ; \text{ if } 1 > I_d > M_u$$

$$I_p : 0.5 + 0.5 ((I_d - M_u) / (M_u)) \quad ; \text{ if } 1 > M_u > I_d$$

Continuously distribution pattern has been shown by M_u and M_c :

$$M_u = (x_{2,0.975}^2 - n + \sum x_i) / (\sum x_i) - 1$$

$$M_c = (x_{2,0.025}^2 - n + \sum x_i) / (\sum x_i) - 1$$

Information:

M_u : Morisita index on uniform pattern of distribution

M_c : Morisita index on clustered pattern of distribution Index

- $\chi^2_{0,975}$: The value of χ^2 with $n-1$ degree of freedom and confidence interval of 97.5%
- $\chi^2_{0,025}$: The value of χ^2 with $n-1$ degree of freedom and confidence interval of $\chi^2_{0,025}$
- x_i : Number of individual species on i -th plot

Principal component analysis (PCA)

The correlation between abiotic factors and the *Rafflesia patma* population was obtained using Principal Component Analysis (PCA) with software PAST3 (Trianto & Purwanto 2020). PCA analysis was carried out to determine the physical factors that had the most influences based on the points of *R. patma*, including temperature, humidity, light intensity, and soil pH. The PCA results will show the factor that most influences the abundance of *R. patma*.

RESULTS AND DISCUSSION

Population structure of *Rafflesia patma*

The results of the study found that there were 114 individuals of *R. patma* in several research areas in Pananjung Pangandaran Nature Reserve, including Gua Parat (3 individuals), Badeto (48 individuals), Cilegon (13 individuals), Curug Leutik (38 individuals), and Pasir Putih (12 individuals) (Figure 2).

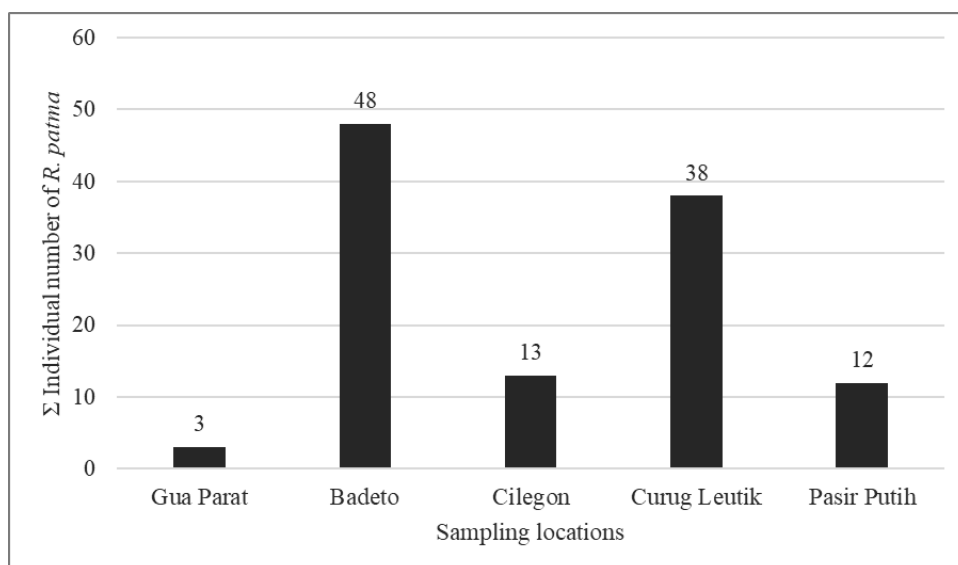


Figure 2. The number of *Rafflesia patma* individuals in the research area in Pananjung Pangandaran Nature Reserve.

