Journal Of Biology Education Research (JBER)
Vol 6(1) 2025 | ISSN: 2774-7859
DOI: 10.55215/jber.v6.i1.31
https://journal.unpak.ac.id/index.php/jber

Lichen *Pseudocyphellaria* Mapping in Cibodas Botanical Garden Conservation Park

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Received: 22 Desember 2024 Revised: 22 Februari 2025 Accepted: 27 Maret 2025

Abstract

Lichens are symbiotic organisms between fungi and algae. In Indonesia, lichen inventory research is very limited. Several Lichen families have entered critical levels such as Lobariaceae. The purpose of this study was to: record and collect the Lobariaceae family as a rare lichen, analyze population data of the Lobariaceae family, growth percentage and development of Lobariaceae family transplants. This research method used exploration with calculations based on the surface area of tree trunks, the number and coverage of thallus, and thallus coverage per square meter for each tree. The results of this study found 340 *Pseudocyphellaria* thallus consisting of *Pseudocyphellaria* sp. *P. aurata*, *P. crocata* and *P. argyracea*. During one year of *Pseudocyphellaria* transplantation, there was no growth in terms of increasing thallus cover. The development that occurred was that the transplant was able to attach well to the substrate. It is estimated that *Pseudocyphellaria* thallus takes longer to adapt well to the substrate to grow and develop. The conclusion of this study is that the transplanted lichen showed satisfactory growth, which indicates that this method can be used for the conservation of threatened lichen species.

Keywords: Cibodas Botanical Garden; conservation; Lichen; Lobariaceae; *Pseudocyphellaria*

INTRODUCTION

Lichen is a symbiotic organism between fungi and algae. Algae on lichen provide advantages as a place to carry out photosynthesis, then the results of photosynthesis are used for their bodies and flow to fungi (Vidal-Russell & Messuti, 2017; Wahidah *et al*., 2022). The types of algae involved consist of two types, namely Chlorophyta and Cyanobacteria. The structure of the lichen thallus is varied consisting of *crustose*, *foliose*, *fruticose*, and *squamulose*. The efficiency level of pollutant accumulation in successive thallus is *foliose* > *crustose* > *fruticose* (Bhagarathi, 2022). Lichen characteristics can be morphologically observed easily based on the symbionts involved. If Lichen has a darker-colored thallus, then it is suspected that the symbiont is a blue-green algae. Meanwhile, if the thallus has a bright or green color, it is suspected that the type of symbiont is green algae. Lichen can live on various substrates, for example, tree trunks, soil, roads, walls, or the lichen itself. Lichen is very fond of humid conditions and temperatures that are below average. Conservation parks or conservation forests are suitable places for the growth of lichen because it is filled with abundant diversity. Human activities play a dominant role in forest conservation (Dhania *et al*., 2023). This issue should receive greater attention from the management of the Cibodas Botanical Gardens (CBG), as biodiversity characteristics vary across different elevations (Supratman *et al.*, 2024).

Lichens are a relatively underexplored subject of research (Supratman, 2023). This study specifically focuses on lichens within the Lobariaceae family. Genera that include. Research on Lobariaceae was conducted by Supratman (2023), finding *Lobaria pulmonaria* in the Curug Cibeureum waterfall area of Gunung Gede Pangrango National Park. CBG is an area very close to the mountains that have an average temperature of 13-32°C (Hernawati *et al*., 2021). The discovery of lichen is because there are many substrates that lichen to grow and develop, the TNGGP area is dominated by woody plants (Prapitasari *et al.*, 2020; Astuti & Munawaroh, 2021). *Pseudocyphellaria* is a rare Lichen belonging to the Lobariaceae family. *Pseudocyphellaria* is a member of the Lobariaceae family that has reached a critical conservation status. Even the BRIN herbarium collection center does not possess any specimens of *Pseudocyphellaria*. Moreover, there is a limited number of scientific articles reporting the discovery of *Pseudocyphellaria* in conservation parks across Indonesia. This is reinforced by the absence of a collection of Lichen family Lobariaceae in Herbarium Bogoriense BRIN – Bakossurtanal Cibinong which is a warehouse for biodiversity collections. In addition, several studies state that in the Bogor botanical garden, there is also no lichen family Lobariaceae. Lobariaceae is a lichen family that is rarely encountered. Several studies have reported the presence of the genera *Lobaria*, *Pseudocyphellaria*, and *Sticta* in the Cibodas Botanical Gardens (CBG) (Supratman, 2024); *Pseudocyphellaria*, *Sticta*, *Crocodia*, and *Podostictina* in the Kermadec Islands, South Pacific (Lücking *et al*., 2017); and *Pseudocyphellaria rainierensis* along the west coast of Canada and the United States, from Oregon to southeastern Alaska (Beese *et al*., 2015).

