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THE POPULATION AND DISTRIBUTION OF AGARWOOD PRODUCING TREE (*AQUILARIA MALACCENSIS*) IN RIAU PROVINCE

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ABSTRACT
YULIZAH, RAHAJOE, J. S., FEFIRENTA, A. D. & NUGROHO, A. D. 2022. The population and distribution of agarwood producing tree (*Aquilaria malaccensis*) in Riau Province. *Reinwardtia* 21(1): 1–11. — Riau is recorded as one of the distribution areas of *Aquilaria malaccensis*, and has the largest export quota of agarwood in Indonesia. In this study, we identified the species distribution and abundance of the population of agarwood producing trees in the nature. The aims of the research were (i) to determine the distribution and abundance of *A. malaccensis* (ii) identification of ecological factors (microclimate and soil nutrients) and analysis of their relationship to abundance. Seven locations of agarwood producing trees were selected: Taman Hutan Raya (TAHURA: Forest Park Garden) Sultan Syarif Hasyim (SSH), three community forests in Siak Sri Indrapura Regency (Gosib, Perincit, and Dosan), and three community forests in Bengkalis Regency (Langkat, Pangkalan Jambi, and Duri Km 13). Random plots were established in the study sites and environmental parameters such as soil moisture, soil pH, temperature, humidity, and the soil macronutrients data were recorded. *Aquilaria malaccensis* planted at TAHURA SSH recorded about 38 individual ha^{-1}, with an average diameter was 15 cm, and the average tree height was 9.51 m. Perincit showed the highest density in wild condition with 8.13 individual ha^{-1}, with an average diameter was recorded for 20.8 cm and the average tree height was 9.11 m. While the lowest tree density was recorded of 0.58 individual ha^{-1} in Gosib; the average diameter and tree height were recorded of 40.15 cm and 14.70 m, respectively. The results of the study provide information in the conservation efforts of *A. malaccensis* through the possibility of planting it in various environmental conditions in Riau Province and land management such as being planted in monoculture or agroforestry systems as well as the ability to be reintroduced into species-rich natural forest. The supporting data gained from this study was used to provide information on location of potential seeds source and seedling. Moreover, the nutrient content as reviewed in this research will also be essential information about the needs of nutrient content in agarwood plantations.

Key words: Agarwood, *Aquilaria malaccensis*, Riau, TAHURA Sultan Syarif Hasyim.

ABSTRAK
YULIZAH, RAHAJOE, J. S., FEFIRENTA, A. D. & NUGROHO, A. D. 2022. Populasi dan distribusi pohon penghasil gaharu (*Aquilaria malaccensis*) di Provinsi Riau. *Reinwardtia* 21(1): 1–11. — Riau tercatat sebagai salah satu daerah distribusi *A. malaccensis*, dan memiliki kuota ekspor gaharu terbesar di Indonesia. Dalam studi ini, kami mengidentifikasi distribusi jenis dan kelimpahan populasi pohon penghasil gaharu di alam. Tujuan dari penelitian ini adalah (i) menentukan distribusi dan kelimpahan *A. malaccensis*, (ii) identifikasi faktor ekologi (iklim mikro dan unsur hara tanah) dan analisis hubungannya dengan kelimpahan. Tujuh lokasi pohon penghasil gaharu dipilih: Taman Hutan Raya (TAHURA: Taman Hutan Raya) Sultan Syarif Hasyim (SSH), tiga hutan masyarakat di Kabupaten Siak Sri Indrapura (Gosib, Perincit, dan Dosan), dan tiga hutan masyarakat di Kabupaten Bengkalis (Langkat, Pangkalan Jambi, dan Duri Km 13). Pembuatan plot secara acak dilakukan di lokasi penelitian dan mengukur parameter lingkungan seperti kelembaban tanah, pH tanah, suhu, kelembaban serta data makronutrien tanah. *Aquilaria malaccensis* yang ditanam di TAHURA SSH tercatat sekitar 38 tanaman ha^{-1}, dengan diameter rata-rata 15 cm, dan tinggi pohon rata-rata 9,51 m. Desa Perincit menunjukkan kepadatan *A. malaccensis* tertinggi dalam kondisi alam,

dengan 8,13 individu ha^{-1} dan diameter rata-rata tercatat 20,8 cm serta tinggi pohon rata-rata 9,11 m. Sedangkan kepadatan pohon terendah tercatat 0,58 individu ha^{-1} di Gosib; diameter rata-rata dan tinggi pohon tercatat masing-masing 40,15 cm dan 14,70 m. Hasil penelitian ini memberikan informasi dalam upaya konservasi *A. malaccensis* melalui kemungkinan penanamannya di berbagai kondisi lingkungan di Propinsi Riau dan pengelolaan lahan seperti ditanam dalam sistem monokultur ataupun agroforestri serta ditanam kembali ke hutan alam yang kaya jenis. Data penelitian juga mendukung informasi lokasi benih dan bibit yang potensial. Selain itu, kandungan nutrisi seperti yang diulas dalam penelitian ini juga akan menjadi informasi penting tentang kebutuhan kandungan nutrisi di perkebunan gaharu.

Kata kunci: *Aquilaria malaccensis*, gaharu, Riau, TAHURA Sultan Syarif Hasyim.

INTRODUCTION

Agarwood trees, belong to Thymelaeaceae (Hou, 1960) and grow well in the tropical forests (Sumarna, 2002). The most well known of agarwood producing genera are *Aquilaria* and *Gyrinops*. There are at least 13 species of agarwood producing trees which belong to *Aquilaria* and *Gyrinops*. The herbarium specimen collection indicates that *Aquilaria* spp. and *Gyrinops* spp. were distributed in the Western and Eastern parts of Indonesia (Roemantyo & Partomihardjo, 2010; Zich & Compton, 2001). Moreover, recent studies found that *Gyrinops verstegii* grows well in the natural habitats and becomes a potential source of seed for young trees for the plant enrichments in Manggarai District, Flores Island (Rindyastuti *et al.*, 2019).

Agarwood is Non Timber Forest Product (NTFP) produced as a product of secondary metabolites from the plant's defense in response to physical disorders or microorganism infections. The secondary metabolites are produced in the form of agarwood resin in agarwood tissue, which subsequently changes its colour from white to dark brown or dark black; this dark part has high economic value and named agarwood sapwood. Due to the high economic value of agarwood products, these trees are declared as one of five product priorities of NTFPs, while the other products are bamboo, rattan, honey, and bees (Santoso *et al.*, 2011). Agarwood is widely used for many purposes such as perfume and incense; therefore, it has been harvested in significant volume in nature.

The export of agarwood producing trees from Indonesia and Malaysia is leading among other countries. CITES export data from 1995 to 1997 recorded that Indonesia became the highest exporting agarwood with a range of 920 tons (Barden *et al.*, 2000). It was supported by the data of agarwood population in the forest; those were recorded for 61,000 from the period of 1991 to 1996. Sumatra is a distribution area of *A. malaccensis*, and one of the places to produce the best agarwood is Riau Province (Soehartono & Newton, 2001). In Riau Province, agarwood was famous since the era of Sultan Syarif Hasyim in the Siak Sri Indrapura Regency. The Sultan and his family used agarwood as fragrance, medicinal plant, and trading commodity. At present, Riau was no longer the center of agarwood trade, which causes the reduction of agarwood producing trees due to the unsustainable harvesting process. The reduction of agarwood trees in nature was mostly caused by land clearing, land use changed for plantations, and annual forest fires. In 2018, about 1,700 ha of forest was burnt and had an impact on the damage of the ecosystem (WALHI Riau, 2019). It also reduced the forest area and affected on the abundance of agarwood in nature, especially *A. malaccensis* in Riau Province.

The Directorate General of Conservation and Natural Resources and Ecosystems from the Ministry of Environment and Forestry has a role in regulating the export quotas of wild plants and animals. This quota regulation greatly influences the sustainable use of plant and animal populations in nature. In 2018, the total quota of *A. malaccensis* was 151,725 kg, with the highest quota recorded around 50,000 kg for Riau Province (KLHK, 2018). Therefore, Riau Province has to improve cultivation technology to produce good quality agarwood resins. There were some studies of agarwood cultivation, including the ecology of agarwood and conservation for sustainable use (Barden *et al.*, 2000; Soehartono & Newton, 2000, 2001; Paoli *et al.*, 2001; Sumarna, 2008), and the technology for producing good quality of agarwood resin by using selected microorganisms (Budi *et al.*, 2010; Santoso *et al.*, 2011). Important information regarding the population studies of *Aquilaria* spp. becomes an essential stage in determining quotas and maintaining the sustainability of the conservation plans. Hence, monitoring and mapping activities of natural agarwood habitats are essential to know the distribution of the population, to maintain the sustainable use of agarwood, and to ensure that there are no threats in nature. The study aimed to determine the distribution and abundance of agarwood populations and the relationship with

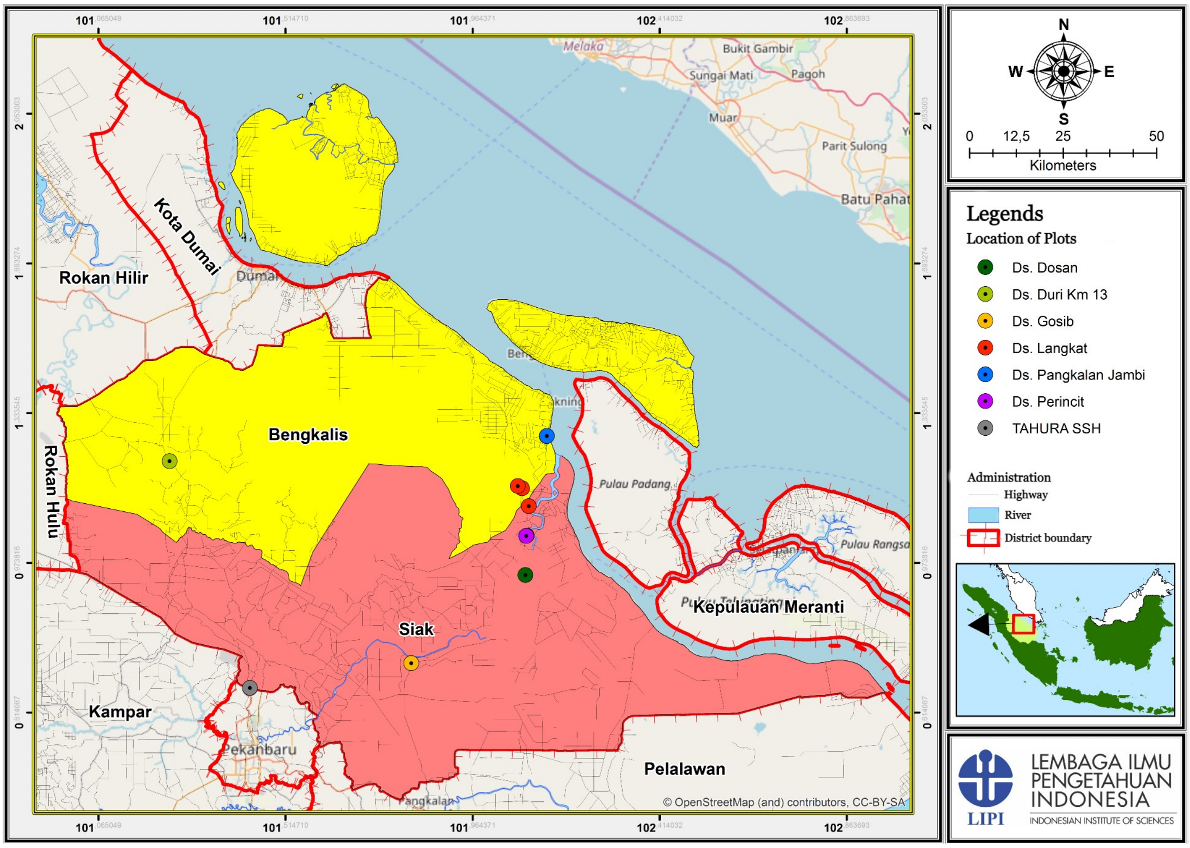

Fig. 1. Research sites of the population of agarwood producing trees in Riau Province.

some environmental properties of wild agarwood producing trees in Riau Province, to find out some of the basic information for cultivation strategy based on their natural habitat, and to support the conservation with cultivation program of agarwood in that region.

MATERIALS AND METHODS

Study Area

The research was conducted in Siak Sri Indrapura and Bengkalis Regencies, Riau Province in April 2019. In Siak Sri Indrapura Regency, the research area were located in the upstream area, *i.e.*, TAHURA Sultan Syarif Hasyim, Gosib, Dosan, and Perincit. While in Bengkalis Regency, they were located in Langkat, Pangkalan Jambi, and Duri Km 13 (Fig.1).

Methods

Analysis of composition was carried out to determine the population of agarwood-producing trees in Riau Province. Interviews with residents were conducted to determine the agarwood species targets and sampling locations. We selected agarwood populations that grow naturally without human interferences such as in conservation areas and community forests and those were planted without special treatment as found in TAHURA Sultan Syarif Hasyim. Vegetation study was carried out with adaptive cluster sampling method with plot of 30 × 30 m which was divided into 10 × 10 m subplots. The tree diameter at 1.3 m above the ground (DBH) and height was measured with hagameter for trees with DBH equal to or bigger than 10 cm. In addition to agarwood species, other plant species in the plots were also recorded and identified. Herbarium samples were collected for identification and validation of agarwood producing tree species at Herbarium Bogoriense, Research Center for Biology.

Soil pH, soil nutrients, air temperature, relative humidity, and light intensity were measured in each subplot. The parameters were measured by using a soil analyzer tester meter for soil pH; meanwhile, relative humidity and air temperature were measured by using a thermo-hygrometer and lux meter equipment. The measurements have been done in each location mainly in the morning at about 10 a.m. to 2 p.m in a base of a tree with two repetitions. Soil samples were then randomly collected at 10 cm depth in each selected subplot with two sampling points and were analyzed for C, N, P, K, Ca, Na, and Mg. Soil samples were taken on three subplots diagonally in each plot with two repetitions. The soil samples were digested by using an acid mixture and the nutrients contents were measured by using Atomic Absorption Spectrophotometry (AAS) Shimadzu Type AA-6800, UV-Vis Spectrophotometer 1240 Shimadzu, and CN Analyzer Yanaco JM 1000. All soil samples were analyzed in Plant Ecology Laboratory, National Research and Innovation Agency.

