International Journal of Life Science Research Archive

ISSN: 0799-6640 (Online)

Journal homepage: https://sciresjournals.com/ijlsra/

(RESEARCH ARTICLE)

Check for updates

Ecological study of titan arum [*Amorphophallus titanum* (Becc.) Becc. Ex arcang] in BOVEN LAIS protected forest, north Bengkulu regency

Wahyudi Arianto *, Wiryono and Guswarni Anwar

Department of Forestry, Faculty of Agriculture, University of Bengkulu, JL. WR Supratman Kota Bengkulu 38122, Indonesia.

International Journal of Life Science Research Archive, 2023, 04(02), 092–108

Publication history: Received on XX Month 2021; revised on 08 June 2023; accepted on 11 June 2023

Article DOI: https://doi.org/10.53771/ijlsra.2023.4.2.0063

Abstract

Amorphophallus titanum (Becc.) Becc. Ex Arcang), known as Titan Arum, is the only plant that has the highest inflorescence (1.6 m – 2.5 m) in the world. This species is classified as an endemic plant since it only found in forest areas on the island of Sumatra. According to the IUCN Red List of Threatened Plants the 2021 edition, *A. titanum* is Endangered (EN). The problem faced by *A. titanum* at this time is the habitat destruction, due to area conversion.

The research on the ecological aspects of *A. titanum* includes population conditions, plant structure and composition, distribution patterns, soil, and climate data. was conducted in the Boven Lais Protected Forest, North Bengkulu Regency, Bengkulu Province. The vegetation analysis method were used to obtain data on the plant structure and composition of the vegetation (importance index) of *A. titanum*, and the habitat's abiotic (physical conditions). Determining the plant's distribution (spatial distribution) using the Morisita Spread Index method.

The results showed that the population of *A. titanum* in the research area was 20 individuals, dominated by tillers with petiole diameters ranging from 0-5 cm. The entire population was found in the vegetative phase. The distribution pattern of *A. titanum* was clustered. The structure and composition of the vegetation in the *A titanum* habitat comprises 25 species belonging to 18 families. The tree-level vegetation was dominated by *Elateriospermum tapos*, the pole level was dominated by *Ficus hispida* L.f., and the seedling-level vegetation was dominated by *Selaginella plana* (Desv. ex Poir.)

The soil type in the A. *titanum* habitat was red-yellow podzolic with sandy clay loam texture, acid soil with a pH of 4.79, medium N (nitrogen) content (0.33%), high C (carbon) content (3.7%) and very low P (phosphorus) content and high CEC.. The habitat was at an altitude of 433 m asl -459 m above sea level, with a slope of 45-60 degrees. Generally, the location where the *A. titanum* grew twas in a steep area. The average humidity in the habitat was 92.87%, the average light intensity was 647.19 lux, and the average temperature was 23.09°C

Keyword: Ecology; *Amorphophallus titanum*; Population; Habitat; Protection forest

1 Introduction

Amorphophallus titanum (Becc.) Becc. Ex Arcang), also known as Titan Arum, has the highest inflorescence in the world. The size of *A. titanum* ranges from 1.6 to 2.5 m [1, 2, 3]. This endemic plant to Sumatra [2, 4] was discovered by Dr Odoardo Beccari in 1878 in the Anai Valley area, West Sumatra [5].

A. titanum naturally spreads throughout the Sumatran rainforest as an undergrowth on calcareous soils, but this plant is also found in open areas, secondary forests, roadsides, riverbanks, or on forest edges. It has three distinct life cycles:

* Corresponding author: Arianto Wahyudi

vegetative, dormant, and generative. The vegetative cycle is mainly for growing tuber which can reach up to 100 kg in weight. This cycle begins at the beginning of the rainy season with the production of a single large leaf and lasts for 6-12 months, followed by a dormant cycle for 1-4 years before entering the flowering cycle, which is generally irregular [6,7,5].

A. titanum has been designated as a protected plant in Indonesia according to Government Regulation No. 7/1999 (Appendix to PP. No. 7/1999), and it is categorized as Endangered (EN) in the IUCN Red List of Threatened Plant 2021 edition due to the decline in a natural population, which is now ranging from 71 to 999,303 individuals [8]. The decline in *A. titanum* population in forest areas in Bengkulu can be ascertained due to the conversion of forest to other land use types. Based on data from the Bengkulu Province Forestry Service, forest area encroachment occurs in production forests, protected forests, and conservation forests. Based on the interpretation of satellite imagery up to 2012 and the ETM lansat, the total forest area in Bengkulu Province is 924,600 ha, of which 74.84% (692,000 ha) is forested, and 25.16 % (232,700 ha) has been converted to the non-forest [9]. The form of encroachment in North Bengkulu and Rejang Lebong Regencies is generally for coffee plantations. Habitat destruction is a major threat to the survival of this plant species in nature.

Since 1878, some international researchers have carried out intensive research on *A. titanum*. In general, research on *A. titanum* is carried out on a greenhouse scale in botanical gardens worldwide, such as in Germany, Italy, America, Japan, Australia, and other countries. All research materials in the form of *A. titanum* tubers and fruit were from plant collections taken since 1887 in the Sumatran forest [2]. Researches that have been carried out on a botanical garden greenhouse and laboratory scale include studies of morphology, anatomy, vegetative and generative growth/spathe and spadic [2,10,11,12,13,14,15], thermogenesis [16], flower odor analysis [17], germination [18], micropropagation [19], estimation of genetic diversity in several populations [20], Flavonoids and xanthones [21], review paper pollinators in genus Amorphophallus [22].

A. titanum studies conducted in its natural habitat are very few. Research on natural habitats has been carried out, among others[23] in West Sumatra in 1994-1995, by [1] on the diversity of carrion flower species and their distribution in Bengkulu [4] in several regencies. location in the Kepahiang area, [24] regarding the Potential of Titan Arum (*Amorphophallus* Bl.) in Bengkulu Province as a Mannan Source. and [25] located in Air Selimang, Tebat Monok and Kelapa Siring. Based on preliminary studies, it is clear that there is a trend of decreasing population in nature [4,25]. If this condition is allowed to continue, it will result in the existence of this species being threatened.

Despite *A.titanum* status as a rare and protected species, and the threats from illegal logging and mining activities, the conservation efforts of *A. titanum* are minimal. The field research on *A titanum*, especially its habitat ecological aspects, is rarely conducted. Therefore this study was done to obtain ecological data of *A. titanum* as the basis for the conservation of the plant in their natural habitat.