The mapping of *Pseudocyphellaria* is essential for documenting and collecting this rare lichen species, as well as for analyzing its population data. The transplantation of *Pseudocyphellaria* is necessary to study its growth and development under controlled conditions. Through transplantation techniques, it has been demonstrated that lichen thalli can be propagated, contributing to the conservation and sustainability of *Pseudocyphellaria*. Several research questions underpin this study: Indonesia has exceptionally high biodiversity; however, information on lichen diversity remains scarce. Therefore, research on lichens is necessary. *Pseudocyphellaria* is a rare lichen species, as evidenced by the absence of its specimens in the Herbarium of the Research Center for Biology – BRIN. Consequently, comprehensive data on Lobariaceae collections as rare lichens are needed. The rarity of *Pseudocyphellaria* requires concrete conservation measures to ensure its preservation . One recommended approach is lichen rejuvenation through transplantation.

Further research on *Pseudocyphellaria* has explored various aspects of its biology and taxonomy. For instance, studies have examined the *Nostoc* photobiont associated with cephalodia, revealing the presence of distinct cephalodia on the same thallus (Prieto *et al.*, 2023). *Pseudocyphellaria crocata* has been identified as a key species distinguishing 13 different monophyletic lineages (Lücking *et al*., 2017). Phylogenetic signals in Pseudocyphellaria have indicated that cyanobacteria serve as the primary photobionts, following a Brownian motion model of evolution (Vidal-Russell & Messuti, 2017). The identification of *Pseudocyphellaria berberina* has been conducted using a polyphasic approach, integrating morpho-physiological, chemical, and molecular characterization (Vobis *et al.*, 2020). Additionally, historical mapping and database-driven studies on *Pseudocyphellaria* have been conducted using the Irish Lichen Database (Cannon *et al.*, 2021). Phylogenetic analyses of 376 genera within the Lobariaceae family have employed nucleotide and amino acid sequence comparisons (Widhelm *et al*., 2019). Lastly, DNA sequencing targeting restriction sites has been used to distinguish *Pseudocyphellaria glabra* and *P. homoeophylla* (Widhelm *et al.*, 2023).

METHOD

The method employed in this study was the exploratory or survey method (Supratman, 2024). This approach was chosen due to the extensive area of the Cibodas Botanical Gardens (CBG), where certain regions have not yet been designated within the official zoning map provided by CBG. Lichen mapping and transplantation were carried out from June 2013 to June 2014 at the UPT Cibodas Botanical Garden Conservation Center. Macroscopic and microscopic observations were carried out in the Integrated Laboratory of the Department of Biology, Faculty of Mathematics and Natural Sciences, IPB, and the Biology Laboratory, FKIP-Unpak. Making permanent preparations using the paraffin method was carried out at the Laboratory of Morphology, Anatomy and Cytology, BRIN Bakossurtanal, Cibinong, can be seen in Figure 6, 8 and 10. CBG has an area of ±125 ha and consists of 22 blocks. Lichen mapping was carried out on all blocks consisting of 3,724 trees, including collection and non-collection plants. Lichen mapping using the roam method. Lichen is obtained from the entire area of the tree trunk with a height of 0-2 m, then each sample is made into a herbarium for collection. Identification of lichen collections from mapping results is carried out at the species stage. Identification key using (Galloway *et al.*, 2001). To determine the structure of the internal tissue of the thallus, fresh tissue preparations and preserved preparations are made. The identification observation parameters consist of macroscopic, microscopic observations and chemical reaction tests using 10% KOH. Macroscopic observations, namely the morphology of the thallus include the color of the thallus, the surface structure of the thallus, vegetative structure, and reproductive organs. Microscopic observation is observing the internal structure of the thallus and the color of the medulla using microtomes and light microscopes. Test the chemical reaction on the medulla by looking at the color change.