Data analysis

Tree density and basal area were determined by using basic ecological calculation. The dispersion of *A. malaccensis* was determined using Morisita Index (Id) (Krebs, 2009):

$$\mathrm{Id} = \mathrm{n}\frac{(\sum {x_i}^2 - \sum x_i)}{(\sum x_i)^2 - \sum x_i}$$

n : the number of sample in plots
x : the number of individuals in each plot

Then its dispersion pattern was determined as follows :

$$\mathrm{Mu} = \frac{X^2_{0,975} - n + \sum x_i}{(\sum x_i) - 1}$$

$$\mathrm{Mc} = \frac{X^2_{0,025} - n - \sum x_i}{(\sum x_i) - 1}$$

Mu : morisita index for regular dispersion patterns
Mc : morisita index for cluster dispersion patterns
$X^2_{0,0975}$: value of Chi Square table with confidence interval 97.5%
$X^2_{0,025}$: value of Chi Square table with confidence interval 2.5%

Then the standard degree of Morisita as calculated using following formula:

$$Ip = 0{,}5 + 0{,}5\left(\frac{Id - Mc}{n - Mc}\right) \quad \text{If Id} \geq \text{Mc} > 1$$

$$Ip = 0{,}5\left(\frac{Id - 1}{Mc - 1}\right) \quad \text{If Mc} > \text{Id} \geq 1$$

$$Ip = -0{,}5\left(\frac{Id - 1}{Mu - 1}\right) \quad \text{If 1} > \text{Id} > \text{Mu}$$

$$Ip = -0{,}5 + 0{,}5\left(\frac{Id - Mu}{Mu}\right) \quad \text{If 1} > \text{Mu} > \text{Id}$$

If Ip = 0 = distribution pattern is random, Ip < 0 = distribution pattern is uniform, and Ip > 0 = distribution pattern is clumped.

The relationship between abundance of *A. malaccensis* and environmental properties was analyses using Canonical Correspondence Analysis (CCA) (Ter Braak, 1987), mainly by using PAST software version 3.

RESULTS

The population and dispersion pattern of *Aquilaria malaccensis* in Riau Province

The study of agarwood natural habitat populations was conducted in the community forests managed by villagers; this location was surrounded by oil palm, rubber, and coffee plantations. Because of the high economic value of agarwood resin well known by the community, therefore agarwood trees were not cut down during the land clearing. Based on the information from villagers in the study site, an old tree of agarwood was still recorded with the age of about 70 years old with the tree diameter was recorded for 75.09 cm. Agarwood producing trees *A. malaccensis* were found in some locations in Riau such as in Siak Sri Indrapura and Bengkalis Regency.

The seven locations are the native habitat of *A. malaccensis*. Although *A. malaccensis* was planted in 2005 for conservation purpose, it has previously been recorded as agarwood plants found in TAHURA SSH. Based on the density of stands, the population in TAHURA SSH is higher than that in other locations, in addition to being in protected forest area, the vegetation conditions strongly support the growth of *A. malaccensis*. Dense vegetation communities and diverse species such as, *Sloetia elongata*, *Rhodamnia cinerea*, *Endospermum diadenum*, *Shorea parvifolia*, *Elaeocarpus griffithi*, *Dillenia reticulata*, *Gironniera parvifolia*, *Randia anisophylla*, and *Nephelium cuspidatum*. Those trees were widely distributed in TAHURA SSH. The results recorded that the highest individual density in the community forest was in Perincit village, Siak Sri Indrapura Regency with the individual density was 8.13 ha^{-1}, and the average tree diameter was 20.8 cm, and the tree height was recorded for 9.11 m (Table 1; Figs. 2 & 3). *Aquilaria malaccensis* can be found around home gardens and plantations around the village of Perincit. Agarwood was in high demand by traders and poachers; therefore, residents initiative to move their houses to the nearest place from the agarwood. Fig. 2 shows a high standard deviation in Gosib Village for the diameter and height of the tree. This result was due to the existence of old trees at Gosib. The

Table 1. Population and density of *A. malaccensis* in Riau Province

Locations	Max diameter (cm)	Max height (m)	Average BA (cm^2)	Stand Density (ind. ha^{-1})	Number of Plots
TAHURA SSH	44.98 ± 7.65	22.0 ± 2.72	232.84 ± 304.62	38.00	10
Gosib	59.71 ± 27.66	21.6 ± 9.75	1,566.08 ±1,743.91	5.80	4
Dosan	75.09 ± 18.98	23.7 ± 5.25	1,181.86 ± 1,371.91	4.50	10
Perincit	30.14 ± 7.57	12.7 ± 2.91	355.81 ± 241.43	8.13	10
Langkat	53.38 ± 18.92	16.3 ± 3.05	1,381.28 ± 924.90	1.25	7
Pangkalan Jambi	50.96 ± 12.69	10.9 ± 7.20	1,345.76 ± 758.06	2.50	8
Duri Km 13	17.25 ± 5.57	8.1 ± 1.07	218.73 ± 151.47	4.15	10

interesting phenomenon was that the agarwood trees of Dosan and Gosib in the peat swamp areas had a bigger diameter.

More common plants are found in community forest areas, namely *Elaeis guineensis*, *Hevea brasiliensis*, *Coffea* sp., and some species of fruit such as *Theobroma cacao*, *Garcinia mangostana*, *Durio zibethinus*, *Mangifera* sp., *Nephelium lappaceum*, *Syzygium* sp., *Artocarpus rigidus*, and other wood plants like *Palaquium hexandrum*, *Ixonanthes icosandra*, and *Artocarpus elasticus*. Conditions on the ground as in Fig. 3. In addition, the development of plantations around people's forest causes native species to degrade. The potential for the speed of growth and wide spread of seeds causes plantation crops to dominate community forest. This is evident from the many seedlings of *Coffea* sp. and *H. brasiliensis* in each location.

The distribution of diameter and height of *A. malaccensis* at each location shows that conditions do not support for the natural regeneration process. No seedlings were found at each location, it was also seen in the conservation area. TAHURA SSH officials said there had never been a flowering *A. malaccensis* tree. Dispersion pattern can explain how population conditions in their habitat (Amaral *et al.*, 2015). Morisita dispersion index (Id) of *A. malaccensis* in TAHURA has Id of 10 and Mc (Morisita Index for cluster distribution patterns) of 1.43, while the value of Ip (standard degree Morisita) is 1,02. Since Id ≥ Mc ≥1, and Ip > 0, therefore it can be concluded that dispersion pattern of *A. malaccensis* in TAHURA SSH is clumped. Similarity, the dispersion pattern of *A. malaccensis* in community forest is also clumped (Gosib (Ip= 0.13), Dosan (Ip = 0,99), Perincit (Ip = 1), Langkat (Ip = 1), Pangkalan Jambi (Ip = 0.91) dan Duri Km 13 (Ip = 1.03).

The relationship between distribution and the ecological factors variables

The influence of environmental factors on agarwood plant growth is very important, such as light intensity during sapling. These environmental factors might give different effects on the tree level growth. The highest average temperature during the study was in Dosan area (38°C) and the lowest in Duri Km 13 (33°C). In addition, the average humidity was 57%, and the light intensity was 287 at all locations (Table 2). The measurement result of this environmental data can not support information on the growth of *A. malaccensis* in the natural habitat but can provide an overview of the environmental conditions where *A. malaccensis* is found.

Based on the mapping of soil types, Gosib, Dosan, Perincit, Langkat dan Pangkalan Jambi were classified as peat soils (belonging to hemic arganosol and gleisol classes). Meanwhile, TAHURA SSH and Duri Km 13 were classified as mineral soil types (Cambic nitosols, cambic arenosol, gleic latosol, oxic latosol, and cambisol) (Balai Tanah Indonesia, 2011). Soil samples from the study sites were analyzed to determine the nutrient content. The nutrient content of P, Ca, and Mg was very low compared to other nutrients in all locations based on the criteria from Balai Penelitian Tanah (2009). The nutrient contents were in the range of 0.003–0.768%, 0.134–0.225%, and 0.035–0.114% for P, Ca, and Mg, respectively. K content was lower in the mineral soils than in the peat soils (Table 3). Sodium (Na) content was categorized from high to very high, with a range of Na being 0.981–1.00%. Nitrogen

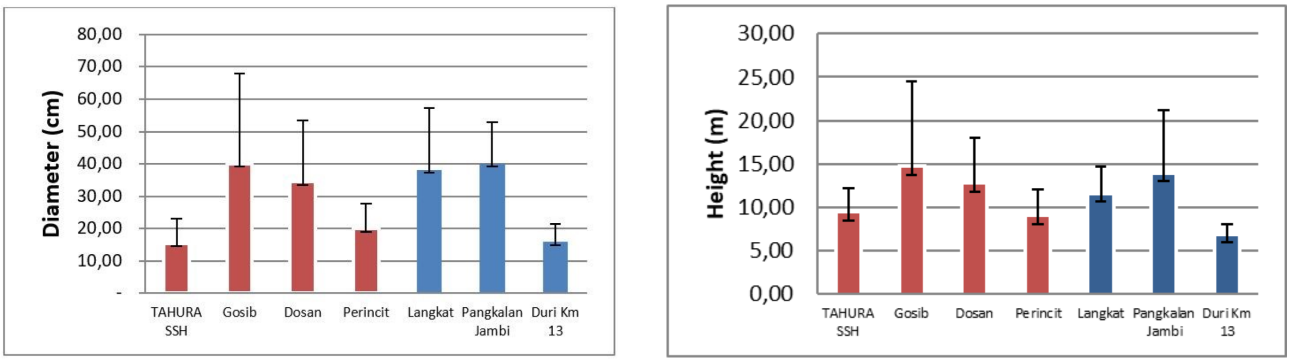

Fig. 2. Average distribution of diameter and height of *A. malaccenssis* in the study site, red bars were agarwood populations in Siak Sri Indrapura Regency, blue bars were in Bengkalis Regency.

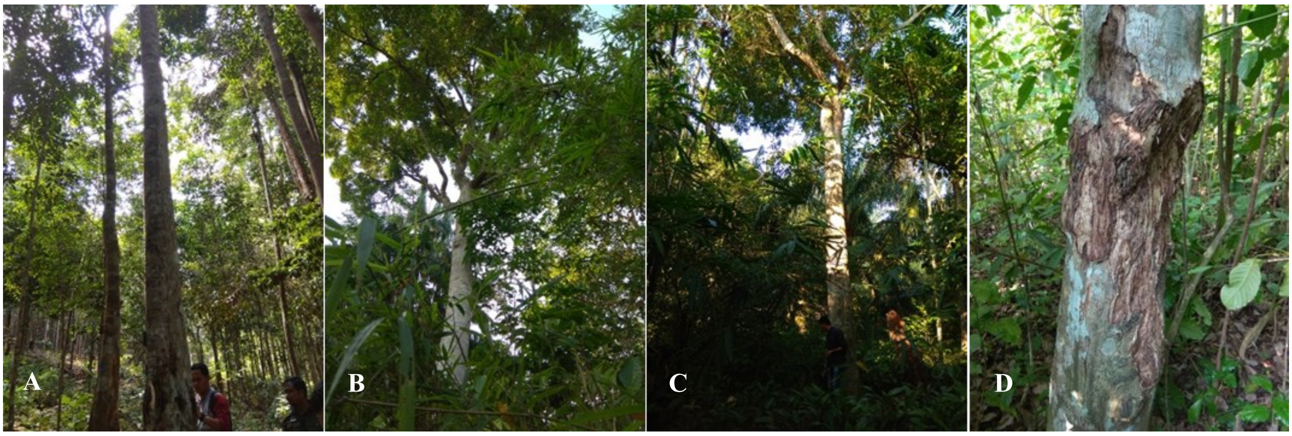

Fig. 3. Agarwood producing trees (*A. malaccensis*) in the conservation area. A. TAHURA Sultan Syarif Hasyim, community forest. B. Gosib, Siak Sri Indrapura Regency, C. Perincit, Siak Sri Indrapura Regency, D. Pangkalan Jambi, Bengkalis Regency. Photos by Yulizah.

content has a very wide range from low, medium, high to very high, with a range of 0.12–0.926%; the lowest and highest N were recorded in the mineral soil. Carbon content in mineral soil was recorded from low to moderate, those were 1.606 and 2.198% in TAHURA and Duri Km 13, respectively, while the carbon contents were recorded from high to very high ranging between 3.787–6.374% in the peat soils, an exception in Langkat, it was recorded in a very low criterion (0.655%).

Outputs of ordination analysis using Canonical Correspondence Analysis (CCA) of PAST version 3 software were in the form of Eigenvalue and ordination diagrams. The Eigenvalue shows the level of distribution of species or plots in the ordination diagram. The results of CCA ordination analysis obtained an eigenvalue of 0.412 which show the population represented by the location is not evenly distributed (Fig. 4).