2 Material and methods

2.1 Location of the study area

This research was conducted in the Boven Lais Protected Forest, North Bengkulu Regency, Bengkulu Province. Determination of the location as a sub-population is based on the results of previous studies.

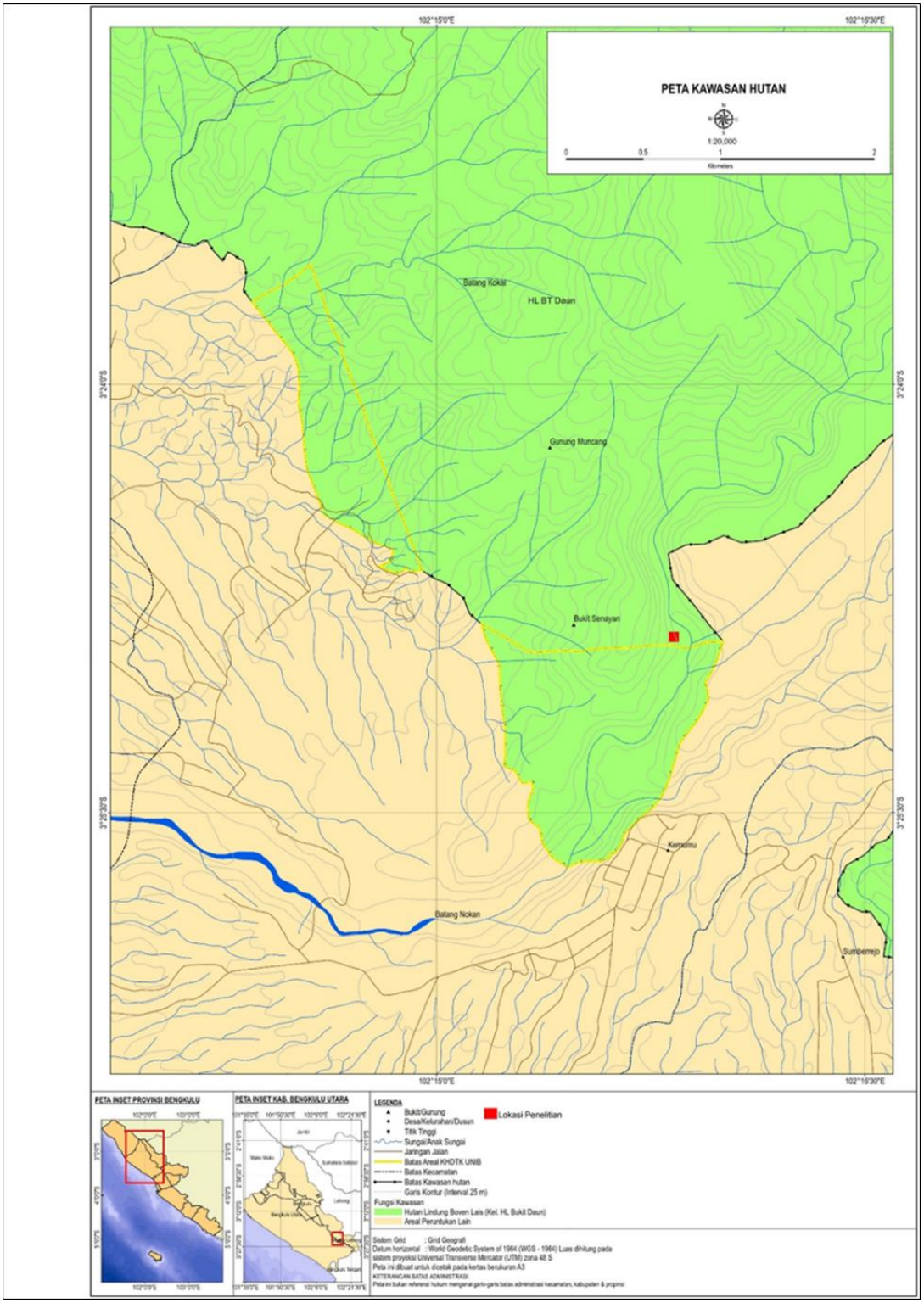

Figure 1 Map of the research location in the Boven Lais Register 41 Protected Forest, North Bengkulu Regency

2.2 Method of collecting data

2.2.1 Population size and distribution pattern of A. titanum in Bengkulu

The population of *A.titanum* was sampled on a plot measuring 20 m x 20 m. Determination of the distribution pattern of *A. titanum* was carried out using the Morisita Spread Index method [26]. Determination of the distribution was carried out with the following steps:

- Calculating the Morisita dispersion index,
- Standardization

2.2.2 Vegetation structure and species composition of A. titanum habitat

The study of the habitat of *A. titanum* was carried out using a purposive sampling method with a plot area of 0.36 ha and a square shape taken on a plot that indicated the presence of *A. titanum*. The laying of plots and sub-plots were carried out in a nested plot. Vegetation grouping categories and area of measuring plots are presented in Table 1.

Table 1 Vegetation grouping categories, area of measuring plots and total number of plots

Category	Criteria	Size of the plot
Tree	Dbh ø>20 cm	20 m x 20 m
Pole	Dbh ø 10-19 cm	10 m x 10 m
Sapling	height > 1.5 m Dbh ø <10 cm	5 m x 5 m
Seedling	Height <1.5 m	2 m x 2 m

Description: Diameter at breast height (Dbh)

2.2.3 Abiotic data collection

Soil data was collected by taking soil samples at 0-20 cm depth in each observation plot [27]. The physical and chemical properties of the soil were analyzed in the soil science laboratory at the University of Bengkulu. Data on climatic conditions were collected by measuring temperature on a wet and dry bulb thermometer, measuring the relative humidity and light intensity [28]. Data collection of altitude and slope of the place was done using GPS (Garmin 76CSX) and Shunto clinometer.

2.3 Species identification

Identification of *A. titanum* species and other plants was carried out directly in the field with the help of field guides. The specimen of unidentified plants were taken and then identified in the Bengkulu University Herbarium (HUB).