The surface area of the tree trunk is calculated based on the formula for the surface area of the tube blanket, namely (Supratman, 2016):

$$\text{TTSA} = 2\pi rt$$

Remarks:
r (radius) = $K/2\pi$
t = tree height
K = circumference of the tree trunk (cm)

The circumference of the tree trunk is obtained by looping the raffia rope around the tree trunk circle. TTSA is converted to m^2 units. Lichen population parameters observed include determination of thallus count, thallus cover, and thallus frequency. How to determine the number of thallus, count the entire thallus on the surface of the tree trunk at a height of 0-2 m. How to determine the cover of thallus Y using transparent plastic measuring 30 x 20 cm attached to the bark of the tree trunk at the point of sampling lichen Y that has been found, then the thallus is traced with plastic. After that, the results of the Y lichen thallus tallus are cut out based on the existing pattern, then weighed using an analytical balance, and the weighing results are used as the weight of the Y lichen thallus. The weight of the Y lichen thallus is converted to cm2 units based on the weight of 1 cm^2 (0.0149 g) of transparency plastic. The cover of the thallus can be calculated using the formula (Supratman, 2016):

$$\text{Thallus cover} = \frac{\text{thallus weight Y}}{0.0149 \text{ g}} \times 1\ (\text{cm}^2)$$

The number of thallus can be expressed in percent, that is, it is calculated based on the number of thallus divided by the total number of thallus multiplied by 100%. Thallus cover (TT) per tree (cm^2) is the amount of TT per tree (cm^2). TT (cm^2) per 1 m^2 TTSA can be calculated using the formula (Supratman, 2016):

$$\text{TT}(\text{cm}^2) \text{ per 1 m}^2 \text{ TTSA} = \frac{1}{\text{TTSA}(\text{m}^2)} \times \text{TT per tree } (\text{m}^2)$$

Frequency is the number of trees overgrown by each *Pseudocyphellaria* species per total number of trees. Frequency uses a modified formula (Dietrich & Scheidegger, 1997).

$$\text{Frequency} = \frac{\text{Number of trees overgrown with } \textit{Lobariaceae} \text{ species}}{\text{Total Number of trees}} \times 100\%$$

RESULT AND DISCUSSION

A total of 412 trees were found to host *Pseudocyphellaria*, comprising four species*: Pseudocyphellaria sp.*, *Pseudocyphellaria aurata*, *P. crocata, and P. argyracea* (Table 1) (Figure 1 - supplementary files).