DISCUSSION

The population and dispersion pattern of *Aquilaria malaccensis*

Riau Province is one of the best agarwood producing areas and has been a trading center for agarwood. In 2016 to 2019 the export quota of *A. malaccensis* in Riau Province has always increased from 35,000 kg to 50,000 kg, but in 2020 the export quota of *A. malaccensis* has decreased to 40,000 kg. Although there is a decrease, the highest export quota of agarwood was in Riau Province. Based on these data, it should be shown that the agarwood population was still quite high with a high utilization as well. However, when we see the condition of the forest in Riau Province, not all forest areas in Riau Province are covered by forest vegetation. The main factor causing the reduction of forest cover was the increasing

Table 2. Average value of environmental factors measured at each location

Locations	Temperature (°C)	Humidity (%)	Light (Lux)	pH
Tahura SSH	29 ± 0.92	79 ± 4.2	340 ± 10.5	6.2 ± 0.50
Gosib	34 ± 0.50	59 ± 3.46	280 ± 5.77	6.4 ± 0.23
Dosan	38 ± 0.53	44 ± 0.46	290 ± 4.62	6.0 ± 0.38
Perincit	35 ± 0.91	54 ± 4.18	210 ± 13.2	5.6 ± 0.28
Langkat	35 ± 0.51	50 ± 1.67	380 ± 0.12	5.6 ± 0.12
Pangkalan Jambi	35 ± 0.00	50 ± 0.57	270 ± 10.5	6.2 ± 0.51
Duri Km 13	33 ± 0.50	57 ± 0.17	240 ± 0.00	5.0 ± 0.25

Table 3. The test of the soil chemical content at each location

Test component (%)	Location						
	Tahura SSH	Gosib	Dosan	Perincit	Langkat	Pangkalan Jambi	Duri Km 13
Ca	0.160±0.018^{VL}	0.134±0.026^{VL}	0.199±0.018^{VL}	0.161±0.006^{VL}	0.18±0.001^{VL}	0.177±0.004^{VL}	0.255±0.010^{VL}
Mg	0.047±0.013^{VL}	0.123±0.009^{VL}	0.074±0.021^{VL}	0.114±0.009^{VL}	0.094±0.008^{VL}	0.110±0.015^{VL}	0.035±0.042^{VL}
Na	0.981±0.036^{H}	1.048±0.042^{VH}	1.000±0.013^{VH}	0.984±0.029^{H}	0.992±0.013^{H}	0.989±0.024^{H}	0.984±0.001^{H}
K	0.103±0.074^{L}	0.442±0.054^{M}	0.217±0.076^{L}	0.376±0.067^{M}	0.543±0.089^{M}	0.445±0.022^{M}	0.011±0.024^{VL}
P	0.003±0.002^{VL}	0.044±0.040^{VL}	0.010±0.009^{VL}	0.017±0.006^{VL}	0.768±0.001^{VL}	0.017±0.149^{VL}	0.005±0.01^{VL}
C	1.606±0.623^{L}	6.374±2.822^{VH}	3.374±0.650^{H}	3.787±0.53^{H}	0.655±1.466^{VL}	6.020±2.621^{VH}	24.20±21.109^{M}
N	0.126±0.032^{L}	0.483± 0.200^{M}	0.231±0.079^{M}	0.301±0.042^{M}	0.711±0.051^{H}	0.334±0.114^{M}	0.926±0.770^{VH}
C/N	12.384±2.771^{M}	13.111± 0.417^{M}	14.575±1.473^{M}	12.600±0.151^{M}	13.588±2.035^{M}	18.017±3.246^{H}	26.134±0.485^{VH}

*VL (Very Low), L (Low), M (Medium), H (high), VH (Very High)
**assessment criteria for the result of soil chemical analysis by Balai Penelitian Tanah, 2009.

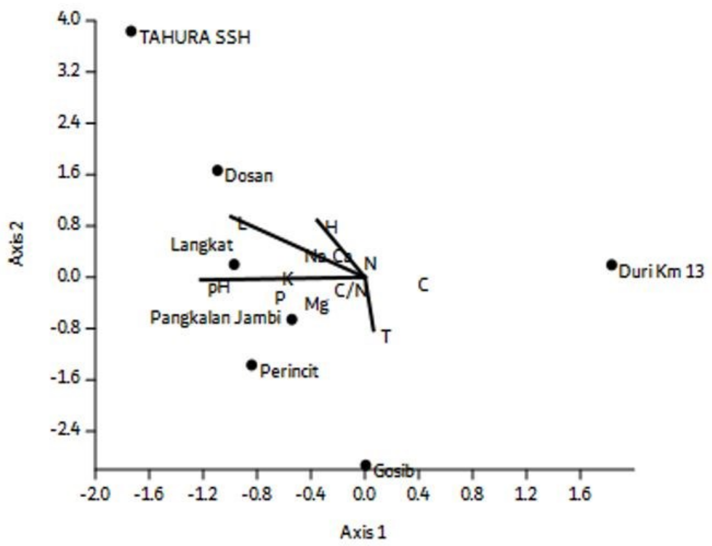

Fig. 4. Result of ordination CCA shows the distribution of sample locations and soil nutrient content on the gradients of an environmental factors (T= Temperature, H= Humidity, L=Light) .

deforestation, one of which is for oil palm plantations. Conversion of land to palm oil plantations and forest fires almost every year certainly disrupt the habitat of agarwood producing trees in nature. In addition, the increasing number of agarwood hunting in nature has decreased the agarwood population in Riau Province.

The population density of *A. malaccensis* in community forest locations was high compared to studies that have been carried out in other locations. Based on some researches, the density of agarwood producing trees (*Aquilaria* spp.) was very low, with an abundance of only 0.01 and 0.2 individuals ha^{-1} in Kutai National Park, and Gunung Palung, respectively (Donovan & Puri, 2004; Pribadi, 2009). The dispersion pattern of *A. malaccensis* in study areas was clumped. This can be stated that all research site has almost the same ecological conditions. *Aquilaria* spp. showed clumped distribution also in Sumatra and Kalimantan (Soehartono & Newton, 2000). Conservation areas such as TAHURA SSH have a high density with dispersion pattern was clumped and average diameter of 18 cm.

In study site, the tree diameter of *A. malaccensis* in some locations was recorded as more than 20 cm (Fig. 2). It was predicted that the harvestable agarwood tree was at about 20 cm DBH, far below the reproductive threshold, which was estimated at 35 cm DBH (Paoli, 2001). This indicates that the diameter of agarwood producing trees in several study sites was still below the harvest threshold, so it was estimated that study sites such as Perincit, and Duri Km 13, still maintain a population of agarwood producing trees. The community and agarwood hunters still maintain large-diameter agarwood trees as the mother tree. This finding was support by the abundance of the seed in Gosib as the source of the seedling of the agarwood tree which will be planted.

The differences in *A. malaccensis* density in each location might be due to the forest degradation, illegal hunting, and destruction of agarwood habitat in Riau Province. In consequence, it reduced or limited shading trees for *A. malaccensis* sapling. At the time of the study, several trees were flowering and bearing fruit. According to local community information, the *A. malaccensis* flowers almost every year, but at the time of the study, the seedlings or saplings were not found under the mother tree and in the plots. It was similar to the research in Gunung Palung National Park, where the distance of agarwood sapling (with the height of > 15 cm) was found about 3–7 m from mature trees, and the sapling density was only recorded about 10 sampling ha^{-1} (Paoli *et al.*, 2001). Based on the information from the local community, Dosan and Gosib areas are a source of seedlings, and those are often visited by agarwood hunters to collect seeds and seedlings. In the Perincit, Pangkalan Jambi, Langkat, and Duri Km 13 areas, *A. malaccensis* populations were found in the middle of rubber and oil palm plantations. The area has been cleared, and there was no shade for the seedling to grow. As well known that the shade from agarwood and surrounding trees were important for the growth of the seedling. Therefore, the shade was one of the reasons for determined the distance between seedlings and saplings from the mother tree.

Sumarna (2008) described the relationship between the tree diameter and tree canopy; this related to the ability of natural regeneration.

In Siak Sri Indrapura Regency, the location of the discovery of *A. malaccensis* is a peat area. Previously, there was not recorded that *A. malaccensis* had ever been found in peat areas. Partomihardjo *et al.* (2008) explained that several *Aquilaria* species can be grown well on peat swamp forest areas, one of which was *A. beccariana* which grows in peat swamp forest at Merang, South Sumatra. At this time, the Siak Sri Indrapura Regency Government has planted agarwood producing trees from *A. malaccenssis*, *A. macrocarpa* and *A. beccariana* in the peat area to prevent forest fires. However, this instance has not been supported by more instensive research.

The relationship between distribution and the ecological factors variables

Based on information from local villagers, agarwood trees have been growing for more than 20 years at the research site. Tables 3 and 4 show ecological variables in the habitats of *A. malaccensis* at seven research sites. *Aquilaria malaccensis* trees grow at altitudes of 0–2,400 m above sea level, in a high temperature range 28–34°C, humidity from low to 80%, and rainfall of 1,000–2,000 mm/year (Sumarna, 2012; Pribadi, 2009). *Aquilaria* spp. are also grow well in dry soils with a high sand content, with soil pH ranging from acidic pH to almost neutral, and tree growth requires shade associated with low light intensity (Pribadi, 2009). That's in line with the results of this study where temperatures at the study site ranged from 29–33°C, with soil pH of 5.4 to 6.8, and humidity ranging from 50 to 79%. Based on soil chemical properties, the population of *A. malaccensis* can be found in infertile to very fertile soil conditions with C organic range 0.655–0.768% which categorized as very low until very high. Forest floor cover is not too thick with litter, especially in Gosib and Dosan which are adjacent to oil palm plantations. Some other types of agarwood research such as *Gyrinops versteegii* in Lombok, light intensity is the main factor affecting the occurrence of *G. versteegii* (Mulyaningsih *et al.*, 2017; Sutomo & Oktaviani, 2019).

Soil pH from acid (5.0) to neutral (6.4) shows of *A. malaccensis* can be found in a variety of environmental conditions. It can be seen in the CCA diagram where variable light intensity and pH form a sharp angle (Fig. 4), this shows that both ecological variables are the primary ecological factors at each location. Variations of vegetation and tree canopy will affect the light intensity on the forest floor and will affect soil moisture levels. In soil nutrients, showing that the nutrient component of the soil is not a contributing factor to the distribution of *A. malaccensis* in Riau, it can be seen in the chemical composition of the soil scattered in the middle of the ordination diagram.

The relationship between distribution of *A. malaccensis* and ecological factor is uneven on the diagram CCA (Eigenvalue <1) (Fig. 4). Ecological variables converge at the center of ordination, while the populations at each location are scattered far away, such as Duri Km 13 (mineral soil) and Gosib (peat soil). Uneven distribution of *A. malaccensis* populations on CCA diagrams, suggests there are other factors have a high role in the distribution of *A. malaccensis* but they were not measured in the study. One of the most high-impact factors is human activities such as hunting and plantations. Winarni (2011) states that disruption of logging and forest management systems causes differences in the population structure of agarwood producing trees. Human activities such as hunting and unsustainable harvesting are major factors in the loss of agarwood populations in nature.

The populations of protected plant species such as *A. malaccensis* need more consideration to keep their populations in nature, so research on population dynamics is important to support conservation programs, especially in providing information about the minimum population sizes. Riau Province, as the conservation of agarwood producing trees was potential as the natural habitat of *Aquilaria* spp. Seedlings of *A. malaccensis* can also be obtained from Dosan and Gosib to produce high quality agarwood trees. Seedlings of agarwood in both villages are always available throughout the year; those were scattered near the mother tree. However, sapling level of agarwood trees was not found because it could not survive without shading and the distance close to the mother tree.

The potential in the conservation development of *A. malaccensis* is very likely, because *A. malaccensis* can be found in various of environmental conditions. In addition, there is support from the provincial government that supports conservation program by including *A. malaccensis* in the list of restoration plants that can be developed in various types of land and cultivation systems. However, this effort was still not enough because there were still many problems faced by farmers, mainly how to produce high quality of agarwood and the stability of agarwood price. Until now, the quality of cultivated agarwood product was low, so this causes the hunting of agarwood in nature is still on going due to the high selling price. Harvesting agarwood by cutting down the trees in natural habitats or plantations was about 75% of the total trees, with crop intensities ranging from 50–100% (Paoli *et al.*, 2001; Turjaman *et al.*, 2016). To protect agarwood producing species, planting trees in natural habitats has to be carried out, and the production of cultivated agarwood needs to be increased (Liu *et al.*, 2013). This was supported by the quality of the growth rate of natural regeneration of seedlings to provide good quality seedling (Sumarna, 2012).

CONCLUSION

This study revealed that *A. malaccensis* is spread from upstream to downstream of Riau Province and spread across various habitat characteristics with various soil type, soil nutrients and micro climate. The local or metapopulation of *A. malaccensis* at each location is scattered in a clumped. Some ecological variables might be important for the abundance of this species are light intensity and pH. The tolerance of *A. malaccensis* to ecological factors is very wide, especially soil nutrients, providing opportunities for conservation of *A. malaccensis* in various environmental conditions and development with monoculture and agroforestry plantation system.

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A NEW VARIETY OF *CANTHIUMERA GLABRA* (RUBIACEAE: VANGUERIEAE)

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ABSTRACT
MAHYUNI, R., CHIKMAWATI, T., ARIYANTI, N. S. & KUSUMAWATY, A. 2022. A new variety of *Canthiumera glabra* (Rubiaceae: Vanguerieae). *Reinwardtia* 21(1): 13–17. — *Canthiumera glabra* var. *laxiflora* (Rubiaceae: Vanguerieae), a new variety from Java and Sumatra is described. The new variety differs from the typical variety in having laxly branched inflorescences and is restricted to south Sumatra (Lampung) and southwestern Java.

Key words: *Canthium glabrum*, Indonesia, inflorescence form, Malesia.

ABSTRAK
MAHYUNI, R., CHIKMAWATI, T., ARIYANTI, N. S. & KUSUMAWATY, A. 2022. Varietas baru *Canthiumera glabra* (Rubiaceae: Vanguerieae). *Reinwardtia* 21(1): 13–17. — *Canthiumera glabra* var. *laxiflora* (Rubiaceae: Vanguerieae), varietas baru yang berasal dari Jawa dan Sumatra telah dipertelakan. Varietas baru ini dibedakan dari kelonggaran cabang perbungaannya dan memiliki sebaran terbatas di Sumatra bagian selatan (Lampung) dan Jawa bagian barat daya.

Kata kunci: Bentuk perbungaan, *Canthium glabrum*, Indonesia, Malesia.

INTRODUCTION

The tribe Vanguerieae is strictly defined by morphological characters such as axillary inflorescences, valvate corolla lobes, recessed stigmatic base, and ovaries with a solitary pendulous ovule. However, one of the problematic groups within Vanguerieae is the *Canthium* alliance, in which members of the alliance were distinguished in having characters such as axillary spines, presence of brachyblast, tufts of hair in stipules, unisexual or bisexual flowers, types of inflorescenses, shapes of calyx tube, and presence of hairs on corolla tubes.

Bridson (1992) laid out the foundation work on Vanguerieae, and subsequently Lantz & Bremer (2004) and Arriola *et al.* (2016) followed in utilising molecular and morphological data to distinguish groups within the *Canthium* alliance. Later, Wong *et al.* (2018) demonstrated that *Canthium s.s.* differed from other named genera in Vanguerieae through the presence of the axillary supernumery buds and spines. It should be noted that molecular studies by Lantz & Bremer (2004) and Razafimandimbison *et al.* (2009) lacked of materials from Southeast Asia and this rendered limited resolutions in their phylogenies.