The number of individuals found varied in each region and did not show a uniform trend in the number of individuals. This is due to the presence of different habitat conditions. The highest number of *R. patma* individuals was in the Badeto area and the lowest was in the Gua Parat area. Mursidawati & Irawati (2017) report that Gua Parat is one of the areas that are very close to human activities. This area is around the entrance gate of the nature reserve (<10 meters). The forest in this area is already fragmented by footpaths that are made to facilitate access to beaches or other tourist areas. Almost every day visitors pass through the tourist area. The population of *R. patma* in this area is found on the left and right of the road to the beach. Some of them grow slightly into the forest, but some of them grow right on the side of roads that are disposed of being walked on and trampled by visitors. Compared to the Badeto area (80-130 m asl) with the highest individual of *R. patma*, this area is one of the areas with a good condition, although it is often passed by visitors. The frequency of visitor arrivals in the

Badeto area is not as intensive as in Gua Parat and Pasir Putih, because the road to this area is quite far. This area is often visited by visitors, especially during the holiday season or weekends (Mursidawati & Irawati 2017). As additional information, Badeto Forest still has a dense population of vegetation (dense) with multi-layered strata. The buds or flowers of *R. patma* are scattered along the river to the waterfall directly into the sea.

Based on the results, the number of *R. patma* individuals observed was higher than the study of Lestari & Rianto (2017) which consisted of 47 *Rafflesia* individuals (67% alive and 33% dead) at the Rhino-Camp Sukaraja Atas Bukit Barisan Selatan National Park (TNBBS), Susatya (2011) which consisted of 59 individuals, and Suwartini et al. (2008) consist of 57 individuals. Compared to previous studies at the same research location in Pananjung Pangandaran Nature Reserve, the results obtained were less than Mukmin & Hikmat (2009) consisting of 312 individuals of *R. patma*. This population decrease is due to the existence of illegal logging and hunting of wild animals in the habitat of *R. patma* which is carried out regularly. This condition resulting in the disruption of the habitat of *R. patma* which leads to the destruction of its natural habitat.

The percentage mortality of *R. patma* found in this study consisted of 54 individuals or 47.37% of dead buds, 28 individuals or 24.56% of live buds, and 32 individuals or 28.07% of rotten blooms (Figure 3, 4). Compared with the research of *R. patma* in other areas that have been carried out, the mortality rate in this study was classified as moderate, especially in the percentage of mortality *R. patma* before the flowers bloom. The mortality rate of *R. patma* in the Bojonglarang Jayanti Nature Reserve is included in the low mortality category, which is only around 12.22% (Ali et al. 2015). Susatya (2011) revealed that the *Rafflesia* mortality rate is low if it is in the range of 20-37% of deaths, and high if it is in the range of 80-100% of deaths.

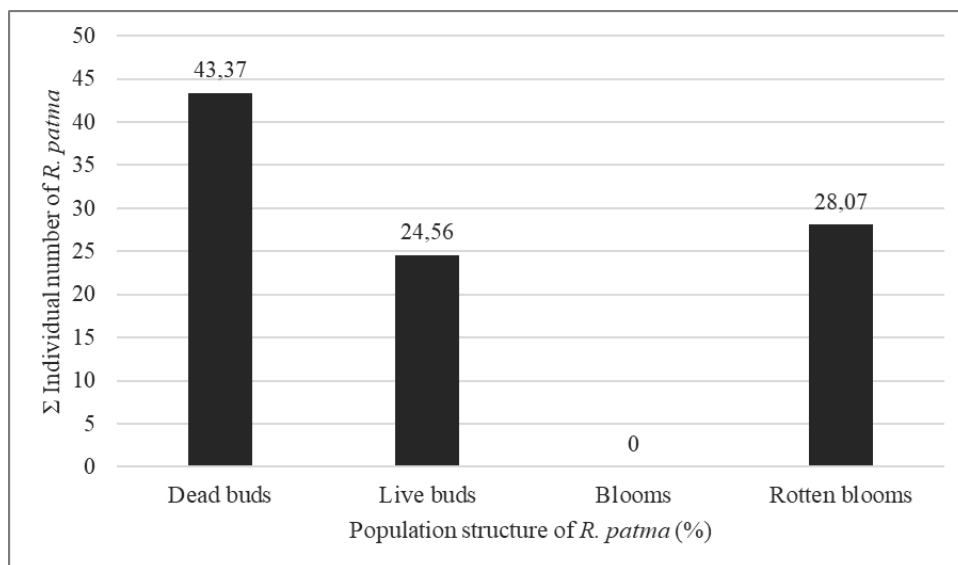


Figure 3. The population structure of *Rafflesia patma* in Pananjung Pangandaran Nature Reserve (Januari-April 2020).