Table 1. Identified *Pseudocyphellaria* species and their characteristics

No.	Found in the block	Types of *Pseudocyphellaria*	Characteristics
1	IA and IIA	*Pseudocyphellaria* sp. (Figure 3)	The thallus exhibits a silvery coloration with a smooth upper surface texture and is loosely attached to the substrate. The photobiont is a green alga, while the medulla is white. The pseudocyphellae are yellow, and the tomentum is dark brown. A potassium (K+) reaction test on the medulla produces a yellow color, whereas the calcium hypochlorite (C−) and KC− tests show no reaction.
2	IA and VIC	*P. aurata* (Figure 5)	The thallus is green with a smooth upper surface texture and is loosely attached to the substrate. The photobiont is a green alga, while the medulla is yellow. The pseudocyphellae are yellow, and the lichen produces yellow soredia, which are located marginally. The tomentum is dark brown to blackish and is found in the central and lower laminal parts of the thallus. The chemical reaction tests for potassium (K−), calcium hypochlorite (C−), and KC− show no reaction.
3	IA, IK, IVD, IVE, VIB and VIC	*P. crocata* (Figure 7)	The thallus is brown with a smooth upper surface texture and is loosely attached to the substrate. The photobiont is *Nostoc*, and the medulla is white. The pseudocyphellae are yellow, and the lichen produces yellow soredia, which are located marginally. The tomentum is dark brown and is concentrated in the central region of the lower thallus surface. A potassium (K+) reaction test on the medulla produces a yellow color, while the calcium hypochlorite (C−) and KC− tests show no reaction.
4	IK and IID	*P. argyracea* (Figure 9)	The thallus exhibits a silvery coloration with a rough upper surface texture due to the presence of pseudocyphellae, which develop into isidia. It is loosely attached to the substrate, with *Nostoc* as the photobiont. The medulla is whitish-yellow, while the pseudocyphellae are white. The tomentum is dark brown and located in the central region of the lower thallus surface. Chemical reaction tests for potassium (K−) and calcium hypochlorite (C−) show no reaction. The KC− test indicates no color change in the medulla. Macroscopic and microscopic characteristics largely align with the identification key; however, there is a discrepancy in the KC− test result.

A distinctive characteristic of the *Pseudocyphellaria* thallus is its foliose structure (leaf-like appearance), the presence of pseudocyphellae, and its symbiotic association, predominantly with cyanobacteria. The differences of the four species of *Pseudocyphellaria* can be described, among others, *Pseudocyphellaria* sp. It has a silvery thallus, the structure of the upper thallus surface is smooth and loosely attached to the substrate, photobionts of algae are green, the medulla is white, pseudocyphellae are yellow, and the tomentum is dark brown. The K+ reaction test on the medulla produces yellow, while the C- and KC- reaction tests. Macroscopically and microscopically a lot of data and information are not suitable between species in the key determination, so naming does not have conclusions up to the species level. Thallus *Pseudocyphellaria* sp. can be seen in Figure 3 and the transverse slices of the thallus of *Pseudocyphellaria* sp. can be seen in Figure 4 - supplementary files. Meanwhile, *Pseudocyphellaria aurata* has a green thallus, the surface structure of the upper thallus is smooth, loosely attached to the substrate, green algal photobionts, the medulla is yellow, pseudocyphellae is yellow, has a yellow soredium and is located marginally, the tomentum is blackish-brown and located in the middle and lower laminal part of the thallus. Test the reaction of K-, C-, and KC-. The anatomy of the *P. aurata* thallus can be seen in Figure 5 - supplementary files and the transverse slices of the *P. aurata* thallus can be seen in Figure 6 - supplementary files.

Pseudocyphellaria crocata has a brown thallus, the surface structure of the upper thallus is smooth, loosely attached to the substrate, *Nostoc* photobionts, the medulla is white, pseudocyphellae are yellow, have a yellow soredium, and are located marginally, the tomentum is dark brown and is located in the middle on the lower surface of the thallus. The K+ reaction test on the medulla produces a yellow color (Figure 7 - supplementary files), while the C- and KC- reaction tests. The thallus of *P. crocata* can be seen in Figure 7 - supplementary files and the transverse slices of the thallus of *P. crocata* can be seen in Figure 8 - supplementary files. Meanwhile, *Pseudocyphellaria argyracea* has a silvery thallus, the surface structure of the upper thallus is rough because it has pseudocyphellae that will develop into isidium, loosely attached to the substrate, *Nostoc* photobionts, yellowish-white medulla, pseudocyphellae white, dark brown tomentum and located in the middle on the lower surface of the thallus. Test K- and C- reactions. The KC- chemical reaction test showed no change in medulla color. Macroscopically and microscopically there is a lot of conformity with the key determination, but there is a mismatch in the KC- test. The thallus of *P. argyracea* can be seen in Figure 9 and the transverse slices of the thallus of *P. argyracea* can be seen in Figure 10 - supplementary files.