One of the segregate genera of *Canthium s.l.* is *Canthiumera* K.M.Wong & Mahyuni, and it is typified by *Canthiumera glabrum* (Blume) K.M.Wong & Mahyuni (Wong *et al.,* 2018). In total, four species were recognised for *Canthiumera* and they can be distinguished based on the presence of hairs on leaf margin and

Fig. 1. Holotype of *Canthiumera glabra* var. *laxiflora* (*M. Jacobs 8297*).

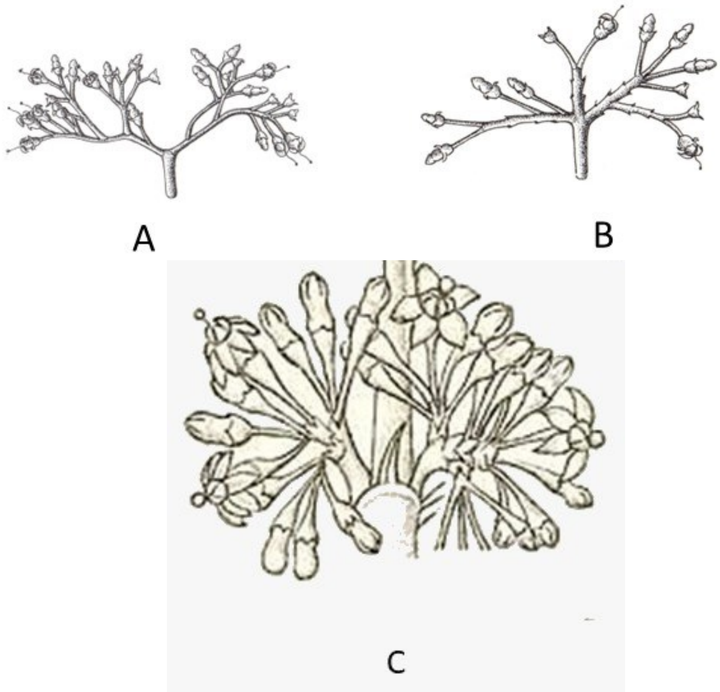

Fig. 2. A & B. *Canthiumera glabra* var. *laxiflora.* A. Sparse inflorescence type observed from *M. Jacobs 8297*. B. Sparse inforescence type observed from *Nengah Wirawan 197*. Drawn by Anne Kusumawaty. C. Dense inflorescence type of *Canthiumera glabra* var. *glabra.* (*Koorders 26702b*, Koorders & Valeton, Atlas der Baaumaten von Java).

morphological characteristics on floral parts (shape of corolla tube, length of calyx, and hairs on style) and shapes of pyrene. *Canthiumera glabrum* is a species distributed in Java, Bali, and Sumbawa, and it has distinct morphological characteristics from the other species, namely *Canthiumera robusta*, *C. siamensis*, and *C. neilgherrensis*, by its 1–1.5 mm long calyx, corolla lobes about the same length as the corolla tube, and a pubescent style.

While sorting through materials of *Canthiumera glabrum* at Herbarium Bogoriense, we came across specimens with distinct differences in inflorescence characteristics but otherwise matches well with other materials of *Canthiumera glabrum*. Based on this distinct morphological character, we hereby describe a new variety to accommodate these materials from Lampung (south Sumatra) and Ujung Kulon (extreme West Java). A description of this new variety and a map of its distribution are provided here.

MATERIALS AND METHODS

This study was conducted following a standard protocol for taxonomic studies in which morphological characteristics of vegetative and generative part were observed from preserved herbarium specimens at Herbarium Bogoriense (BO), Forest Research Institute of Malaysia (KEP), Sandakan Herbarium (SAN), Sarawak Forest Department (SAR), and Singapore Botanic Gardens (SING).

RESULTS AND DISCUSSION

Distribution of *Canthiumera glabra* includes Java, Bali, and Sumbawa. We are unable to establish if *C. glabra* var. *glabra* occurs in Sumatra. In general, morphological characters between *C. glabra* var. *glabra* and *C. glabra* var. *laxiflora* largely overlaps, with the exceptions of fruit pedicels of *C. glabra* var. *laxiflora* which is

Fig. 3. Flower buds of *Canthiumera glabra* var. *glabra* (Ridha, *s.n.*, Bogor Botanic Garden). Photo by Ridha Mahyuni.

shorter than those of the typical variety, *i.e., ca.* 0.5 mm long. The two varieties of *Canthiumera glabra,* namely *Canthiumera glabra* var. *glabra* and *C. glabra* var. *laxiflora* can only be distinguished by their inflorescence type. In addition, *Canthiumera glabra* var. *laxiflora* is found to be restricted to southwestern Java and the Lampung district of Sumatra.

Taxonomy

Canthiumera glabra var. laxiflora Mahyuni, *var. nov.* — TYPE: INDONESIA, Sumatra, Province of Lampung, NW of Kota Agung, 5° 23'S, 104°25'E, 350–450 m, 9 May 1968, *M. Jacobs 8297* (holotype BO!, isotype SING). Fig. 1.

This new variety has laxly branched subumbellate cymes, peduncle 3–5 mm long branches, which has 1–2 mm long.

Other specimens examined. INDONESIA, Java, Province of Banten; Ujung Kulon Nature Reserve, Mt. Pajung. 31 Dec 1963, *Nengah Wirawan 167* (BO). Sumatra, Lampung, no specific locality, 6 Jul 1965, *H.F. Sun 9935* (BO); Mt. Tanggamus, 27 April 1968, *M. Jacobs 8075* (BO); Baturadja, Dec 1928, *T. Hoelt s.n.* (BO).

Etymology. The new variety epithet refers to the laxly branched inflorescences.

Distribution. Endemic to southwestern Java and south Sumatra (Lampung Province) (Fig. 4). At present, precise distribution of this new variety is unknown, apart from the present localities in Bukit Barisan National Park and the Ujung Kulon Nature Reserve.

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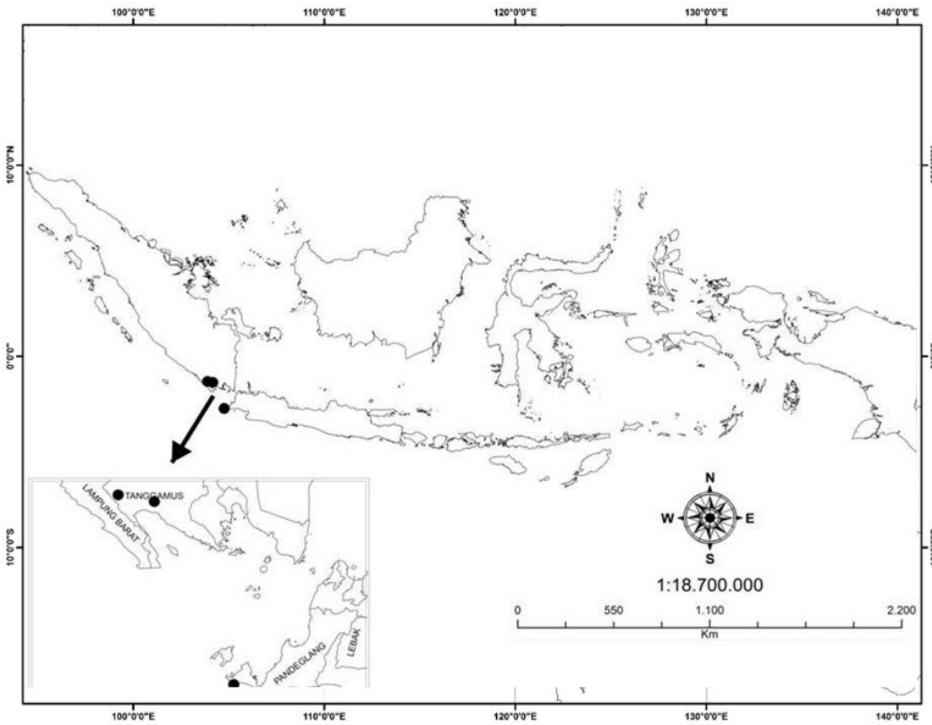

Fig. 4. Distribution of *Canthiumera glabra* var. *laxiflora.*

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NEPENTHES HARAUENSIS, A NEW SPECIES OF NEPENTHACEAE FROM WEST SUMATRA

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ABSTRACT
HERNAWATI, SATRIA, R. & LEE, C. C. 2022. *Nepenthes harauensis*, a new species of Nepenthaceae from West Sumatra. *Reinwardtia* 21(1): 19–23. — A new species of *Nepenthes* (Nepenthaceae) from the Harau region of West Sumatra is described as *Nepenthes harauensis* Hernawati, R.Satria & Chi.C.Lee. This species shares specific characteristics with both *N. bongso* and *N. singalana* but is unique in its thickly coriaceous and petiolate leaves, which are elliptic-oblong and have a distinctly peltate tendril insertion.

Key words: Harau, Nepenthaceae, *Nepenthes*, Sumatra.

ABSTRAK
HERNAWATI, SATRIA, R. & LEE, C. C. 2022. *Nepenthes harauensis,* jenis baru Nepenthaceae dari Sumatra Barat. *Reinwardtia* 21(1): 19–23. — Jenis baru *Nepenthes* (Nepenthaceae) dari kawasan Harau Sumatra Barat dipertelakan sebagai *Nepenthes harauensis* Hernawati, R.Satria & Chi.C.Lee. Jenis ini mempunyai kemiripan karakter morfologi dengan *N. bongso* dan *N. singalana* tetapi memiliki keunikan dalam tekstur daun yang tebal dan kaku, berbentuk jorong yang melonjong, mempunyai tangkai daun dan memiliki sisipan sulur yang jelas menyerupai perisai.

Kata kunci: Harau, Nepenthaceae, *Nepenthes*, Sumatra.

INTRODUCTION

Nepenthes (Nepenthaceae) belongs to the group of carnivorous pitcher plants and is one of the groups with the highest number of species consisting of at least 160–180 species worldwide (Murphy *et al.*, 2020). The island of Sumatra has long been recognized as one of the most diverse regions for the genus *Nepenthes*. Following Clarke's 2001 regional monograph, which listed 29 *Nepenthes* species for the island, eight additional taxa, all endemic, have been described: *N. izumiae* (Clarke *et al.*, 2003), *N. rigidifolia* (Akhriadi *et al*., 2004), *N. jamban* and *N. lingulata* (Lee *et al.,* 2006), *N. flava* (Wistuba *et al.,* 2007), *N. naga* (Akhriadi *et al.,* 2009), *N. putaiguneung* (Metusala *et al.,* 2020), and *N. longiptera* (Victoriano, 2021). The steady rate of these discoveries is likely due to increased exploration of previously inaccessible regions of Sumatra. It suggests that the full diversity of *Nepenthes* on the island is far from being fully resolved.

In 2015, Robi Satria made the first observations of an unidentified *Nepenthes* species in Harau, West Sumatra. Researchers from the Nepenthes-Team Padang (NP-Team Padang) visited the same locality in 2016 but found only a few individual plants that did not have pitchers. In July and September 2021, NP-Team Padang conducted repeat visits to this site and eventually successfully procured complete specimens of this *Nepenthes* that possessed both upper and lower pitchers. Upon detailed examination and comparisons with other Sumatran *Nepenthes*, it was clear that this represented a distinct taxon described herein as a new species.

MATERIALS AND METHODS

The fieldwork was carried out in July and September 2021 in Harau, West Sumatra. The locality and population distribution can be seen in Fig. 1. Morphological characters of *N. harauensis* were photographed and noted from the living plant in the wild. Measurements were made using a ruler and a Vernier calliper. Herbarium specimens were prepared and deposited at Herbarium Universitas Andalas (ANDA). The morphological characters

Fig. 1. Distribution of *Nepenthes harauensis* Hernawati, R.Satria & Chi.C.Lee

of *N. harauensis* were then compared with the collection of specimens of *N. bongso*, *N. ovata*, and *N. singalana* stored in the Herbarium of Andalas University (ANDA) Padang.

RESULTS AND DISCUSSION

Nepenthes harauensis Hernawati, R.Satria & Chi.C.Lee *spec. nov*. — TYPE: INDONESIA, West Sumatra, Lima Puluh Kota, Harau, growing terrestrially on shady sandstone clift, 1,100–1,400 m asl, flowering and fruiting, 22 September 2021, *Nepenthes-Team Padang (Hernawati, Havid, Ihsan), NPT 220921-1* (holotype ANDA!, isotype BO!). Fig. 2.

Nepenthes harauensis has several morphological characteristics similar to *N. bongso*, but the pitcher shape is more like the *N. singalana*. The most prominent distinguishing character is the thick and stiff coriaceous leaf structure, the peltate tendril insertion, and the sheath-like petiole, which clasps the stem for ¾–½ of its circumference.