2.4 Data analysis

The distribution pattern of *A.titanum* in the plant community was determined using the Morisita index calculated as follows:

$$\text{Id} = n\frac{(\sum x^2 - \sum x)}{(\sum x)^2 - \sum x}$$

Where
Id : the Morisita index that reveals the dispersion pattern,
N : total number of plots
$\sum x^2$: The sum of the squares of the total individuals of a species in the community
$\sum x$: The total number of individuals of a species in the community

Furthermore, the Chi-square test was carried out using the equation:

2.4.1 Degree of uniformity:

Degree of Uniformity

$$\text{Mu} = \frac{(x^2 0.975 - n + \sum x_i)}{(\sum x_i) - 1}$$

Where,
Mu : Degree of uniformity
$x^2 0.975$: Value of Chi-square from the table with a degree of freedom (df) of (n-1), confidence interval (CI) of 97, 5%
$\sum x_i$: The sum of number of individuals of the ith species

n : Number of plots

Degree of grouping

$$Mc = \frac{(x^2 0.025 - n + \sum x_i)}{(\sum x_i) - 1}$$

Where
Mc : Degree of grouping
$x^2 0.025$: Chi-square value from the table with df of (n-1), CI of 2, 5%
$\sum x_i$: Sum of number of individuals of the ith species
n : Number of plots

The standard Morisita degree (Ip) was calculated by using the four equations under one of the following conditions:

If Id ≥Mc> 1, then Ip was calculated as follows:

$$Ip = 0.5 + 0.5 \left(\frac{Id - Mc}{n - Mc}\right)$$

If Id >Mc≥ 1, then Ip was calculated as follows:

$$Ip = 0.5 \left(\frac{Id - Mc}{Mc - 1}\right)$$

If Id >Mc> 1, then Ip was calculated as follows:

$$Ip = 00.5 \left(\frac{Id - Mu}{Mu - 1}\right)$$

if 1 >Mu> 1, then Ip was calculated as follows:

$$Ip = 0.5 + 0.5 \left(\frac{Id - Mu}{Mu}\right)$$

The standard Morisita degree (Ip) has an interval of -1.0 to 1.0 with a 95% confidence level at the limits of 0.5 and -0.5. The Ip value is used to show the tendency of the distribution pattern of corpse flower plant species in the study area with an interval of value:

- Ip = 0, random distribution pattern
- Ip>0, a clustered distribution pattern
- Ip <0, a uniform distribution pattern (uniform)

The structure and species composition of vegetation was described using the importance value index [29], calculated using the following formula:

$$\text{Density} = \frac{Number\ of\ individuals\ of\ a\ species}{Area\ of\ Sample\ Units}$$

$$\text{Relative Density (RD)} = \frac{Density\ of\ a\ species}{Total\ density\ of\ species} \text{ X } 100\%$$

$$\text{Frequency} = \frac{Number\ of\ plots\ found\ a\ species}{total\ number\ of\ plots}$$

$$\text{Relative Frequency (RF)} = \frac{Frequency\ of\ a\ species}{Total\ frequency} \text{ X } 100\%$$

$$\text{Domination} = \frac{Number\ of\ basic\ planes\ of\ a\ species}{area\ of\ all\ plot}$$

$$\text{Relative Dominance (RDo)} = \frac{Domination\ of\ a\ species}{Domination\ of\ all\ species} \text{ X } 100\%$$

Importance Value Index (Trees and Poles) IVI = RD + RF + RDo

Importance Value Index (Seedlings, Saplings, Undergrowth) IVI= RF + RF

The diversity of plant species in the *A. titanum* observation plot, the Shannon-Wiener diversity index, was used [26]. The diversity index of the Shannon-Wiener is as follows

$$H' = \sum_{i=1}^{S} [\left(\frac{ni}{N}\right) Ln \left(\frac{ni}{N}\right)]$$

Where
H' = Shannon-Wiener diversity index
S = Number of species
Ni = Number of individuals of the i^{th} species
N = Total number of individuals of all species

The distribution of species abundance was determined using the Evenness index [26] as follows::

$$EI = \frac{H'}{\ln(S)} = \frac{In(N1)}{In\ (No)}$$

$$Ni = e^{1.33} = 3.78$$

Where:
EI= Evenness index
S= Number of Species

The interspecific association for the case of many species was determined using the following equation:

$$\sigma_T^2 = \sum_{i=1}^{S} pi(1 - pi)$$

Where: pi =ni/N

$$S_T^2 = \frac{1}{N} \sum_{j=1}^{N} (T_j - t)^2$$

T= average number of species per sample

Then, the variance ratio (VR) was calculated.

$$VR = \frac{S_T^2}{\sigma_T^2}$$

VR is an index of association between all species. If VR=1 (no association), if VR>1 (all species show positive association) and if VR<1 (negative association)

If the value of W lies at the limit of the chi-square distribution with 90% probability, then accept the hypothesis that there is no s bpecies association

$X^2 0, 5N<W<X^2 0,95N$

Community similarity analysis was carried out using Ward's minimum variance method [30] with the help of Minitab 17 software version 17.3.1.

3 Results and discussion

3.1 Population size and structure of *A. titanum*

Twenty individuals of *A titanum* were found in 3 study plots in the Boven Lais Protection Forest, all were in the vegetative phase. Most of them (15 individuals) had a petiole diameter of 0-5 cm (Figure 2). Only three individuals had stem diameters of 18-23 cm. The diameter class distribution shows that the *A.titanum* population as in the early stages, indicated by the many and indicated by small individuals. The populations found were in the vegetative phase, and no surviving generative phase was found. The generative phase found has withered and decayed and could not be observed clearly. It was estimated that this flower bloomed two months before the observation.

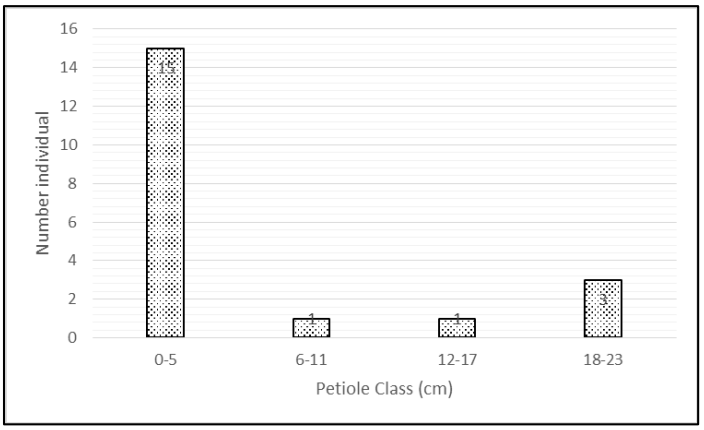

Figure 2 Number of individuals of *A. titanum* by Petiole class

The population size of *A. titanum* in this study was smaller than that at Air Ketapang, Bukit Jufi, Datar Lebar Waterfall, i.e., 34 individuals consisting of 12 adults and 22 juveniles [4]. More individuals were found by [25] in 3 locations (Palak Siring, Tebat Monok and Air Selimang), i.e., 49 individuals, but the distribution pattern of *A titanum* found in both studies was the same.