The total number of thallus is 340 consisting of *Pseudocyphellaria* sp, *P. aurata*, *P. crocata*, and *P. argyracea*. *Pseudocyphellaria* sp. was found in 2 blocks, namely blocks IA and IIA on 2 trees with LPBP 9.4 m^2. *Pseudocyphellaria* sp. consists of 61 thallus (17.94%) and TT per tree 920.873 cm^2 and TT per 1 m^2 TTSA 201.32 cm^2 or average TT per 1 m^2 TTSA 100.66 cm^2 and frequency 0.06%. *P. aurata* was found in 2 blocks, namely IA and VIC blocks on 2 trees with an TTSA of 3.4 m^2. *P. aurata* consists of 91 thallus (26.76%) and TT per tree 812,672 cm^2 and TT per 1 m^2 TTSA 372.58 cm^2 or average TT per 1 m^2 TTSA 186.29 cm^2 and frequency 0.06%. *P. crocata* was found in 6 blocks namely IA, IK, IVD, IVE, VIB, and VIC blocks on 6 trees with an TTSA of 26.22 m^2. *P. crocata* consists of 178 thallus (52.36%) and TT per tree 2 211.266 cm^2 and TT per 1 m^2 TTSA 484.65 cm^2 or average TT per 1 m^2 TTSA 80.77 cm^2 and frequency 0.18%. *P. argyracea* was found in 2 blocks, namely IK and IID blocks on 3 trees with an TTSA of 3.84 m^2. *P. argyracea* consists of 10 thalluses (2.95%) and TT per tree 363,992 cm^2 and TT per 1 m^2 TTSA 407.54 cm^2 or average TT per 1 m^2 TTSA 135.87 cm^2 and frequency 0.08% (Tables 1 and 2). The average number of thallus per 1 m^2 TTSA and the average thallus cover per 1 m^2 TTSA in *Pseudocyphellaria.*

A total of 340 *Pseudocyphellaria* thalli were identified. The most abundant species found were *P. crocata* and *P. aurata*, with their distribution spanning multiple trees. Notably, a single tree, *Araucaria* sp. (Block IVE), hosted a substantial number of *P. crocata* thalli, extending to heights above 2 m. Regarding its resilience, field studies have consistently confirmed the persistence of *P. crocata*, although its population size remains variable. This suggests that *P. crocata* possesses a higher level of adaptability compared to other *Pseudocyphellaria* species. This finding aligns with previous reports documenting *P. crocata* in the Ciwalen trail of TNGGP (Supratman, 2023). Observations and interviews indicate that fluctuations in thallus numbers are largely due to the frequent use of tree trunks for outdoor activities, which leads to mechanical abrasion of the thalli. In contrast, *P. argyracea* was found in significantly lower numbers, primarily on trees located in areas with minimal human traffic. This suggests that *P. argyracea* requires a higher level of adaptation for growth and survival.