Terrestrial climber up to 3 m tall. *Rosette* not found. *Short shoots* cylindrical 0.8–1.0 cm with congested leaves (2 per cm of the stem), internodes obscured. *Climbing stem* angular 0.5 cm, internodes 4.0–6.9 cm long. *Leaves of short shoots* thickly and stiffly coriaceous, petiolate; petiole 2.0–5.9 cm long, sheath-like, clasping stem for ¾ circumference; lamina elliptic to oblong, 9.5–15.9 × 5.2–6.7 cm, apex obtuse to truncate, gradually attenuate to the base; midrib flattened above and raised beneath, longitudinal veins 2 on each midrib, inconspicuous, pinnate veins inconspicuous; tendrils 27.0–49.5 cm long, peltate, *ca.* 0.4 cm from the apex. *Leaves of climbing stem* same as those of short shoots but petiole 3.0–4.0 cm long, clasping stem for ½ circumference and not decurrent; lamina elliptic to oblong or slightly spathulate, 8.5–10.0 × 3.5–4.0 cm; tendrils sub-apical close to the apex, 12.0–29.0 cm long with 2–3 curls in the middle. *Lower pitchers* originating abruptly from the tendril, ovoid 1/3–1/2 in the lower half (6.1–9.0 × 3.7–5.2 cm), constricting to the hip, then cylindrical toward the mouth (8.5–12.8 × 2.7–3.9 cm); inner surface pale green on the glandular zone, pale green with dark red blotches on the waxy portion extending from the constriction of the hip to the top of the pitchers; two fringed wings present on the front of the pitcher, 2.9–4.4 × 0.1–0.2 cm, run from the mouth to the bottom, with fringed elements 0.2–0.5 cm long; mouth ovate, oblique throughout, elongated into a short neck (≤ 2 cm) toward the lid; peristome more or less cylindrical, narrow at the front (≤ 0.6 cm), widening toward the rear (≤ 1.4 cm), ribs distinct, ≤ 0.1 cm apart, raised ≤ 0.1 cm, inner margin ending in teeth *ca.* 0.2 cm long; lid cordate to orbicular 4.1–5.1 × 3.6–5.1 cm, apex obtuse, with rounded protrusions, *ca.* 0.2 cm thickness on the lower surface, spaced *ca.* 0.4 cm from the lid tip, glands more or less evenly distributed across the undersurface although larger, and more densely packed along the midrib; spur simple ≤ 0.2 cm long. *Upper pitchers* originating laterally from the tendril, narrowly ovoid in the lower third (4.3–6.0 × 2.4–2.7 cm), constricting to

Table 1. Morphological characters of *N. harauensis*, *N. bongso*, *N. ovata,* and *N. singalana*

Characters	*N. harauensis*	*N. bongso*	*N. ovata*	*N. singalana*
Stem	Cylindrical to angular	Cylindrical to angular	Cylindrical	Cylindrical, occasionally angular
Internode	Obscured on the short shoots; 4.0–6.9 cm long on the climbing stems	≤ 15 cm long on the climbing stems	≤ 15 cm long on the climbing stems	≤ 15 cm long on the climbing stems
Leaves	Stiffly coriaceous, petiolate, clasping the stem, lamina elliptic to oblong	Coriaceous, sessile, lamina spathulate to lanceolate	Coriaceous, sessile to broadly sub-petiolate, lamina lanceolate-spathulate	Thinly coriaceous, sessile, lamina lanceolate to lanceolate-spathulate
Tendril insertion	Peltate/sub-apical	Sub-apical	Apical	Apical
Longitudinal veins	2 on each side of the midrib	2–5 on each side of the midrib	3 on each side of the midrib	3–6 on each side of the midrib
Lower pitcher	Ovoid then cylindrical on the upper part	Broadly ovoid throughout	Broadly ovoid throughout	Narrowly ovoid then cylindrical on the upper part
Peristome	Cylindrical, widening toward the rear	Cylindrical or flattened expanded toward the rear	Flattened expanded toward the rear	Cylindrical, widening to the rear, expanded to the inside
Lid	Cordate to orbicular with a simple thickened bump near the apex	Cordate to orbicular with a simple, bifid, or grossly appendage near the apex	Ovate with a pro-nounced appendage near the basal part	Slightly cordate to orbicular, no appendage
Upper pitcher	Narrowly ovoid cylindrical and widening above	Infundibular	Cylindrical then infundibular above	Narrowly ovoid and cylindrical above
Inflorescence	1-flowered	1-2 flowered	1-flowered	1-flowered

the hip, then cylindrical and widening toward the mouth (8.2–10.7 × 1.2–3.2 cm); inner surface same as that of the lower pitcher but the red blotches in the waxy zone are fewer and smaller; wings reduced to ribs; mouth ovate, oblique throughout, elongated into a short neck (≤ 1 cm), peristome same of those lower pitcher, but narrower (≤ 0.2 cm at the front and ≤ 0.5 cm at the rear) with three small lobes on each side, teeth ≤ 0.1 cm long; lid same of those lower pitcher, but smaller (3.7–4.8 × 2.8–4.0 cm); spur simple ≤ 0.7 cm long. *Male inflorescence* a raceme, peduncle to 11.0–13.0 cm long, rachis 10.0–12.0 cm, pedicels 0.8–1.1 cm long, each bearing a single flower with a filiform bracteole 0.5 × 0.1 cm, spaced *ca.* 0.3 cm from the base of the pedicel, tepal broad ovate 0.5–0.6 × 0.3 cm, pale green, staminal column ≤ 0.3 cm long. *Female inflorescence* is similar to the male but with a longer peduncle (19.5 cm long). *Fruits* capsule 1.1–1.6 × 0.2–0.4 cm. *Indumentum,* all parts of the plant are glabrous. *Colour* of living specimens: stem and midrib pale green, occasionally purplish red; leaves light green above, pale green below; lower pitcher reddish-green with dark red blotches to dark red; upper pitcher pale green; peristome dark red on a lower pitcher and pale green with the dark red stripe on the upper pitcher; inflorescence pale green.

Distribution. *Nepenthes harauensis* is only known from the type locality in Harau, West Sumatra, Indonesia.

Habitat. Growing terrestrially on shady cliffs of the stunted forest of the sandstone hills around Harau. Numerous canyons in Harau are formed among flat-topped sandstone outcrops with near-vertical walls. Tropical lowland evergreen rain forests grow at the bases and summit of the outcrops. Vegetation and open areas which result

Fig. 2. *Nepenthes harauensis* Hernawati, R.Satria & Chi.C.Lee. A. Population of *N. harauensis* in the habitat. B. Habit of the short shoots. C. Leaf apex showing peltate tendril insertion. D. Lower pitcher. E. Upper pitcher. F. Male inflorescence. G. Fruits. H. Glandular zone on the lid. From *Nepenthes-Team Padang (Hernawati, Havid, Ihsan) NPT 220921-1*. Photos by Robi Satria and Havid Ramadhan.

from their structure provide important habitat for several *Nepenthes* species, including *N. adnata*, *N. albomarginata*, *N. eustachya*, *N. longifolia*, and *N. tenuis*. *Nepenthes harauensis* generally grows on cliffs above an altitude of 1,100 m asl.

Etymology. The specific name refers to the place “Harau,” a sub-district of Lima Puluh Kota Regency.

Conservation status. Based on observations, there are at least six populations in the type locality with an estimated number of young plants <100 individuals. Despite having many individuals, this species rarely produces pitchers, especially the upper pitchers. Habitats of *N. harauensis* are located in protected forest areas, so at this time, deforestation is not a serious threat to this species. Illegal collection by plant collectors can be a potential threat if there is no early management of the species. Further observations are still needed to assess the conservation status of *N. harauensis.*

Notes. This species is most readily distinguished from all other Sumatran *Nepenthes* by its unique combination of morphological characters. Particularly unusual are the strongly petiolate leaves, a feature not seen in any other Sumatran montane *Nepenthes*. The peltate tendril insertion is also unusual in the genus *Nepenthes*. In Sumatra, it is only shared with *N. rigidifolia* and *N. bongso*.

Based on the characteristics of the pitchers, *N. harauensis* is appeared to be most closely allied to *N. bongso*, *N. ovata*, and *N. singalana*, none of which occur in the Harau region. From *N. bongso* and *N. ovata,* it can be distinguished in having its pitchers either abruptly cylindrical or slightly expanded in their upper half (vs being ovoid or infundibular throughout). From *N. singalana,* it differs in having a distinctly rounded, thickened protrusion on the undersurface of the apex of the lid. Moreover, a peristome that does not expand on its inner edge. These differences are outlined in Table 1.

Although hybridization is a frequent occurrence among *Nepenthes*, the possibility of a hybrid origin for *N. harauensis* is unlikely, given that there are no putative parental species in the Harau region that could contribute morphological features that are distinct for this species. With the addition of *N. harauensis*, 11 *Nepenthes* species have now been recorded within the Harau region of West Sumatra, making it one of the most diverse localities for this genus. Although most of endemic *Nepenthes* species from Sumatra are restricted to the upper montane mossy forest of the Barisan Mountains, typically above 2,000 m, the highest peak within Harau reaches only 1,460 m. Despite this considerably lower elevation, the stunted forest of the sandstone hills around Harau may mimic certain habitat conditions of higher mountains, making it possible for montane *Nepenthes* to occur at lower altitudes. The presence of *N. inermis* evidences this, a species typically restricted to higher summits, found to grow near *N. harauensis*.

Other specimens examined. INDONESIA, Sumatra, West Sumatra, Lima Puluh Kota, Harau, 1,100–1,400 m asl., 06 July 2021, *Nepenthes-Team Padang (Hernawati, Havid, Ihsan)*, *NPT 060721-1* (ANDA).

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LIGHT PREFERENCES IN TWO LANDSCAPE MANAGEMENTS AND ONTOGENIC LIGHT REQUIREMENTS OF TERRESTRIAL FERNS IN KEBUN RAYA BATURRADEN, CENTRAL JAVA

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ABSTRACT
SEDAYU, A., SARASWATI, R. A. & ASTUTI, Y. P. 2022. Light preferences in two landscape managements and ontogenic light requirements of terrestrial ferns in Kebun Raya Baturraden, Central Java. *Reinwardtia* 21(1): 25–33. — Human management on landscapes influences environmental requirements including solar irradiation, which may affect fern establishment in different age classes. Two contrasting terrestrial fern communities were inspected in Kebun Raya Baturraden, Central Java; the first thrives among the garden (collection) area, representing the well managed area, and the latter living on the less managed area closest to a natural forest remnant. We found 78.7% species living exclusively in either landscape type; only 21% were shared on both, indicating a light preference among ferns and lycophytes. The four most common species (out of 32 fern and lycophyte species), *Cyclosorus heterocarpus*, *Selaginella ornata, Nephrolepis biserrata*, and *Sphaerostephanos arbuscula* in three different age classes and under gradient canopy openness were surveyed. Statistical test on the canopy openness of individuals of *S. ornata* and *N. biserrata* showed that three age categories used significantly different canopy openness, which is not the case for *C. heterocarpus* and *S. arbuscula*. It showed that some ferns and lycophytes ontogenically have gradual requirements on light exposure, while others are able to live in wide range of light exposure. This implies that in terms of wild species management, including ferns, the Baturraden gardens landscape management must be directed toward the ecological understanding of species of interest for Botanical Gardens and conservation.

Key words: Canopy openness, density, garden, less managed area, lycophytes.

ABSTRAK
SEDAYU, A., SARASWATI, R. A. & ASTUTI, Y. P. 2022. Preferensi cahaya dalam dua pengelolaan lanskap dan kebutuhan cahaya ontogenik dari paku-pakuan terestrial di Kebun Raya Baturraden, Jawa Tengah. *Reinwardtia* 21(1): 25–33. — Pengelolaan oleh manusia pada lanskap mempengaruhi banyak persyaratan lingkungan paku-pakuan termasuk penyinaran matahari, yang dapat mempengaruhi kemampuan hidup paku-pakuan di kelas umur yang berbeda. Dua komunitas paku dan likofita yang kontras di Kebun Raya Baturraden telah diobservasi; yang pertama tumbuh di antara areal taman (koleksi), mewakili areal yang dikelola dengan baik, dan yang kedua hidup di areal yang kurang terkelola yang paling dekat dengan sisa-sisa hutan alam. Kami menemukan 78,7% jenis yang hidup secara eksklusif di kedua tipe lanskap; sementara hanya 21% yang berbagi pada keduanya, menandakan preferensi cahaya pada paku-pakuan dan likofita. Empat jenis yang paling umum (dari total 33 jenis paku dan likofita terestrial), *Cyclosorus heterocarpus, Selaginella ornata, Nephrolepis biserrata*, dan *Sphaerostephanos arbuscula* di tiga kelas umur yang berbeda dan di bawah gradien keterbukaan kanopi telah disurvei. Uji ANOVA dan *post-hoc* terhadap bukaan tajuk individu *S. ornata* dan *N. biserrata* menunjukkan bahwa ketiga kategori umur menggunakan bukaan tajuk yang berbeda nyata, tidak demikian untuk *C. heterocarpus* dan *S. arbuscula.* Hal ini menunjukkan bahwa beberapa paku-pakuan dan lycophytes secara ontogenik memiliki persyaratan paparan cahaya yang bertahap, sementara yang lain mampu hidup dalam rentang paparan cahaya yang luas. Hal ini menyiratkan bahwa dalam hal pengelolaan jenis liar - termasuk paku-pakuan, pengelolaan landskap kebun Baturraden harus diarahkan pada pemahaman ekologis jenis yang diminati dan penting bagi Kebun Raya dan konservasi.

Kata kunci: Bukaan kanopi, densitas, kawasan yang kurang dikelola, likofita, taman.

INTRODUCTION

Terrestrial ferns and lycophytes are major components in both natural and man-made landscapes, especially in tropical regions as Indonesia. Due to airborne dispersal of lightweight spore, fern and lycophyte species are easily exchanged across different landscapes. Fern spores are capable to travel long distances by wind and colonize disjunct areas only from a single grain of spore (De Groot *et al.*, 2012). If long distance dispersal is common in ferns, seasonal or continuous short distance travel from two adjacent type of landscapes should be relatively easy (Hock *et al.*, 2006). Spore interchange between two adjacent landscapes means that a generalist species will be able to be found in two adjacent landscapes, while specialist species should be confined to one type of landscape.

One major habitat differentiation in natural and man-made landscape is light environment as a consequence of landscape management. In general, as also in Indonesia, a more natural landscape will be characterized by a more forested, thus higher canopy coverage which filters light on the undergrowth vegetation including ferns and lycophytes. The man-made landscape is abundance of light exposure in a more open landscape. Species of terrestrial ferns and lycophytes colonizing the two light environments may be distinct as classically expressed as *sun ferns* in the open and *shade ferns* in the more forested area (Holttum, 1966). The KR (*Kebun Raya* = Botanic Garden) Baturraden was designed as gardens adjoining the remnant forest on the slope of Mt. Slamet (3,428 m) in Central Java, providing suitable locations to study the ferns and lycophytes inhabiting two light environments, shaded on the less managed-forested area and open on the garden-well managed area.

Researches on the light environments of ferns and lycophytes have been conducted mostly in natural forest landscapes (Saldaña *et al.*, 2005; Sedayu, 2006; Saldaña *et al.*, 2007); however, as the growing population demand, and more land converted into man-made landscape, including gardens, it is important to understand the biology and ecology of species that reside in the garden. With the position of KR Baturraden adjoining the natural remnant forest, it is possible that certain parts of the garden may act as refugia for forest fern and lycophyte species, as also studied in the spermatophytes (Tadesse *et al.*, 2014; Atha *et al.*, 2016). Thus, understanding the light preference of ferns living in the garden (those excluding the collections) may also contribute to the conservation of Javan mountain forest ferns and lycophytes.