In this study, the individual conditions of *R. patma* that died were different. The perigon condition of *R. patma* was black indicates that the knob has been blooming for more than one week and finally rot (Figure 4). Lestari & Rianto (2017) suggested that the mortality that occurred in the *Rafflesia* flower was caused by several factors, such as the disturbance of wild animals or humans and the inadequate distribution or distribution of nutrients from the host to the *Rafflesia* knob. The highest mortality rate was on knobs less than 3 cm in diameter, whereas most knobs with a size of > 16



Figure 4. Condition of *Rafflesia patma* population: A. Dead buds, B. Live buds, and C. Rotten blooms.

cm were able to survive (Nais 2001). The mortality of *Rafflesia* knobs generally varied from 60% to 90% (Sofiyanti et al. 2007). Furthermore, Ramadhani et al. (2017) show that 2-3 *Rafflesia* knobs die before bloom. Throughout the year, *R. patma* is always present and is found in various phases of development, from the bud (knob) phase to fruit (Mursidawati & Irawati 2017).

Distribution pattern of *Rafflesia patma*

In an ecosystem, there are three basic patterns of distribution of a species that has been recognized, namely: random, clustered, and uniform (Ludwig & Reynolds 1988). To identify the spatial distribution pattern of a species, various distribution indices can be used, including the ratio of variance and mean, clumping index, green coefficient, standardized Morisita index. One index that is often used is the Morisita index because the results of simulation research prove that this index is the best method for measuring the spatial distribution pattern of an individual independent of population density and sample size (Morisita 1962). The standardization of the Morisita index is an improvement of the Morisita index by placing an absolute scale between -1 to 1. The distribution pattern of organisms in a region varies widely, including organisms from members of the Rafflesiaceae family.

Members of the Rafflesiaceae family are entirely parasitic plants, including *Sapria* and *Rhizanthus* (Nikolov & Davis 2017). This clan is popular in tropical areas, especially Southeast Asia including the Philippines and Thailand. *Rafflesia* can be found both in primary forests and secondary forests. Its spread is highly dependent on the spread of its host tree, namely *Tetra stigma*. In general, *Rafflesia* can be found in hosts that live near water sources. Land altitude and slope where it grows varies greatly depending on the species ranging from 5 m asl (*R. patma* in West Java) to 1400 m asl (*R. pricei* in Sabah and *R. rochusenii* in West Java). The spread of *Rafflesia* in Indonesia covers the regions of Sumatra, Kalimantan, and Java (Mursidawati & Irawati 2017), one of which is in the Pananjung Pangandaran Nature Reserve.

The population of *R. patma* in this study was found in five observation areas in Pananjung Pangandaran Nature Reserve, namely Gua Parat (2.63%), Badeto (42.10%), Cilegon (11.40%), Curug Leutik (33.33%), and Pasir Putih (10.53%). Mursidawati & Irawati (2017) suggested that the population of *R. patma* in Pangandaran Nature Reserve spread over several very specific areas. *R. patma* was found growing on hosts along the river. Some of them grow some distance from the river. In the Pasir Putih location, generally, the flowers found, both medium and past flowering, are male. The same thing was also found in Upper Badeto. The dominance of male flowers in the Pangandaran area has also been reported by Hidayati et al. (2000), that the

Table 1. Distribution pattern of *Rafflesia patma* in Pananjung Pangandaran Nature Reserve.

Location	Σxi	Σxi^2	Id	Mu	Mc	Ip	Distribution
Nature reserve	114	4070	1,535	0,97	1,06	0,56	Clustered

Captions:

- Σxi = Total number of individual species on i-th plot
- Σxi^2 = Total quadrate of number of individual species on i-th plot
- Id = Morisita Index
- Mu = Morisita index on uniform pattern of distribution
- Mc = Morisita index on clustered pattern of distribution
- Ip = Standardized of Morisita Index

area around waterfall and Rajamantri appears to have several mixed colonies between male and female.

According to the population level, the distribution pattern of *R. patma* in Pananjung Pangandaran Nature Reserve is clustered with the Morisita index value > 1 (Table 1). Brower et al. (1990) explained that the distribution patterns of species in a population can be divided into three categories, namely random, uniform, and clustered. It is said to be clustered if the Morisita index value (Id) > 1. This is in accordance with Bullock et al. (2008) statement that plant populations in nature are more often spread out in groups.