Table 2. Number of thallus and thallus cover of *Pseudocyphellaria*

Block	Trees	Species	TTSA (m^2)	Number of thallus per TTSA (thallus)	Number of thallus per TTSA (%)	TT per tree (cm^2)	TT (cm^2) per 1 m^2 TTSA
IA	*Prunus cerasoides*	*Pseudocyphellaria* sp.	4.22	25	7.35	536.040	127.02
IIA	*Eucalyptus punctata*	*Pseudocyphellaria* sp.	5.18	36	10.59	384.832	74.29
	Subtotal		**9.4**	**61**	**17.94**	**920.873**	**201.32**
	Average TT per 1 m^2 TTSA						**100.66**
IA	*Rhadermachera* sp.	*P. aurata*	1.04	76	22.35	745.242	716.58
VIC	*Cerasus cerasoides*	*P. aurata*	2.36	15	4.41	67.430	28.57
	Subtotal		**3.4**	**91**	**26.76**	**812.672**	**372.58**
	Average TT per 1 m^2 TTSA						**186.29**
IA	*P. cerasoides*	*P. crocata*	2.38	31	9.12	139.789	58.73
IK	*Yucca elephantipes*	*P. crocata*	6.16	7	2.06	140.893	22.87
IVD	*Neonauclea excelsa*	*P. crocata*	3.98	2	0.59	48.577	12.21
IVE	*Araucaria* sp.	*P. crocata*	7.6	80	23.53	1.158.349	152.41
VIB	*P. cerasoides*	*P. crocata*	3.74	9	2.65	436.309	116.66
VIC	*C. cerasoides*	*P. crocata*	2.36	49	14.41	287.349	121.76
	Subtotal		**26.22**	**178**	**52.36**	**2 211.266**	**484.65**
	Average TT per 1 m^2 TTSA						**80.77**
IK	*Oreocnide scabra*	*P. argyracea*	0.54	2	0.59	147.489	273.13
IK	*Lithocarpus pallidus*	*P. argyracea*	1.36	4	1.18	103.772	76.30
IID	*Y. guatemalensis*	*P. argyracea*	1.94	4	1.18	112.732	58.11
	Subtotal		**3.84**	**10**	**2.95**	**363.992**	**407.54**
	Average TT per 1 m^2 TTSA						**135.87**
	Total		**42.86**	**340**	**100**	**4 308.803**	**1 466.08**

Information :
TTSA: Tree Trunk Surface Area;
TT: Thallus cover

Table 3. Number of thalli per species

Species	Block	Tree	TTSA (m^2)	Number of thalli
***Pseudocyphellaria* sp.**	IA	*Prunus cerasoides*	4.22	25
	IIA	*Eucalyptus punctata*	5.18	36
	Subtotal			**61**
P. aurata	IA	*Rhadermachera* sp.	1.04	76
	VIC	*Cerasus cerasoides*	2.36	15
	Subtotal			**91**
P. crocata	IA	*P. cerasoides*	2.38	31
	IK	*Yucca elephantipes*	6.16	7
	IVD	*Neonauclea excelsa*	3.98	2
	IVE	*Araucaria* sp.	7.6	80
	VIB	*P. cerasoides*	3.74	9
	VIC	*C. cerasoides*	2.36	49
	Subtotal			**178**
P. argyracea	IK	*Oreocnide scabra*	0.54	2
	IK	*Lithocarpus pallidus*	1.36	4
	IID	*Y. guatemalensis*	1.94	4
	Subtotal			**10**
Total				**340**

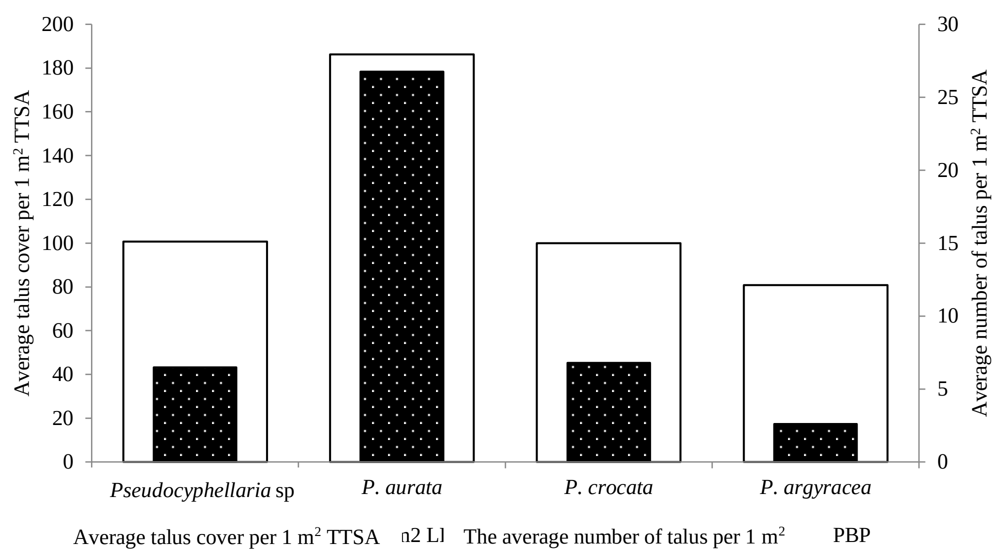

Figure 11. The average number of thallus per 1 m^2 TTSA and average thallus cover per 1 m^2 TTSA in *Pseudocyphellaria*