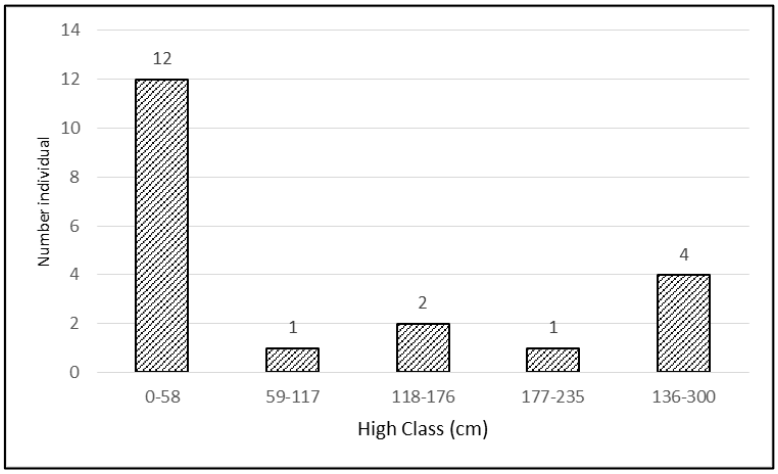

Figure 3 Height class of A. *titanum* "stem"

The small number of individuals with stem diameters greater than 15 cm may be due to the relatively low biotic potential of *A.titanum* and habitat disturbance either naturally or due to humans (stepping on and being slashed with machetes) relatively high.

Because only a few individualsreach the adult stage, only a few individuals will produce flowers, and consequently, the survival of *A. titanum* is in jeopardy.

According to "stem" height class, the highest number of individuals found was height class 0-58 cm, i.e., 12 individuals (Figure 3). The highest height of the *A. titanum* recorded was 277 cm.

Figure 4 The vegetative phase of *A. titanum* was found at the research site (Boven Lais Protected Forest).

3.2 Spatial distribution of *A. titanum*

The Morisita index showed that the distribution pattern of A. *titanum* was clustered with a standardized Morisity index (Ip) of 0.031. This distribution pattern indicates that the presence of an individual at one point will increase the probability of the presence of the same individual at another nearby point [31]. The same result was reported by [4] and [25].

Field observations indicate that this clustered distribution is probably caused by gravity and the water flow on the forest floor, which carries *A. titanum* seeds to the bottom. Several factors cause the spatial distribution pattern of the community, namely: (1) vectorial factors, which are caused by external environmental forces (e.g., wind, water flow and light intensity), (2) reproductive factors, caused by reproductive modes (cloning and generational offspring), (3) social factors are innate behavior (territorial behavior), (4) coactive factors are the result of intraspecific interactions (competition), and (5) stochastic factors are the result of random variations from previous factors (vectorial factors, reproductive, social and coactive) [32].

Some experts assume that the spread of *A. titanum* is assisted by hornbills [2,4]. Their thoughts are inaccurate as,based on the observations of flowers that have already produced fruit other experts did not find any activity of hornbills as the dispersal of *A. titanum* seeds. This opinion is supported by [33] and [34] findings that plant species used as food sources by the six species of hornbill found in Sumatra are *Oncosperma horridum* (Arecaceae)*, Litsea* spp (Lauraceae)*, Aglaia spectabilis, Chisocheton ceramicus (*Meliaceae*), Horsfieldia tomentosa, Myristica elliptica (*Myristicaceae*), Sterculia sp (*Sterculiaceae*)* and none of the literature mentions the *A. titanum* flower as a source of food of hornbill. Ecologically, the hornbill is a bird that lives in the upper forest canopy and never on the forest floor.

3.3 Vegetation structure and species composition of A*. titanum* habitat

3.3.1 Trees

Twenty five species of trees belonging to 18 families were found in the study site (Table 2). The Shannon-Wiener diversity index ('H') was 2.7, which could be categorized as medium. The 'H' value is determined by species richness and evenness, (and the species richness is largely determined by the plot size [26]. One of the problems with diversity measures is that sample size greatly affects species richness [35].

The tree-level vegetation was dominated by *Elateriospermum tapos* Blume, with an IVI of 92%, followed by *Polyalthia lateriflora* (Blume) Kurz, with an IVI of 17.03%.

Table 2 Importance value index (IVI) of tree species in *A.titanum* habitat in Boven Lais Protected Forest

NO	Species	Family	RD (%)	RF (%)	RDo (%)	IVI (%)
1	*Elateriospermum tapos* Blume	Euphorbiaceae	35.71	21.21	35.94	92.87
2	*Polyalthia lateriflora* (Blume) Kurz	Annonaceae	2.38	3.03	11.62	17.03
3	*Cephalomappa malloticarpa* J.J Smit	Euphorbiaceae	4.76	6.06	4.43	15.25
4	*Quercus* sp	Fagaceae	4.76	6.06	2.74	13.56
5	*Urophyllum arboreum* (Reinw.ex Blume) Koord	Rubiaceae	2.38	3.03	5.32	10.73
6	*Ficus drupacea* Thunb.	Moraceae	2.38	3.03	4.43	9.84
7	*Bhesa paniculata* Arn.	Celastraceae	2.38	3.03	4.43	9.84
8	*Aporosa frutescens* Blume	Phyllanthaceae	2.38	3.03	4.43	9.84
9	*Archidendron jiringa* (Jack) I.C. Nielsen	Leguminosae	2.38	3.03	3.82	9.23
10	*Diospyros sumatrana* Miq.	Ebenaceae	2.38	3.03	3.82	9.23
11	*Prunus arborea* (Blume) Kalkman	Rosaceae	4.76	3.03	1.33	9.12
12	*Syzigium* sp	Myrtaceae	2.38	3.03	2.57	7.98
13	*Tabernaemontana macrocarpa* Jak	Apocynaceae	2.38	3.03	2.41	7.83
14	*Claoxylon indicum* (Reinw.ex Blume)	Euphorbiaceae	2.38	3.03	1.97	7.38
15	*Mitrephora rufescens* Ridley	Annonaceae	2.38	3.03	1.97	7.38
16	Ficus sp	Moraceae	2.38	3.03	1.70	7.11
17	*Palaquium dasyphyllum* Piere ex Dubard	Sapotaceae	2.38	3.03	1.70	7.11
18	*Dipterocarpus* sp	Dipterocarpaceae	2.38	3.03	1.45	6.86
19	*Schefflera* sp.	Araliaceae	2.38	3.03	1.45	6.86
20	*Aglaia rubiginosa* (Hiern) Pannell	Meliaceae	2.38	3.03	1.22	6.63
21	*Aglaia teysmanniana* (Miq) Miq	Meliaceae	2.38	3.03	1.22	6.63
22	*Ryparosa caesia* Kurz ex King	Achariaceae	2.38	3.03	0.00	5.41
23	*Microcos florida* Burret	Malvaceae	2.38	3.03	0.00	5.41
24	*Lithocarpus korthalsii* (Endl) Soepadmo	Fagaceae	2.38	3.03	0.00	5.41
25	*Macaranga* sp	Euphorbiaceae	2.38	3.03	0.00	5.41