The distribution pattern of *R. patma* is related to the system and its physiological conditions in a region. Mursidawati & Irawati (2017) and Pelsler et al. (2013) explained that *Rafflesia* reproduces with seeds whose distribution is assisted by wind, water, and animals, including insects, hedgehogs, squirrels to wild boar, which are still estimated and need further research. This is supported by the data that the *Rafflesia* fruit rind is hard and tough, it can only be cracked by these animals. Physiographic conditions are also thought to be able to significantly influence the distribution of *Rafflesia*. This is supported by the research of Mukmin & Hikmat (2009) that *R. patma* in the Pananjung Pangandaran Nature Reserve is found mostly near the Cikamal River and Tributary at the closest distance of 0.50 m from the water source. Other factors that also affect the distribution of *R. patma* are soil conditions or edaphic factors. Soil is a medium for the growth and development of plants. The soil conditions that directly affect plants are fertility. Indicators of soil fertility, among others, are seen from the content of humus or organic matter, nutrients, soil texture and structure, and the amount of water in the soil's pores (Triana et al. 2017).

Environmental conditions

The success rate of an individual to be able to live (grow and reproduce) is influenced by physical or abiotic environmental factors. The results showed that the average temperature at the location where *R. patma* was found in the Pananjung Pangandaran Nature Reserve was in the range of 28.42 °C, humidity 84.52%, soil pH equal to 5.72, and light intensity of 1.080,5 lux. (Table 2).

The abiotic conditions obtained in this study were included in the normal range to affect the growth of *R. patma*. Ramadhani et al. (2017) stated that the abiotic conditions of temperature (25-29 °C), 90% humidity and acidic pH (5.5) were able to guarantee the breeding and growth of *Rafflesia* in Rhino-Camp Sukaraja Atas Bukit Barisan Selatan National Park (TNBBS). Simamora et al. (2017) also reported that air humidity (76-84%) and air temperature (19.5-24.4 °C) were able to support the growth of *Rafflesia* in Batang Gadis National Park, North Sumatra. Meanwhile, the *Rafflesia* species

Table 2. Abiotic conditions of the Pananjung Pangandaran Nature Reserve.

Locations	Abiotic Factors			
	Temperature (°C)	Humidity (%)	Light intensity (lux)	pH
Gua Parat	28	84,8	1.013	5,54
Badeto	29	80,6	1.081,6	5,8
Cilegon	27,4	86,4	1.052,8	5,58
Curug Leutik	28,2	82,4	1.120,6	5,58
Pasir Putih	29,4	88,4	1.134,6	6,1
Total	142	422,6	5.402,6	28,6
Average	28,4	84,52	1.080,5	5,72

found by Lestari et al. (2014) in Meru Betiri National Park grew in temperature conditions of 25-29 °C with a humidity of 79-96%.

Data of abiotic environmental conditions with the number of *R. patma* individuals in five research areas in Pananjung Pangandaran Nature Reserve were further analyzed using the Principal Component Analysis (PCA) method with PAST3 software. The purpose of this analysis is to see the dominant character that affects the variation of the individual grouping pattern of *R. patma*. The correlation analysis between groups yielded the Eigenvalue and % Variance shown in Table 3.

Table 3. Result Eigenvalue and % Variance.

PC	Eigenvalue	% Variance
1	2451.77	99.595
2	9.57712	0.38904
3	0.398346	0.016181
4	0.0028106	0.00011417

The main component that can be used and represents the data in the analysis process Principal Component Analysis (PCA) is the value on PC1. A study by Bascos et al. (2019) revealed that the number of main components that can be used or is considered sufficiently representative, that is if the % variance produced is more than 70%.

The results of the analysis showed that the abiotic environmental conditions could affect the distribution patterns and abundance of the *R. patma* population in an area. Grouping also occurs because of the role of each character being analyzed. According to Jolliffe (2002) principal component analysis is an analytical technique that is often used in taxonomic research because this technique can identify the role of each character in each formed group.