Pseudocyphellaria is found on the trunks of *Araucaria angustifolia*, *Cerasus cerasoides*, *Eucalyptus punctata*, *Lithocarpus* sp., *Neonauclea excelsa*, *Oreocnide scabra*, *Prunus cerasoides*, *Rhadermacera* sp., *Yucca elephantipes*, and *Y. guatemalensis* which has woody characteristics, rough, moist, and wet trunk structure (Figure 12).

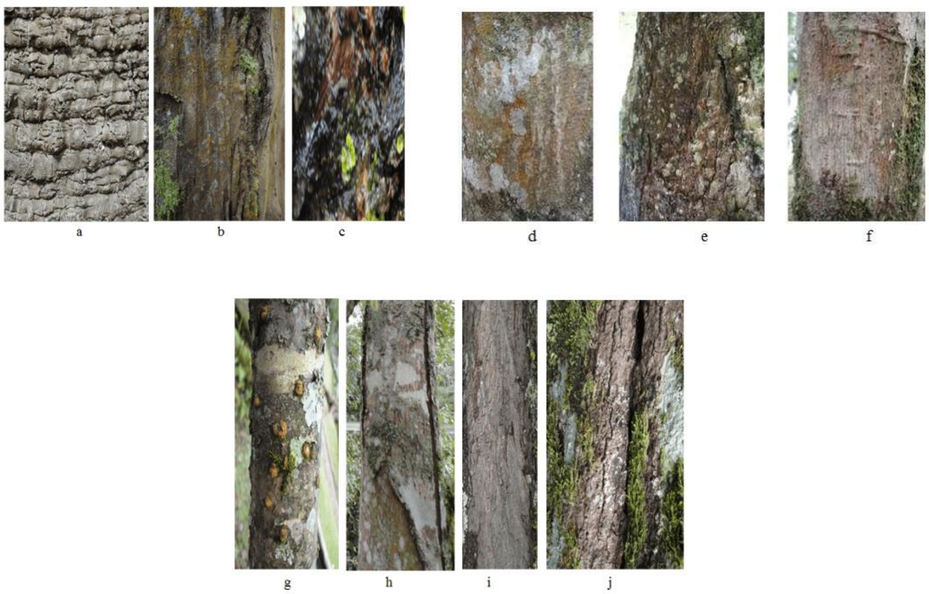

Figure 12. Tree trunk a. *Araucaria angustifolia*, b. *Cerasus cerasoides*, c. *Eucalyptus punctata*, d. *Lithocarpus* sp., e. *Neonauclea excelsa*, f. *Oreocnide scabra*, g. *P. cerasoides*, h. *Rhadermacera* sp., i. *Yucca elephantipes*, and j. *Y. guatemalensis* overgrown with *Pseudocyphellaria*.

The characteristics of the bark of *Araucaria angustifolia, Cerasus cerasoides, Eucalyptus punctata, Lithocarpus* sp., *Neonauclea excelsa, Oreocnide scabra, Prunus cerasoides, Rhadermacera* sp., *Yucca elephantipes,* and *Y. guatemalensis* overgrown with *Pseudocyphellaria* are woody, the structure of the trunk is rough, moist, and wet. Each tree species has a different ability to store water, depending on the porosity and texture of the trunk (Hale, 1967) . The rough surface of the stem can be utilized by the thallus so that it can adhere well. Bhagarathi (2022) stated that each tree can secrete chemical compounds naturally that can support lichen life. In addition, the nature and condition of the bark of the plant affect the shape and growth of the thallus. The type of tree trunk surface structure that supports the growth of *Pseudocyphellaria* is woody, with a rough, moist, and wet texture. The combination of a woody trunk and a rough surface provides an optimal substrate for lichens to attach and persist for extended periods. Rhizoids on the lower cortex can easily anchor onto the rough bark, enhancing their ability to survive. Additionally, the moist and wet conditions of the trunk facilitate water supply, which is essential for lichen metabolism and overall physiological processes. *Pseudocyphellaria* transplants were performed on two species, namely *P. aurata* and *P. crocata. P. aurata* transplantation is carried out on a natural substrate, namely on the trunk of the *Rhadermachera* tree. While *P. crocata* is carried out on different tree trunks, namely on spruce tree trunks. Transplant results on *P. aurata* did not show changes in quantity such as talus growth in size, However, in quality, out of 10 transplants only 6 survived and were able to adhere well to the tree trunk substrate. In terms of quality changes in *P. crocata* transplants out of 10 transplants, only 6 transplants were able to attach well to the tree trunk substrate. In the second transplant there was a development, namely the emergence of the apothesium in the 9th month.