Description: Relative Density (RD), Relative Frequency (RF), Relative Dominance (RDo)

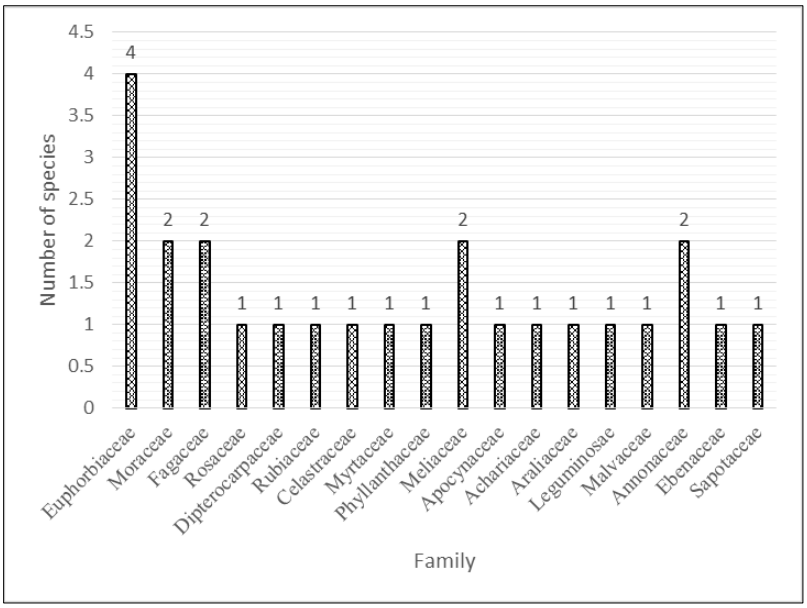

Figure 5 Number of tree species in *A.titanum* habitat

Euphorbiaceae had the highest number of (4 species), followed by Moraceae, Fagaceae, Meliaceae and Annonaceae, each having two species (Figure 5). The composition of species and families of trees show typical lowland forest vegetation.

Figure 6 The structure and species composition of vegetation at tree level in the Boven Lais Protected Forest

3.3.2 Poles

Eighteen species of poles belonging to 12 families (woody plants with DBH of 10-20 cm) were found in the study site (Table 3). *Elateriospermum tapos* Blume was the most dominant species with an IVI of 41.53%, followed by *Macaranga* sp with an IVI of 35.28%. *Cephalomappa malloticarpa* had the smallest IVI, which was 10.91%. Euphorbiaceae was the most dominant family, indicating that the vegetation was undergoing succession.

Table 3 Importance value index (IVI) of pole-level vegetation of *A. titanum* habitat in the Boven Lais Protected Forest

No	Species	Family	RD(%)	RF(%)	RDo(%)	IVI(%)
1	*Elateriospermum tapos* Blume	Euphorbiaceae	16.0	13.64	11.89	41.53
2	Macaranga sp	Euphorbiaceae	16.0	9.09	10.19	35.28
3	*Palaquium dasyphyllum* Pierre ex Dubard	Sapotaceae	8.0	9.09	8.80	25.89
4	*Phoebe grandis* (Nees.) Merr.	Lauraceae	4.0	4.55	7.06	15.60
5	*Baccaurea lanceolata* (Miq.) Muell. Arg.	Phyllanthaceae	4.0	4.55	6.34	14.88
6	*Artocarpus* sp	Moraceae	4.0	4.55	6.34	14.88
7	*Quercus* sp	Fagaceae	4.0	4.55	6.34	14.88
8	*Palaquium sumatranum* Burck	Sapotaceae	4.0	4.55	5.65	14.20
9	*Tabernaemontana macrocarpa* Jack	Apocynaceae	4.0	4.55	5.65	14.20
10	*Knema latifolia* Warb.	Myristicaceae	4.0	4.55	5.65	14.20
11	*Pouteria malaccensis* (C.B. Clarke) Baehni	Sapotaceae	4.0	4.55	3.83	12.38
12	*Aglaia teysmanniana* (Miq.) Miq.	Meliaceae	4.0	4.55	3.83	12.38
13	*Alstonia* sp	Apocynaceae	4.0	4.55	3.83	12.38
14	*Litsea* sp	Lauraceae	4.0	4.55	3.30	11.85
15	*Macaranga hullettii* King ex Hook.f.	Euphorbiaceae	4.0	4.55	3.30	11.85
16	*Pseuduvaria reticulata* (Blume) Miq.	Annonaceae	4.0	4.55	2.82	11.36
17	*Macaranga triloba* (Thunb.) Muell. Arg.	Euphorbiaceae	4.0	4.55	2.82	11.36
18	*Cephalomappa malloticarpa* J.J.Sm.	Euphorbiaceae	4.0	4.55	2.37	10.91

Description: Relative Density (RD), Relative Frequency (RF), Relative Dominance (RDo)

3.3.3 Saplings

Twenty two species of saplings were found, with the Shannon-Wiener diversity index of 2.93 (Table 4). *Ficus hispida* was the most dominant species with an IVI of 15.70%, followed by *Cephalomappa malloticarpa* with an IVI of 15.50%. Meanwhile, the smallest IVI was found in 10 species, namely 6.61% each (*Microcos florida*, *Procris pedunculata, Santiria oblongifolia, Harpullia arborea, Dysoxylum densiflorum, Alangium javanicum, Neonauclea lanceolata, Drypetes longifolia, Syzygium splenrutes*), and *Aporosa frutescens***.**

Table 4 Importance value index of vegetation at the sapling level of the *A.*' '*titanum*'s habitat in the Boven Lais Protected Forest