During their ontogenic course of development, plants, including ferns and lycophytes are constantly adjusting their energy requirements with the energy available (Lusk *et al.*, 2008). It is known that a seedling may require less light during their development, and larger saplings or trees require larger amount of light exposure for photosynthesis as they approach their generative cycle/maturity (Kenzo *et al.*, 2006), while the morphology, physiology and biochemistry of the plants are adjusting accordingly. We expect to understand this pattern in the fern and lycophyte assemblages within the KR Baturraden during their different ontogenic development (age classes). This study may contribute to understanding the life of forest, and perhaps, protected species, as well as open garden, and perhaps, potential weed species. In general, this study will broaden our understanding upon the less studied ferns and lycophytes in comparison to the studies largely for spermatophytes.

MATERIALS AND METHODS

Study Site

The KR Baturraden is a 143.5 hectares garden located right in the center of Java (Fig. 1, inset), with elevation between 702–1,076 m above sea level, and terrain inclination between 20–70%. The annual temperature ranged between 20–30°C, while humidity between 85–98% and precipitation between 5,000–6,174 mm, classified as *Af* (tropical rain forest) in Koppen-Geiger classification (Peel *et al.*, 2007). The gardens were laid in various landscape management, from reserve forest with natural-semi natural forest vegetation at the slope of Mt. Slamet, low utilization zone, on which, mid utilization zone, on which and intensive utilization zone where well managed gardens, amenities and public services are located.

Total of 135, 1 × 1 m, quadrats were purposely laid down to exemplify two contrasting environments. Sixty-eight quadrats were laid at the boundary between forest and gardens (Fig. 1, A), representing the less managed area of the gardens, while 67 we laid on the more managed areas or coincided with the intensive utilization zone (Fig.1, right). These 67 quadrats are 12 on Flora of Java Gardens I, 10 Flora of Java Gardens II, 15 on Liana Gardens, 15 White Latex Gardens and 15 on Fern Gardens, respectively (Fig. 1, B1–B5). The quadrats in B1–B5 coincide with the intensive utilization zone (Fig. 1, right).

Fig. 1. Study site: approximate location of quadrats (left); map of land utilization in KR Baturraden (right, Departemen Pekerjaan Umum, 2005); Inset: location of KR. Baturraden in Central Java.

Quadrat sampling and hierarchical clustering

Within a single quadrat, the presence and absence of species of terrestrial ferns and lycophytes were noted and arranged in a present-absent matrix. Only native taxa were noted in this study, with omitting cultivated species. In gardens (especially the fern gardens), extremely careful consideration was made to justify whether an individual sighted is regarded as wild (at least escapee) or as cultivated. Some native species, e.g. *Alsophila junghuhniana* might start as wild sporeling and kept as a decorative landscape adornment. The matrix is converted into a distance matrix using binary method and subsequently reconstructed using hierarchical clustering (*hclust*) into a fan-shaped dendrogram using *as.phylo* plotting method. Herarchical clustering was done in R Studio version 3.6.1 (R Studio Team, 2020). Identification was done using Flora Malesiana Series 2 Pteridophytes vol. 1–4 (1959–2012).

Fern and lycophyte density

As the number of every fern and lycophyte within all quadrats are noted, we were able to count the density of the species for the whole sampling area. The density of a species is denoted as the number of individual/the total of quadrat area. We then assigned four species of the highest density for the following study.

The canopy openness effect on different fern/ lycophyte age classes

We used four species with the highest densities to further study the effect of light exposure on different fern and lycophyte age classes. Every individual of these species (i.e. *Cyclosorus heterocarpus, Selaginella ornata, Nephrolepis biserrata,* and *Sphaerostephanos arbuscula*; see Table 1) were assigned to one of three age classes: (1) sporelings, i.e., individuals with few fronds and/or with primordial frond still visible; (2) juveniles, i.e., individuals with larger fronds, however non spore-producing; and (3) adults, i.e., individuals with sori-producing fronds.

We used canopy openness to exemplify the environmental solar exposure. Canopy openness was measured using GLAMA (Tichý, 2016) on Realme C2 mobile phone, right above the crown of each individual. The difference of canopy openness among age classes was calculated using one way ANOVA and was done in R Studio. When significant, Tukey's post-hoc test was applied on the pairs.

RESULTS

Clustering

Hierarchical clustering showed that the terrestrial fern and lycophyte communities within the study area are clustered distinctively based on land management. Fig. 2 shows that the quadrats

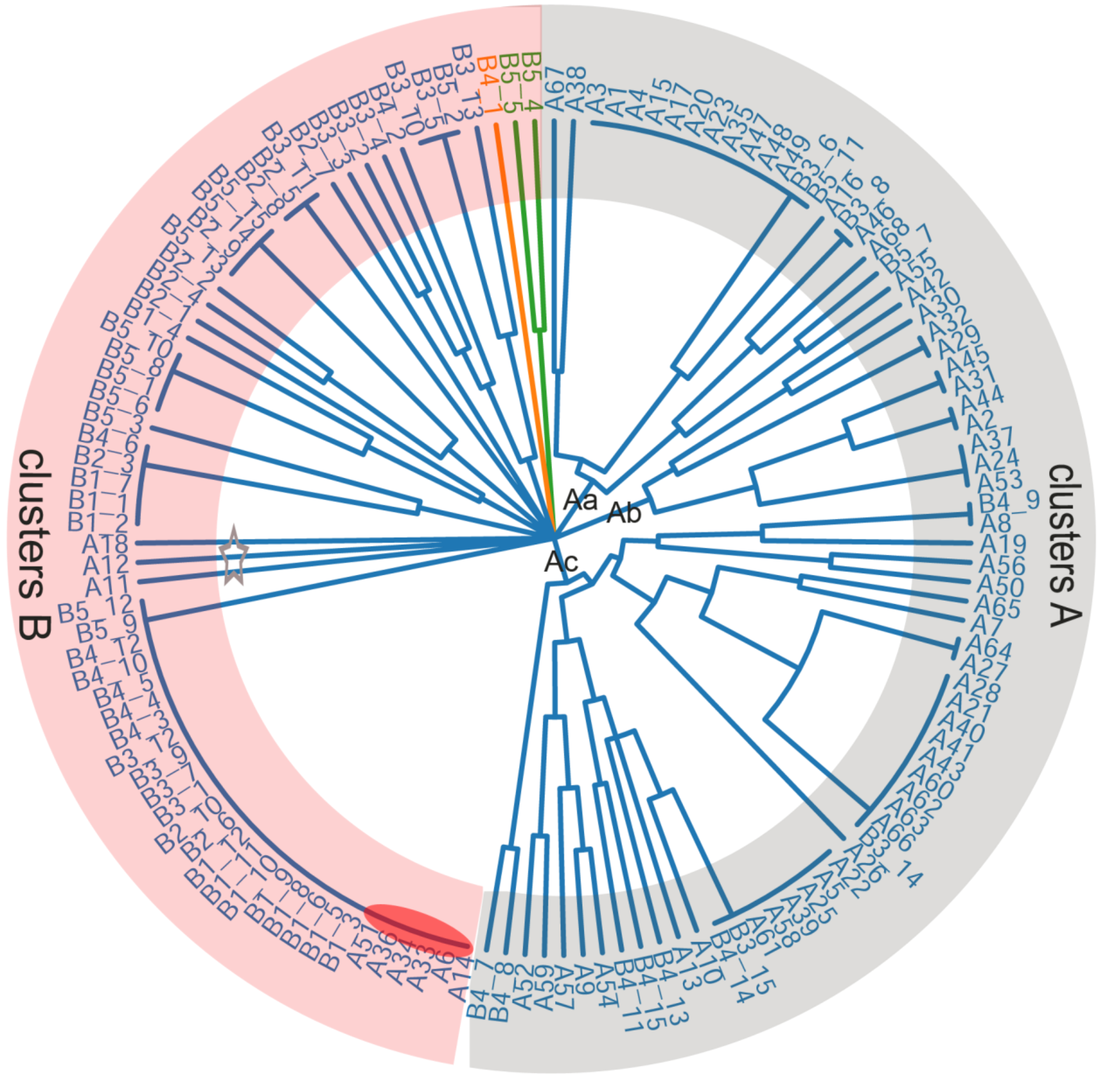

Fig. 2. Dendrogram of terrestrial ferns and lycophytes communities. Cluster A represents quadrats in forested-less managed area; Cluster B represents quadrats in gardens-well managed area.

laid on the forest-forest edge (A) are clustered into 3 major clusters (Aa, Ab and Ac; highlighted in grey) with some B quadrats, squeezed in among A, for instance B3_6 and B5_11 within cluster Aa and B5_7 in cluster Ab. Cluster Ac consist of 40 quadrats, with 39 (78%) belong to A group, with 9 quadrats belong to B group. The other part conversely composed of largely B quadrats (highlighted in pink) included only 9 quadrats belong to A group (6 in a red ellipse mark and 3 with the star mark); however, since the part collapsed in the base.

Species assemblage and the four highest density terrestrial ferns and lycophyte

We found 32 species of ferns and lycophytes, consisted of 27 species of ferns and five species of lycophytes, all of which from the genus *Selaginella* (Table 1). Twelve species were found exclusively in the forested-less manage quadrats (A), as opposed to 13 species found only in garden-well managed quadrats (B). Only seven species overlapped in both landscapes. The vegetation analysis reckoned four species with the highest density subsequently chosen for light environment study.

Light environment of four chosen ferns and lycophyte in in three age classes

Table 1 showed that *Cyclosorus heterocarpus* and *Sphaerostephanos arbuscula* did not indicate any distinction in light enviroments across three different age classes as showed by the non-significant ANOVA test. On the contrary,

Table 1. Density of the terrestrial ferns and lycophytes within two differently managed area in the KR Baturraden; boldface denotes species with highest density; A: forest-less managed area; B: gardens-well managed area; A+B: present in both A and B; 1: present; 0: absent; taxonomy follows PPG I (PPG I, 2016).

No	Family	Species	Density (indvidu/m^2)	A	B	A+B
1	Athyriaceae	*Deparia confluens* (Kunze) M.Kato	0.0963	0	1	0
2	Athyriaceae	*Deparia petersenii* (Kunze) M.Kato	0.02222	0	1	0
3	Athyriaceae	*Diplazium bantamense* Blume	0.2	1	0	0
4	Athyriaceae	*Diplazium pallidum* (Blume) T.Moore	0.18519	1	0	0
5	Athyriaceae	*Diplazium subserratum* (Blume) T.Moore	0.4444	1	1	1
6	Blechnaceae	*Blechnum orientale* L.	0.03704	0	1	0
7	Cyatheaceae	*Alsophila junghuhniana* Kunze	0.02222	1	1	1
8	Cyatheaceae	*Sphaeropteris glauca* (Blume) R.M.Tryon	0.04444	0	1	0
9	Cyatheaceae	*Sphaeropteris squamulata* (Blume) R.M.Tryon	0,02963	1	0	0
10	Dennstaedtiaceae	*Histiopteris incisa* (Thunb.) J.Sm.	0.04444	1	0	0
11	Didymochlaenaceae	*Didymochlaena truncatula* (Sw.) J.Sm.	0.00741	0	1	0
12	Dryopteridaceae	*Dryopteris sparsa* (D.Don) Kuntze	0.03704	1	1	1
13	Gleichenicaeae	*Dicranopteris linearis* (Burm.F.) Underw.	0.00741	1	0	0
14	Lindsaeaceae	*Lindsaea lobata* Poir.	0.02222	1	0	0
15	Lindsaeaceae	*Nesolindsaea caudata* (Hook.) Lehtonen & Christenh	0.01481	1	0	0
16	Nephrolepidaceae	***Nephrolepis biserrata* (Sw.) Schott (3)**	**0.85926**	1	1	1
17	Pteridaceae	*Pityrogramma calomelanos* (L.) Link	0.04444	1	1	1
18	Selaginellaceae	*Selaginella doederleinii* Hieron	0.35556	0	1	0
19	Selaginellaceae	***Selaginella ornata* (Hook. & Grev.) Spring. (2)**	**1.05185**	1	1	1
20	Selaginellaceae	*Selaginella plana* (Desv. ex Poir.) Hieron	0.16296	0	1	0
21	Selaginellaceae	*Selaginella* sp.1	0.02222	1	0	0
22	Selaginellaceae	*Selaginella willdenowii* (Desv. ex Poir.) Baker	0.01481	1	0	0
23	Tectariaceae	*Tectaria* sp.1	0.05185	0	1	0
24	Thelypteridaceae	*Christella dentata* (Forssk.) Brownsey & Jermy	0.05926	0	1	0
25	Thelypteridaceae	*Christella* sp.1	0.02222	0	1	0
26	Thelypteridaceae	***Cyclosorus heterocarpus* (Blume) Ching (1)**	**1.08148**	1	1	1
27	Thelypteridaceae	*Cyclosorus repandus* (Fée) B.K.Nayar & S.Kaur	0.05185	0	1	0
28	Thelypteridaceae	*Amblovenatum terminans* (Wall. ex Hook.) J.P.Roux	0.01481	1	0	0
29	Thelypteridaceae	*Pneumatopteris* sp.1	0.17037	0	1	0
30	Thelypteridaceae	***Sphaerostephanos arbuscula* (Willd.) Holttum (4)**	**0.77778**	0	1	0
31	Thelypteridaceae	*Thelypteridaceae* sp.1	0.00741	1	0	0
32	Thelypteridaceae	*Thelypteridaceae* sp.2	0.00741	1	0	0
				19	20	
			TOTAL	(12+7)	(13+7)	7

Table 2. Canopy openness above terrestrial fern and lycophyte individuals in three age classes and its ANOVA test; mean in percent followed by same letter on the same line does not differ significantly (0.05) according the Tukey's post hoc test; species sequence sorted from largest density; boldface denotes P-value < 0.05.

No	Species	Sporeling		Juvenile		Adult		F	P-value
		Mean	± SE	Mean	± SE	Mean	± SE		
1	*Cyclosorus heterocarpus*	12.43	1.1	16.24	0.85	15.08	1.29	2.865	0.06
2	*Nephrolepis biserrata*	15.33^{a}	1.34	16.23^{a}	1.15	32.99^{b}	0.87	5.364	**0.006**
3	*Selaginella ornata*	14.7^{ab}	1.1	17.39^{b}	1.13	11.07^{a}	0.77	5.809	**0.004**
4	*Sphaerostephanos arbuscula*	23.65	1.26	27.58	1.79	-	-	3.403	0.069

Nephrolepis biserrata showed significant difference in adult age class while *Selaginella ornata* in all three age classes with slightly different trend.