The results of the principal component analysis are shown in the PCA diagram (Figure 6). Based on the results of the PCA analysis, results were obtained that supported grouping based on cluster analysis. Based on the four abiotic environmental conditions analyzed, the most dominant character in influencing the distribution patterns and population structure of *R. patma* in Pananjung Pangandaran Nature Reserve is light intensity. This can be seen from the length of the resulted line (Figure 5), and the picture of Loading Plot of Component 1 (Figure 6) produced.

Light intensity greatly affects the level of air temperature in an area. The data found in this study; many light intensities occur due to the

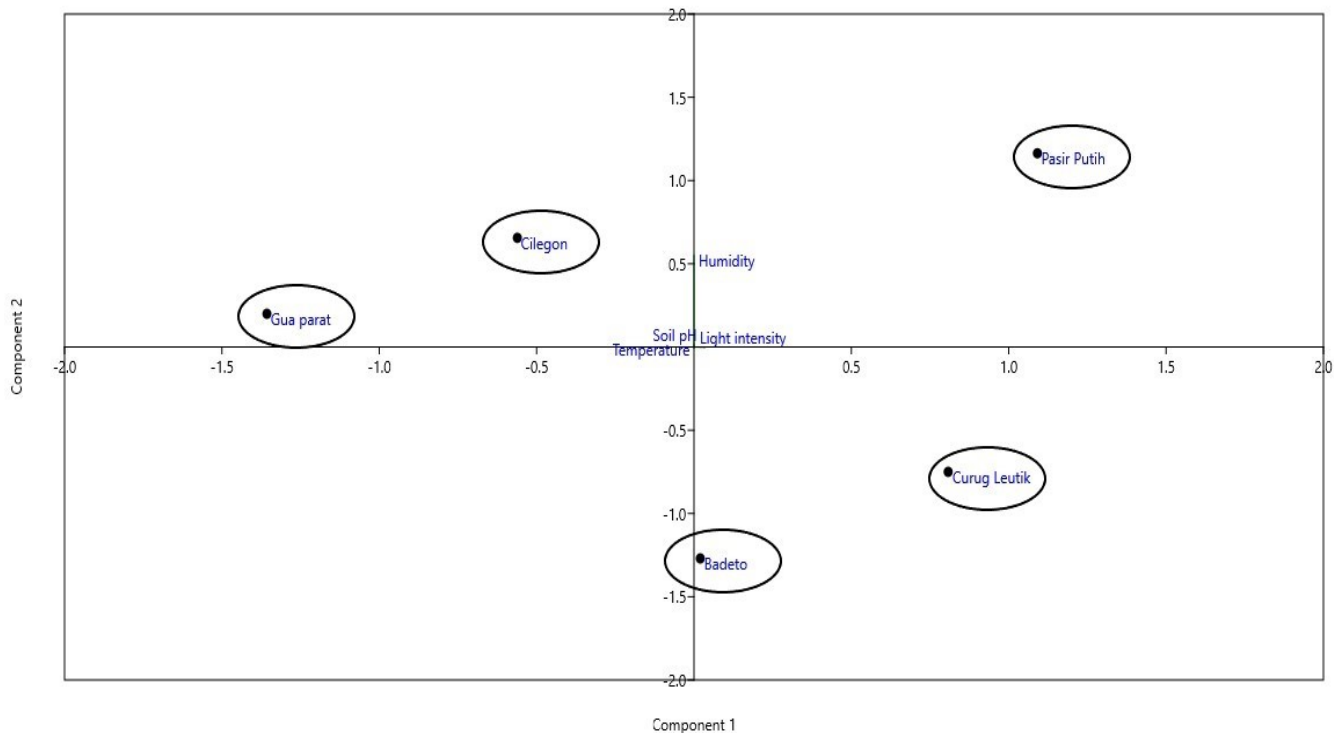


Figure 5. Biplot analysis on Principal Component Analysis (PCA) of abiotic factors that affect the abundance of *Rafflesia patma*.