No	**Species**	**RD (%)**	**RF (%)**	**IV (%)**
1	*Ficus hispida* L.f.	11.36	4.34	15.70
2	*Cephalomappa malloticarpa* J.J.Sm.	6.82	8.68	15.50
3	*Elateriospermum tapos* Blume	9.09	4.34	13.43
4	*Urophyllum arboreum* (Reinw. ex Blume) Korth.	9.09	4.34	13.43
5	*Antidesma stipulare* Blume	6.82	4.34	11.16
6	*Urophyllum corymbosum* (Blume) Korth.	6.82	4.34	11.16
7	*Ficus subulata* Blume	4.55	4.34	8.89
8	*Turpinia spaherocarpa* Hassk.	4.55	4.34	8.89

9	*Claoxylon indicum* (Reinw. ex Blume) Hassk.	4.55	4.34	8.89
10	*Dichroa febrifuga* Lour.	4.55	4.34	8.89
11	*Myristica iners* Blume	4.55	4.34	8.89
12	*Iteadaphne confusa* Blume	4.55	4.34	8.89
13	*Microcos florida* Burret	2.27	4.34	6.61
14	*Procris pedunculata* (J.R. Forst. & G. Forst.) Wedd.	2.27	4.34	6.61
15	*Santiria oblongifolia* Blume	2.27	4.34	6.61
16	*Harpullia arbrea* (Blanco) Radlk.	2.27	4.34	6.61
17	*Dysoxylum densiflorum* (Blume) Miq.	2.27	4.34	6.61
18	*Alangium javanicum* (Blume) Wangerin	2.27	4.34	6.61
19	*Neonauclea lanceolata* (Blume) Merr.	2.27	4.34	6.61
20	*Drypetes longifolia* (Blume) Pax & K. Hoffm.	2.27	4.34	6.61
21	*Syzygium splendens* (Blume) Merr. & Perry	2.27	4.34	6.61
22	*Aporosa frutescens* Blume	2.27	4.34	6.61

Description: Relative Density (RD), Relative Frequency (RF)

3.3.4 Seedlings /undergrowth vegetation

The undergrowth vegetation comprised 25 plant species consisting of 21 families (Table 5), with 'H' of 1.80. The undergrowth vegetation was dominated by *Selaginella plana* with an IVI of 81.98%, followed by *Schismatoglottis calyptrata* with an IVI of 18.09%. *Drynaria sparsisora*, with an IVI of 8.60%. Nine species had the lowest and same IVI, namely 3.39%.

[25] who studied at the Bengkulu University Educational Forest also found that the undergrowth vegetation was dominated by S. *plana* with an IVI of 53.82%.

Table 5 Importance value index (IVI) of vegetation at the seedling/undergrowth level of *A. titanum* habitat in Boven Lais Protected Forest

No	Species	Family	RD(%)	RF(%)	IVI(%)
1	*Selaginella plana* (Desv. ex Poir.) Hieron.	Selaginellaceae	59.76	22.22	81.98
2	*Schismatoglottis calyptrata* (Roxb.) Zoll. & Moritzi	Araceae	9.76	8.33	18.09
3	*Drynaria sparsisora* (Desv.) Moore	Polypodiaceae	3.05	5.56	8.60
4	*Litsea* sp.1	Lauraceae	1.83	5.56	7.38
5	*Lindera* sp.	Lauraceae	3.66	2.78	6.44
6	*Ophiorrhiza junghuhniana* Miq.	Rubiaceae	2.44	2.78	5.22
7	*Endiandra rubescens* (Blume) Miq.	Lauraceae	1.83	2.78	4.61
8	*Enkleia malaccensis* Griff.	Thymelaeaceae	1.83	2.78	4.61
9	*Asplenium cuspidatum* Lam	Aspleniaceae	1.83	2.78	4.61
10	*Glycosmis pentaphylla* (Retz.) DC.	Rutaceae	1.22	2.78	4.00
11	*Diospyros* sp.	Ebenaceae	1.22	2.78	4.00
12	*Cyrtandra picta* Blume	Gesneriaceae	1.22	2.78	4.00
13	*Spatholobus* sp.1	Leguminosae	1.22	2.78	4.00

14	*Asplenium tenerum* G. Forst.	Aspleniaceae	1.22	2.78	4.00
15	*Ziziphus horsfieldii* Miq.	Rhamnaceae	1.22	2.78	4.00
16	*Calamus* sp.1	Arecaceae	1.22	2.78	4.00
17	*Friesodielsia acuminata* (Merr.) Steenis	Annonaceae	0.61	2.78	3.39
18	*Pternandra cordata* Baill	Melastomaceae	0.61	2.78	3.39
19	*Helicia serrata* Blume	Proteaceae	0.61	2.78	3.39
20	*Syzygium lineatum* (DC.) Merr. & L.M. Perry	Myrtaceae	0.61	2.78	3.39
21	*Macaranga* sp	Euphorbiaceae	0.61	2.78	3.39
22	*Drynaria sparsisora* (Desv.) Moore	Polypodiaceae	0.61	2.78	3.39
23	*Roureopsis emarginata* (Jack) Merr.	Connaraceae	0.61	2.78	3.39
24	*Coffea canephora* Pierre ex A.Froehner	Rubiaceae	0.61	2.78	3.39
25	*Cyathocalyx maingayi* Hook.f.& Thomson	Annonaceae	0.61	2.78	3.39

Figure 7 Seedling/underground vegetation in the *A. titanum* habitat

3.4 Diversity and evenness indexes

The Shannon-Wiener diversity index of tree to seedling ranged from 1.80 to 2.94, considered medium, while the evenness index ranged from 0.56 to 0.97, considered medium to high (Table 6).Species richness and species evenness are independent characteristics of biological communities that constitute their diversity. Evenness is the distribution of each species' abundance. The pole and sapling vegetation had almost a maximum evenness index indicating that each species had almost the same abundance. The evenness index of seedling or undergrowth vegetation was only 0.56, indicating that almost 50% of species had different abundance.

Table 6 Indexes of species diversity and evenness at the level of trees, poles and seedlings at the research site

Strata	Diversity Index	Evenness Index
Tree	2.67	0.83
Pole	2.71	0.94
Sapling	2.94	0.97
Seedling	1.80	0.56

3.5 Interspecific associations (many species)

The variant ratio calculation shows that all species in the Boven Lais Protected Forest had negative associations (Table 7). This result differed from [25] at the Air Selimang and Tebat Monok locations which showed positive associations for all species. This condition shows that , there is a dependence between species in the Air Seliman and Tebat Monok locations, and the use of the same resources is positive (Table 7).