DISCUSSION

Fern and lycophyte communities in two contrasting landscapes

The results of clustering analysis (Fig. 1) can be considered as a clear grouping of terrestrial fern and lycophyte communities in the study area, with the more forest-less managed area (A) forming into clear clusters but B did not form apparent clusters. Since the clusters was made of the present-absent data of ferns and lycophytes species, this implied that species living in the more forested-less managed area are composed of different species compared to more open gardens-well managed area. The tendency of fern and lycophyte to occupy different light exposure in the forest had been studies (Sedayu, 2006), however light exposure effects on the ferns in man-made landscape as gardens are not well documented.

The clear clustering of the As separated from the Bs can be explained in the high number of species living exclusively in only one type of landscape management. Out of 19 species found in As, 12 species found exclusively in the A, while the opposite, out of 20 species found in B, another different 13 species found living there. Both (12 in A and 13 in B) made up 25 species or 78.1% of overall species in the study area living solely in one type of landscape management. This clearly shows that species established in forest-less managed area differ from those in gardens-well managed area.

One of the most important determinants for species diversity is land cover (Čepelová & Münzbergová, 2012). Our finding at Kebun Raya Baturraden confirmed this, as there is high number of species living in only in forest-less managed area, absent in the gardens-well managed area. In forest-less managed area, the land cover is denser due to its proximity to the forest, while sparser on gardens-well managed areas. Ecologically, ferns and lycophytes are traditionally grouped into sun fern with the tendency of living in the open area and shade fern living under the cover of trees (Holttum, 1938; 1966). Our finding might have reflected this as species found in the forest-less managed area are mostly known shade/forest fern. One exception is *Dicranopteris linearis*, which is largely considered as sun fern (Yang *et al.*, 2020), found in this study only in forest-less managed area. *D. linearis* is infamously noxious, that they are always weeded out in their early life stages in gardens-well managed area.

Many species living in the gardens-well managed area are indeed sun ferns. One notable species is *Christella dentata*, a well-known sun-loving ferns, sometimes considered as weed (Yañez *et al.*, 2020) found only in gardens-well managed area. Others, like *Sphaeropteris glauca, Blechnum orientale* and *Selaginella plana* are also known for their resilience for high solar exposure on their crown (Holttum, 1966).

Only seven species of ferns and lycophytes are found on both A and B (*Diplazium subserratum, Alsophila junghuhniana, Dryopteris sparsa, Nephrolepis biserrata, Pityrogramma calomelanos, Selaginella ornate*, and *Cyclosorus heterocarpus*; Table 1). This means that the two landscape management types shared only 21.8% of their fern and lycophyte species, not with standing the adjacent position of the two landscape managements.

Out of seven species found on both forest-less managed and gardens-well managed area (*Diplazium subserratum, Cyathea junghuhniana,* *Dryopteris expansa, Selaginella ornata, Nephrolepis biserrata, Pityrogramma calomelanos,* and *Cyclosorus heterocarpus*), first four were forest species, while the latter three are known to thrive prolifically in wide range of habitats, even in cities. It is not surprising that all three latter species are included in the list of species with highest density (Table 1) in the study area.

The occurrence of two tree fern species, *Sphaeropteris glauca* and *Alsophila junghuhniana*, in the gardens-well managed area must be noted particularly. These two native forest species found in gardens-well managed area are evidences that gardens-well managed area may serve as refugium of wild species from forest (Vojík *et al.*, 2020). In our study this role is highlighted as *S. glauca* and *A. junghuhniana* are among those regulated by CITES Appendix II, and coincidentally showing decorative appearance as garden adornment. The gardeners of KR Baturraden might inadvertently keep the attractive tree ferns within the garden proper though they are adventive plants (spontaneous recruits). By letting those two species thrive in the garden, the keeper not only accommodate the refuge of forest species in the garden, but also conserves two species listed in CITES Appendix II. As ferns mostly are dispersed by airborne spores, gardens-well managed area may receive 'spore rain' from the forest, as well as other place, thus serve as refugium for forest species. When adequately directed on forest species conservation priority, garden managements, operators and possibly visitors may have important role in the conservation of forest (and protected) species.

Light exposure on three age classes of the common fern species

To further understand the role of solar irradiation in the life stages of common ferns and lycophytes, we chose the four species with highest density within our study site and measured the canopy openness above the plots. It turns out that two species, *Selaginella ornata* and *Nephrolepis biserrata*, prefer significantly different degrees of canopy openness among the three age classes (Table 2). Conversely, two species of Thelypteridaceae, *Cyclosorus heterocarpus,* and *Sphaerostephanos arbuscula*, did not show any preference for a certain canopy openness regime. They tend to occupy similar light exposures at all stages; however, *Sphaerostephanos arbuscula* is found only in two age classes in the study area. The adult individual of this species is quite robust and might be spotted and weeded out by the garden keepers.

In *Nephrolepis biserrata* and *S. ornata* the significant inclination toward canopy openness in different age classes signifies that each age class in both species thrive in different light exposure. In *N. biserrata,* difference between adults and sporeling-juvenile was significant by the post-hoc test (p-value = 0.006, Table 3). This might be an indication that during the age class of spore germination (sporeling) through the establishment of the sporophytes (juvenile), *N. biserrata* may thrive in less light exposed area; while as adult, during the spore producing age class, with larger energy demand in spore production, *N. biserrata* are found more in the open canopy area. This means that during the establishment through the adult stage, many individuals of *N. biserrata* were singled out in the less exposed area. Those living in the more exposed area would thrive better and reaching the adult, spore producing stage, more than those in closed area.

It is almost similar case in *S. ornata*, regardless the difference the data may look. It looks that the juvenile age class occupies higher light exposure area compared to the sporeling age class, while the adults occupied in the area with lowest light exposure. Is it because that the adult, spore producing *S. ornata* requires less solar energy for photosynthesis? We believe this is unlikely the case, since the trend of *S. ornata* light requirement in sporeling age class is significantly (p-value = 0.004) increasing in the juvenile age class, and supposedly even higher in adult age class.

The significant drop of light exposure in the adult age class individuals may not reflect the physiological demand of *S. ornata*, but instead the garden management. Many *Selaginella* grow into untidy bush-like clumps, and may be seen as potential weed by gardeners. We think this is exactly the reason why more individuals of adult age class of *S. ornata* found in low canopy openness area, closest to the forest-less manages area, for those living in the open, garden-well managed area are weeded out by the gardeners. The result is many sporeling and many more juvenile individuals in garden-well managed area.

These results in general show that different species of ferns and lycophytes may perform differently under the same light exposure at different age classes. Thelypteridaceae species like *Cyclosorus heterocarpus* and *Sphaerostephanos arbuscula* may not demand light exposure differently during their different age classes; however, species like *N. biserrata* and *S. ornata* may require different light environment during their life stages. The case of *N. biserrata* and *S. ornata* may be comparable to several Bornean tropical rain forest Dipterocarps

(*Dipterocarpus globosus, Dryobalanops aromatica, Shorea acuta, S. beccariana,* and *S. macroptera*), which not only exhibit different light requirement during the growth of the stem, but also different morphological and ecophysiological traits during different life stages (Kenzo *et al.*, 2006). Reflecting to this study in Dipterocarps, it is implied that there should be further study in ferns and lycophytes in terms of morphology and physiology and biochemical properties during different life stages, affected by light environment as comparisons to the widely studied spermatophytes.

Our findings suggest that while fulfilling its task as education and scientific center in providing *ex situ* specimens of living plants, Kebun Raya Baturraden has a great potential to fulfill another task as *in situ* conservation and refugium area for species from the neighboring forest. This may be accomplished by adjusting its management according to protected species, like *Sphaeropteris glauca* and *Alsophila junghuhniana*. Furthermore, Kebun Raya Baturraden may participate in the conservation of forest ferns and lycophytes of Java by adjusting its management according to the ecophysiology, including ontogenetic light requirements, of ferns and lycophytes living in garden-well managed area as well as forest-less managed area.

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A NEW SPECIES OF *MUKIA* (CUCURBITACEAE) FROM SUMBA ISLAND, INDONESIA

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ABSTRACT
PRATAMI, M. P., CHIKMAWATI, T. & RUGAYAH. 2022. A new species of *Mukia* (Cucurbitaceae) from Sumba Island, Indonesia. *Reinwardtia* 21(1): 35–40. — *Mukia sumbensis* Pratami is described and illustrated as well as compared with its closely related species *M. maderaspatana* (L.) M.Roem. and *M. leiosperma* (Wight & Arn.) Wight. It differs in its tendril size, stem diameter, petiole hairiness, midrib indumentum on upper leaf surface, as well as in shape, margin, and surface of seed. Anatomically the leaf of the new species has two palisade layers, unlike the other two species which have only one layer.

Key words: Cucurbitaceae, *Mukia,* new species, Sumba.

ABSTRAK
PRATAMI, M. P., CHIKMAWATI, T. & RUGAYAH. 2022. Jenis baru *Mukia* (Cucurbitaceae) dari Pulau Sumba, Indonesia. *Reinwardtia* 21(1): 35–40. — *Mukia sumbensis* Pratami dipertelakan dan dibuat ilustrasinya. Jenis tersebut berkerabat dekat dengan *M. maderaspatana* (L.) M.Roem. dan *M. leiosperma* (Wight & Arn.) Wight tetapi berbeda pada ukuran sulur, diameter batang, rambut pada tangkai daun, dan juga pada ibu tulang daun, serta bentuk, ukuran, tepi, dan permukaan biji. Secara anatomi jenis baru ini memiliki dua lapisan palisade, tidak seperti dua jenis lainnya yang hanya memiliki satu lapis.

Kata kunci: Cucurbitaceae, jenis baru, *Mukia*, Sumba.

INTRODUCTION

Mukia Arn. is a cucurbitaceous genus of nine species distributed in Africa, South Asia, South-East Asia, and Australia (de Wilde & Duyfjes, 2010). The genus was firstly published by Arnott (1840), with one species *M. scabrella* (L.) Arn. as type species (now *M. maderaspatana* (L.) M.Roem.). In Australia, Telford (1982), enumerated six species, two of them *M. maderaspatana* (L.) M.Roem and *M. micrantha* (F.Muell.) F.Muell [now, *Austrobryonia micrantha* (F.Muell.) I. Telford] were widespread and polymorphic, while the other species were not validly published (Schaefer *et al.*, 2008). As many as six species have been recorded in Asia by de Wilde & Duyfjes (2006), namely *Mukia gracilis* (Kurz) W.J.de Wilde & Duyfjes, *M. rumphiana* (Scheff.) W.J.de Wilde & Duyfjes, *M. ritchiei* (C.B.Clarke) W.J.de Wilde & Duyfjes, *M. javanica* (Miq.) C.Jeffrey, *M. leiosperma* (Wight & Arn.) Wight, and *M. maderaspatana* (L.) M.Roem.

Based on molecular data, the Asian species were found to be nested within the *Cucumis* (Schaefer, 2007; Renner *et al.*, 2007; Ghebretinsae *et al.*, 2007a; Telford *et al.*, 2011). Therefore, they transferred all of them to *Cucumis* (Ghebretinsae *et al.*, 2007b).

Nevertheless, in revising the Malesian Cucurbitaceae, de Wilde & Duyfjes (2010) continued to recognize *Mukia* as distinct from *Cucumis*. Pratami *et al.* (2019) found further seven seed characters (colour, shape, size, surface pattern, seed edge, transverse section at seed neck, and the markings of the inner seed coat surfaces), it supported de Wilde & Duyfjes in separating *Mukia* from *Cucumis*. Further molecular analysis on this group by Pratami *et al.* (2020) showed that, ISSR

Table 1. Characters differences of *M. maderaspatana, M. sumbensis,* and *M. leiosperma*

No	Character states	*M. maderaspatana*	*M. sumbensis*	*M. leiosperma*
1	Stem diameter	0.4–1.4 mm	1.8–1.9 mm	0.8–1.2 mm
2	Tendril	Thin (0.1 mm)	Thick (0.2 mm)	Thin (0.1 mm)
3	Indumentum types of petiole	Scabrous and hispid	Retrorse	Villous
4	Midrib indumentum size on upper leaf surface	Uniform	Not uniform	Uniform
5	Indumentum colour	Whitish, not shiny	Whitish, not shiny	Golden, shiny
6	Seed shape	Broadly ovate	Ovate	Ovate
7	Average seed size	4.27 × 3.16 mm	4.31 × 2.96 mm	5.50 × 3.40 mm
8	Seed surface	Convex and irregularly papillate	Convex and pitted or nearby smooth	Flat and smooth
9	Stomata in adaxial surface	Present	Absent	Absent
10	Size of stomata	19.70 × 11.31 µm	61.86 × 42.17 µm	21.92 × 14.21 µm
11	Size of epidermal cells	31.89 × 21.41 µm	159.15 × 105.40 µm	56.60 µm × 31.14 µm
12	Palisade layer	One	Two	One

markers can be used to distinguish *Cucumis* and *Mukia* as separate genera.

In working out all specimens of *Mukia* deposited in Herbarium Bogoriense (BO), there is one specimen *Iboet 497* from Sumba which has different characteristics from the other species of *Mukia.* Previously, de Wilde & Duyfjes have already noted on the specimen sheet that it has hairy petiole and different seed edges, which differ from *M. maderaspatana.* Therefore, we decided to do further observations on this specimen as well as on *M. leiosperma.*

MATERIALS AND METHODS

Morphological observations were carried out on all specimens of *Mukia* – in all numbering 285 sheets – deposited in Herbarium Bogoriense (BO) and in National Herbarium of the Netherlands (virtual herbarium).

Leaf anatomical preparations of *Iboet 497* herbarium specimen, has been made at the Laboratory of Ecology and Plant Resources, Department of Biology, IPB University, by making paradermal and transversal sections using Sass methods (1951). For the *M. maderaspatana* we used specimens *MPP 24, MPP 25*, and *MPP 55,* while for *M. leiosperma* specimens *Sauliere 68* and *Sauliere 142* were used.

RESULTS AND DISCUSSION

The results of our morphological observations on *Iboet 497*, showed that if it compared with *M. maderaspatana* it has bigger stem diameter, thicker tendril, retrorse indumentum on petiole, bigger indumentum on midrib, and pitted surface of its seed. Comparison with *M. leiosperma* showed that *Iboet 497* has similar shape, size, and colour of fruit characters, but it has thinner tendril, smaller seeds which have smooth surface (Table 1).