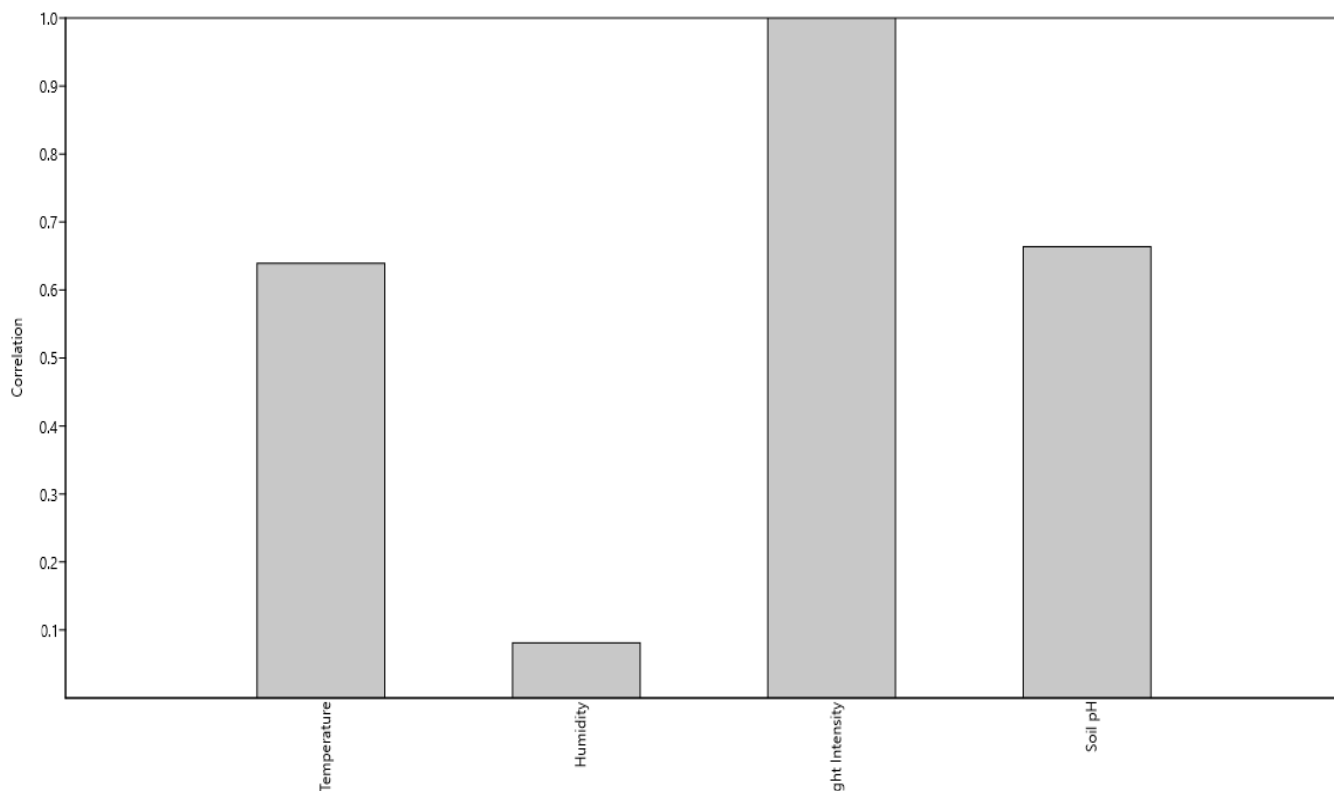


Figure 6. The Loading Plot of Component 1

openness of the forest canopy which can affect the level of sunlight reaching the forest floor. Sunlight that enters the forest floor can give a negative impact on *Rafflesia* survival. Exposure to the forest floor directly causes excessive evaporation and the soil surface becomes too humid so that the *Rafflesia* knob becomes dry and does not support *Rafflesia* growth (McNaughton & Wolf 1990; Banerjee & Linn 2018).

CONCLUSION

There were 114 individuals of *Rafflesia patma* found in Pananjung Pangandaran Nature Reserve, including 54 dead buds, 28 live buds, 32 rotten blooms, and no blooming flowers were found. The distribution pattern of *R. patma* in Pananjung Pangandaran Nature Reserve is clustered with the Morisita index value (Id) > 1. The result of PCA analysis also showed that light intensity became the most affecting abiotic environmental factor on the growth of *R. patma*.

AUTHORS CONTRIBUTION

B.A.A. designed the research, collected and analyzed the data. B.A.A., S.H., and P wrote, revised, and approved the manuscript. S.H. and P supervised all the processes.

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CONFLICT OF INTEREST

The authors state there is no conflict of interest.

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