Table 7 Community interspecific associations at 3 locations of *A.* ' '*titanum*'s habitat

No	Location	Index Association between all species (VR)	Conclusion	Description
1.	Boven Lais Protected Forest	0.66	There are negative associations among all species	This research
2	Air Selimang	1.59	There is a positive association among all species	Arianto *et al.*, 2019
3	Tebat Monok	3.78	There is a positive association among all species	Arianto *et al.*, 2019
4	Palak Siring	0.96	All independent species	Arianto *et al.*, 2019

Interspecific association among species occurs because those species choose or avoid the same habitat or habitat factors andhave common abiotic and biotic factor requirements [26]; they have an affinity for the other species. The association of plants is characterized by a relatively consistent floristic composition, relatively uniform physiognomy, and similar habitat.

3.6 Abiotic factors

The habitat of *A. titanum* in the Boven Lais Protected Forest is located at altitudes of 433 m - 459 m above sea level (asl), with slopes of 45-60 degrees, considered very steep.

3.6.1 Climatic conditions

Table 8 The environmental factors in the *A. titanum* habitat in the Boven Lais Protected Forest

Measurement point	Humidity (%)	Light Intensity (Lux)	Temperature (°C)
1	94.5	1870	23
2	94.7	1750	23
3	99	55,5	23
4	97	546	23
5	96	531	23
6	95	510	23
7	95	485	23
8	95	479	23
9	96	337	24.5
10	95	381	24
11	96	174	21.5
Average	95.75	647.14	23.09

The humidity measured in the corpse flower habitat ranged from 95% to 99%, with an average humidity of 95.75%, indicating that *A.titanum* likes high humidity. The same result was also reported by [25] in the *A. titanum* habitat in University of Bengkulu Educational Forest, which was 98%.

3.7 Soil

The *A.titanum* habitat had red-yellow podzolic soil with chemical and physical properties as presented in Table 9. The soil is acidic with a pH of 4.99, lower than the soil pH of *A. titanum* habitat in University of Bengkulu Educational Forest [25]. The soil in lowland forests in the Sarawak region of Brunei had pH ranging from 3.6 to 5.1 [36] and the soil pH in lowland forest areas of Sumatra ranged from 4.3 to 7.3 [37].

The content of N was 0.33%, classified as medium the organic carbon was 3.7%, as high and the phosphorus was 3.31 ppm, classified as very low (Table 9). The N, P and organic C in the soil are parts of soil organic matter derived from the decomposition of plant and animal tissues. [25] also found high organic C in University of Bengkulu Educational Forest. Phosphorus (P) is the second most important element after N, which plays an important role in photosynthesis and root development. Most P forms are bound by soil colloids, making them unavailable to plants. Soils with low organic content, such as Oxisols and Ultisols are widely found in Indonesia. The soil texture in *A.titanum* habitat in the Boven Lais protected forest was sandy clay loam, while that in University of Bengkulu education forest was clay and silty loam.

Table 9 The physical and chemical properties of soil in *A titanum* habitat in Boven Lais Protected Forest

N	**C**	**P**	**K**	**pH**	**cation exchange capacity (KTK)**	**Al-dd**	**Ca**	**Mg**	**Texture (%)**		
…%..		ppm	(me/100 g)		(me/100 g)				sand	Clay	Silt
0.33	3.70	3.31	0.24	4.79	22.34	2.54	0.24	0.13	53.92	21.99	24.04

Table 10 Criteria for assessing soil chemical properties according to the Soil Research Center Institute (LPPT), Bogor

Soil properties	**Very low**	**Low**	**Medium**	**High**	**Very high**
C (%)	<1.00	1.00-2.00	2.01-3.00	3.01-5.00	>5.00
N (%)	< 0.10	0.10-0.20	0.21-0.50	0.51-0.75	> 0.75
C/N	<5	5-10	11-15	16-25	>25
P2O5 Bray	<10	10-15	16-25	26-35	>35
Kation					
K(me/100g)	<0.1	0.1-0.3	0.4-0.5	0.8-1.0	>1.0
Na(ms/100g)	<0.1	0.1-0.3	0.4-0.7	0.8-1.0	>1.0
Mg(ms/100g)	<0.4	0.4-1.0	1.1-2.0	2.1-8.0	>8.0
Ca (ms/100g)	<2	2-5	6-10	11-20	>20

4 Conclusion

The population of A. *titanum* in the Boven Lais Protected Forest was 20 individuals, dominated by tillers with stem diameters ranging from 0-5 cm. The entire population was found in the vegetative phase.

Vegetation conditions in the *A. titanum* habitat at the tree level comprised 25 species, including 18 families. *Elateriospermum tapos* Blume dominates the tree-level vegetationwith an important value index of 92.87%. The pole-level vegetation comprised 18 species belonging to 10 families and dominated by *Elateriospermum tapos Blume* with an important value index of 41.53%. The sapling vegetation consisted of 22 species and was dominated by Ficus hispida L.f. with an important value index of 15.70%. The vegetation at the seedling/underplant level comprised 25 species belonging to 20 families and was dominated by *Selaginella plana* (Desv. ex Poir.) Hieron with an important value index (INP) of 81.98%.

The soil type in the corpse flower habitat is red-yellow podzolic with sandy clay loam texture, acid soil with a pH of 4.79 medium N (nitrogen) content (0.33%), high C (carbon) content (3.7%) and very low P (phosphorus) content and high CEC.

Compliance with ethical standards

Acknowledgments

This research was carried out with financial assistance from the Research Center and Community Service, University of Bengkulu.

Disclosure of conflict of interest

The authors declare no conflict of interest.

References

[1] Arianto W, Deselina, Ridwan. Diversity of Titan Arum (*Amorphophallus* Bl) Species and Their Distribution Patterns in Bengkulu Province. Directorate of Research Development and Community Service, Directorate General of Higher Education, Ministry of Education and Culture; 1999.

[2] Barthlott W, Lobin W. *Amorphophallus titanum*. Akademie Der Wissenchaften Ind Der Literatur; 1998.

[3] Giordano, C. Karyological and Palynological Observation on *Amorphophallus titanum* (Becc.) Becc. Ex Arcangeli. Caryologia International Journal of Cytology, Cytosystematic and Cytogenic. 1999; 52 (n 1-1):65-73.

[4] Hidayat S, Yuzammi. Study of Natural Population of Titan Arum (Amorhophallus titanum (Becc.) Becc: Case Study in Bengkulu Forest area. Bulletin of Indonesian Botanical Gardens. 2008;11(1):9-15

[5] Hetterscheid W.L.A, Ittenbach S. Everything you always wanted to know about *Amorphophallus* but were afraid to stick your nose into. Aroideana. 1996; 19: 7–131.