Table 1 as well as the accompanying Fig. 2 and Fig. 3 also summarises the results of our anatomical observations of the three species. It shows that the transversal leaf section has two layers of palisade tissue of *Iboet 497*.

Mukia sumbensis Pratami *spec. nov*. — TYPE: INDONESIA, Sumba, Taimanga, Kenangar, 15 Mei 1925, *Iboet 497* (holotype BO!, isotype L [photo!]). Figs. 1–3.

Morphologically the new species is closely related to *M. maderaspatana* but it has bigger stem

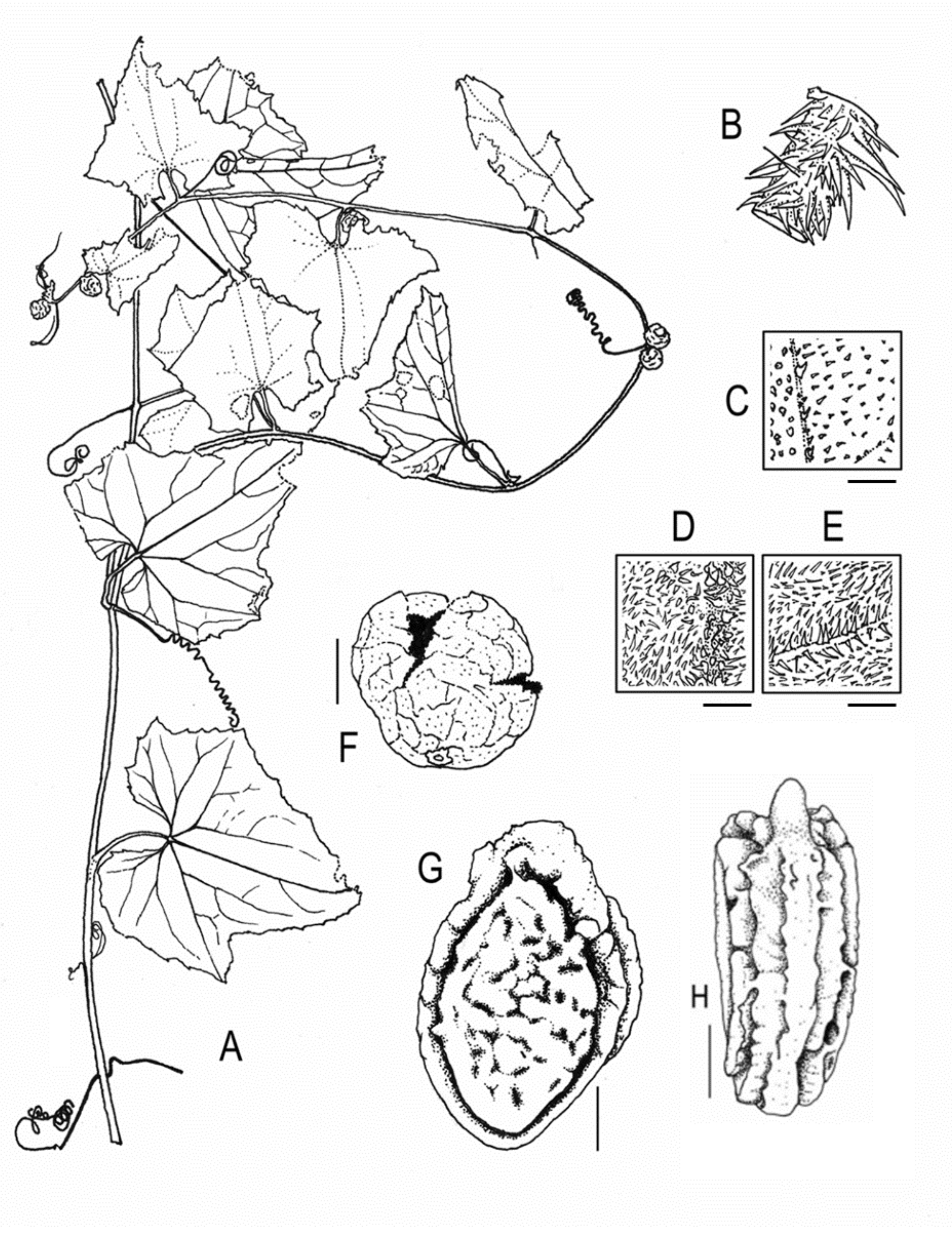

Fig. 1. *Mukia sumbensis* Pratami *spec. nov*. A. Habit, climbing stem. B. Petiole. C. Leaves adaxial. D–E. Leaves abaxial. F. Fruit. G. Seed. H. Seed edge. Scale bar = 1 mm. From *Iboet 497*. Drawn by W. A. Mustaqim.

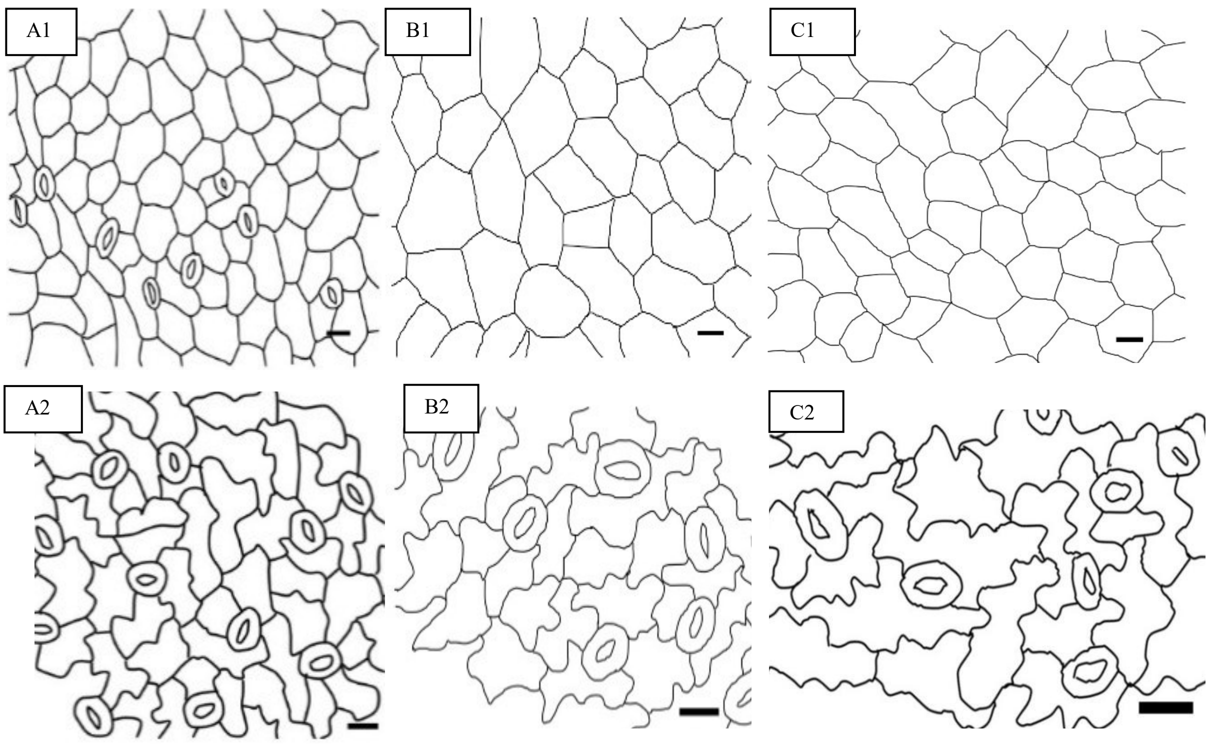

Fig. 2. Leaf anatomy (paradermal section) of *Mukia* spp. A. *Mukia maderaspatana**. B. *M. sumbensis*. C. *M. leiosperma*. 1. adaxial surface. 2. abaxial surface. Scale bar = 20 µm. *Photo taken from Pratami *et al.* (2019).

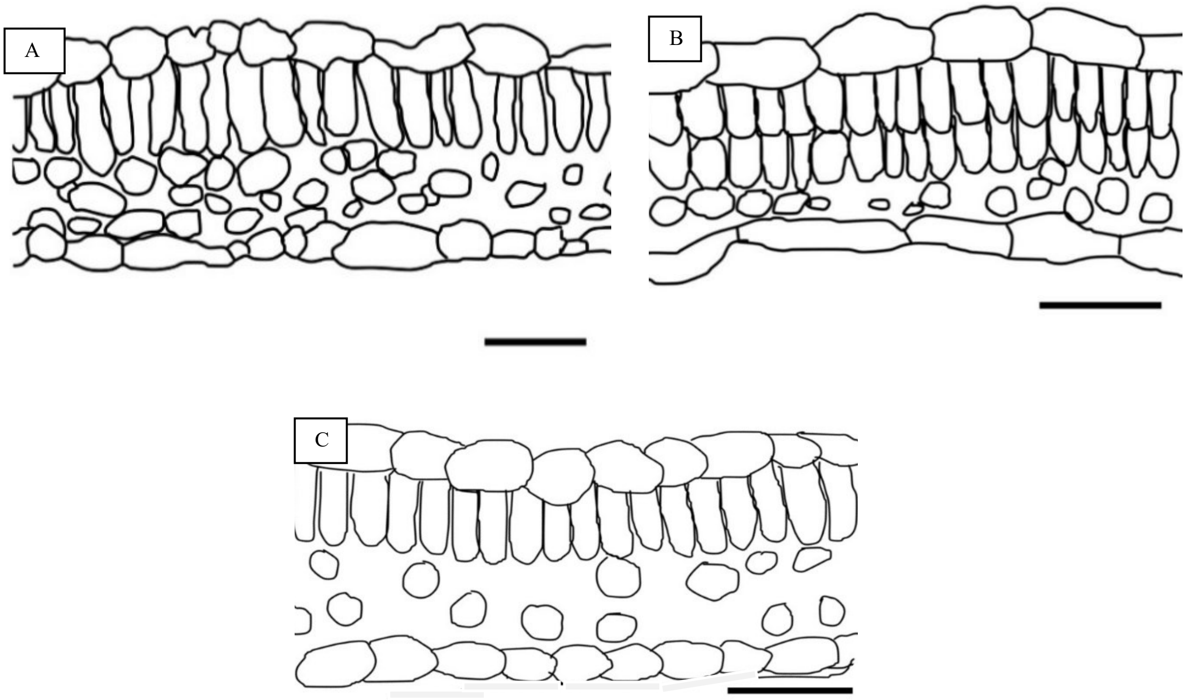

Fig. 3. Leaf anatomy (transverse section) of *Mukia* spp. A. *Mukia maderaspatana**. B. *M. sumbensis*. C. *M. leiosperma*. Scale bar = 50 µm. *Photo taken from Pratami *et al.* (2019).

diameter, thicker tendril, retrorse indumentum on petiole, bigger indumentum on midrib, and pitted surface of its seed. Compared to *M. leiosperma* however, it has thinner of tendril, smaller size of seeds which have smooth surface.

Climbing herbs, monoecious. *Stem* scabrous or stiffly-hairy, 1.8–1.9 mm diameter. *Probract* absent. *Tendrils* simple and thick (0.2 mm). *Leaves*: petiole 1.7–2.3 cm long, 0.7–0.9 mm diameter, hispid with short to long, downwardly curved hairs (retrorse); blade subentire or 3–5-lobed, broadly ovate, subcircular or broadly hastate in outline, 10–29 cm diam., base shallowly to deeply cordate, apex acuminate, margin variously up to 5 mm dentate, upper leaf surface hispid or scabrous-hairy, lower leaf surface hirsute hairy, bigger on midrib, indumentum color withish not shiny. *Male flowers* in fascicles of 2–20; pedicel 1–2 (–10) mm long. *Female flowers* solitary or in group up to 8; pedicel 1–2 mm long; calix and corolla not seen. *Fruit* 1–2 in axillary clusters, pedicel 0.2–0.5 cm, green and pale green, ripening red, darker striped or not, globose, 0.5–1.5 cm diam., with few coarse hairs; coarsely wrinkled when dry. *Seeds* numerous, whitish or pale brown, seeds not shining, ovate, 4.31 mm by 2.96 mm, margin narrow, faces convex, pitted or nearly smooth, groove along the edges of the seed.

Paradermal leaf section showed that anatomically the anomocytic stomata are confined to the abaxial surface, scattered among the irregularly shaped epidermal cells which are somewhat elongated, bumpy or lobed. From the leaf transversal section, characteristically it has two layers of palisade tissue.

Distribution. So far only known from Sumba.

Habitat & Ecology. Highland forest.

Etymology. The specific epithet refers to the name of the Island.

Conservation status. The status of this species is unknown according to the criteria of IUCN Red List. However, it can be categorized as an endangered new species, because so far it was only found once in one location.

Rarity note. Admittedly, the characterization of *M. sumbensis* is only based on a single herbarium specimen collected almost a century ago from a semi arid area in the Lesser Sunda Islands group. Nevertheless, we believe that the publication of this new species belonging to a problematical genus is fully justified especially to draw special attention to the need to do further explorations to recollect and to ascertain its very existence in relation to the present precarious situation due to the threat of extreme climate changes now taking place.

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ERRATA

WIDODO, P. & VELDKAMP, J. F. The confusing taxonomy and nomenclature of *Syzygium confusum* complex (Myrtaceae).

In the article entitled "The confusing taxonomy and nomenclature of *Syzygium confusum* complex (Myrtaceae)" by WIDODO, P. & VELDKAMP, J. F. Reinwardtia 20(2): 43–49.

DOI: 10.14203/reinwardtia.v20i2.4160, the following changes should be made:

On p. 45, in the description of 3rd species "3. SYZYGIUM BLUMEI (Steud.) Merr. & L.M.Perry — Fig. 3." should be changed to "3. SYZYGIUM BLUMEI (Steud.) Merr. & L.M.Perry — Fig. 3 A."

On p. 46, in the description of 4th species "4. SYZYGIUM INSIGNE (Blume) Merr. & L.M.Perry — Fig. 4." should be changed to "4. SYZYGIUM INSIGNE (Blume) Merr. & L.M.Perry — Fig. 3 B."

On p. 46, in the description of 5th species "5. **Syzygium sipirokense** Widodo & Veldkamp *spec. nov.* **—** Fig. 5." should be changed to "SYZYGIUM BLUMEI (Steud.) Merr. & L.M.Perry — Fig. 3 C."

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