[6] Bown D. Aroids, Plants of The Arun Family: London; (1988).

[7] Graham C, Hadiah J.T. *Amorphophallus titanum* Becc. Eksplorasi. 2004; 4(2): 12-15.

[8] Yuzammi, Hadiah JT. *Amorphophallus titanum* The IUCN Red List of Threatened Species Categories. 2018.

[9] Ministry of Forestry. Ministry of Forestry Statistics 2013. Ministry of Forestry; 2014.

[10] Lobin W, Neumann M, Radscheit M, Barthlott W. Cultivation of Titan Arum (*Amorphophallus titanum*)- A Flagship Species For Botanic Gardens.Sibbaldia The Journal of Botanic Garden Horticulture. 2007; 5: 69-86.

[11] Sholihin R, Purwantoro R.S. Vegetative Growth of *Amorphophallus titanum* (Becc) Becc in Cibodas Garden. Biodiversity . 2005; 6(3) :190-193.

[12] Purwantoro R.S, Latifah D. Ex situ conservation of *Amorphophallus titanum* (Becc.) Becc: Propagation by leaf Cuttings. International Conference on Global Resource Conservation & 10th Indonesian Society for Plant Taxonomy Congress Brawijawa University. 2013.

[13] Gandawijaja D, Idris S, Nasution R, Nyman L. P, Ardititi J. *Amorphophallus titanum* Becc : Historical Review and Some Recent Observation. Am.Bot . 1983; 51: 269-278.

[14] Claudel C, Mangelsdorff R.D, Hetterscheid W.L.A. The first successful hybrid of *Amorphophallus titanum*.Aroideana. 2012; 35:81-85.

[15] Hejnowicz Z, Barthlott W. Structural and mechanical peculiarities of the petioles of giant leaves of *Amorphophallus* (Araceae).American Journal of Botany. 2005; 92(3):391-403.

[16] Barthlott W, Szarzynski J, Vlek P,Lobin W, Korotkova N. A torch in the rain forest: thermogenesis of the Titan arum (*Amorphophallus titanum*). Plant Biology 11. 2009; 499–505

[17] Fujioka K, Shirasu M, Manome Y, Ito N, Kakishima S, Minami T, Tominaga T, Shimozono F, Iwamoto T, Ikeda K, Yamamoto K, Murata J, and Tomizawa Y. Objective. Display and Discrimination of floral from *Amorphophallus titanum*, bloomed on different dates and locations using an electronic nose. Sensor .2012;12: 2152-2161

[18] Latifah D, Purwantoro R.S. Seed germination of the corpse giant flower *Amorphophallus titanum* (Becc.)Becc ex Arcang: The influence of testa [Perkecambahan biji bunga bangkai Raksasa *Amorphophallus titanum* (Becc.)Becc ex Arcang:Pengarus testa.Berita Biologi . 2015; 14 (1):39-47.

[19] Irawati. Micropropagation of *Amorphophallus titanum* Becc. (Araceae). Buletin Kebun Raya. 2011; 14 (1):29-36.

[20] Poerba Y.S, Yuzammi. Estimation of Genetic Diversity of Amorphophallus titanum Becc. Based on Marka Random Amplified Polymorphic DNA. Biodiversity .2008; 9(2):103-107.

[21] Iwashina T, Destri, Rahayu S, Tsutsumi C, Yuzammi, Mizuno T, Widyatmoko D. Flavonoids and xanthones from the leaves of *Amorphophallus titanum* (Araceae).Biochemical Systematics and Ecology.2020; 90:1-3.

[22] Claudel C. The Many elusive pollinators in the genus *Amorphophallus*.Arthropod-Plant Interaction. 2021 September;15: 833-844.

[23] Giordano C. Karyological and Palynological Observation on *Amorphophallus titanum* (Becc.) Becc. Ex Arcangeli. Caryologia International Journal of Cytology, Cytosystematic and Cytogenic. 1999; 52 (n 1-1):65-73.

[24] Arianto, W. Potential of the species of Titan Arum (*Amorphophallus* Bl) in Bengkulu Province as a Mannan Source. Bengkulu University Research Report; 2000.

[25] Arianto W, Zuhud EAM,Hikmat A, Sunarminto T, Siregar, IZ. Population and composition structure of the Titan Arum habitat (*Amorphophallus titanum* [Becc.] Becc. Ex Arcang) in the Bengkulu forest area. JPSL. 2019; 9(2):241-257.

[26] Ludwig J.A, Reynolds J.F. Statistical Ecology, A Primer on Methods and Computing. Canada (CA): John Wiley & Sons, Inc; 1988.

[27] Ramdaniah Y. Study of soil quality on land cover types of natural forest, pine forest and grasslands in the Curug Cilember sub-watershed, Cisarua, Bogor. [thesis]. Bogor (ID): Bogor Agricultural Institute; 2001.

[28] Verta L. Pengaruh vegetasi terhadap perubahan iklim mikro di kampus Institut Pertanian Bogor, Bogor. [skripsi]. Bogor (ID): Institut Pertanian Bogor; 2004.

[29] Dieter Mueller-Dombois, Ellenberg HAims and Methods of Vegetation Ecology. United States of America: John Willey &Sons; 1974.

[30] Romersburg HC. Cluster Analysis for Researchers. Belmont (CA): Lifetime Learning Publication; 1984.

[31] Mcnaughton S.J, Wolf L.L. General ecology. Second edition. Saunders College Publishing, 1979.

[32] Hutchingson G E. The concept of pattern in ecology.Proceeding Academy Natural Sciences, Philadelphia, 1953.

[33] Poonswad P, Kemp A, Strange M. Hornbills of The World A Photographic Guide. Draco Publishing and Distribution Pte.Ltd and Hornbill Research Foundation; 2013.

[34] Poonswad P. The Asian Hornbills: Ecology and Conservation. Biodiversity Research and Training Program National Center for Genetic Engineering and Biotechnology. (Edited); 1998.

[35] Magurran A. E. Ecological Diversity and Its Measurement. Princeton University Press; 1988.

[36] Ashton PS, Hall P. Comparisons of Structure among mixed Dipterocarp Forest of North-Western Borneo. Journal of Ecology. 1992; 80: 459-481.

[37] Van Schaik CP, Mirmanto E. Spatial variation in the structure and litterfall of a Sumatran rain forest. Biotropica. 1985;17:196-206