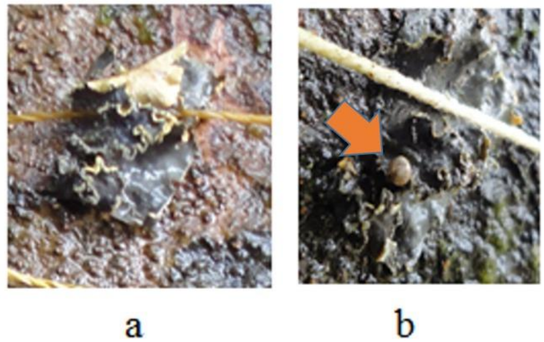

Figure 13. *P. crocata* transplant growth a. June 2013 b. Apotecium growth

Pseudocyphellaria was transplanted on the trunk of the tree *Rhadermachera* sp., transplantation was carried out on the same tree trunk and grew in CBG so that the transplant grew and developed properly on its natural substrate. Coppins & Coppins (2005) stated that talus foliose transplantation is more suitable on tree trunk bark than on rocks. The transplant material used is the thallus which has lobule. Some things that must be considered in choosing a talus to be used as a transplant material include a wide lobe that grows faster than a narrow lobe, a talus that contains a whole young lobe that develops faster than an adult thallus that has soredium, variations in lobe growth depend on the lobe not derived from the talus as a whole. The underlying reason for lobe growth variation is due to the allocation, production and differences in carbohydrate metabolism (Armstrong & Smith, 1994).

The transplant results were 55% successful (11 transplants), while 45% did not grow well. Several things that occur that cause transplant growth to be less good include talus that dries and changes color, talus does not stick well to the substrate, the size of the talus is reduced, and the talus does not contain young lobes. The results obtained are similar to the research of Phillips (1969) which states that transplants manage to grow well while the growth of other lobes does not grow at all. Mature thallus can grow in all conditions, while isidium growth is affected by light intensity and wind direction. *Pseudocyphellaria* transplants show no growth in terms of increased talus cover. The development that occurs is that the transplant is able to stick well. It is thought that it takes approximately 12 months for the talus of *Pseudocyphellaria* to adapt well to the substrate in order to adhere properly. The development of transplants in *P. crocata* in the tenth month appears apothesium. With the advent of the apothesium it is suspected that the thallus is already mature in terms of sexual reproduction. Another conjecture is that the transplanted *P. crocata* talus has a very large size that allows reproductive regeneration to undergo such a rapid process (Roziaty, 2016).

Pseudocyphellaria with its characteristics has a leaf-like thallus morphology that is thought to be able to capture pollutants around the place of growth. The more pollutants, the thallus will not be able to survive properly, if it can grow even then the state of the thallus will be in abnormal form, so if the thallus is not found it indicates that the level of pollutants around the place has been very contaminated in the weight category. The discovery of abundant *Pseudocyphellaria* in CBG indicates that the air quality around CBG can still be in the very good category. This is closely related to the regulations stipulated that there are certain days of implementation of not being able to carry vehicles to reduce the amount of vehicle emissions to the surrounding environment. The climatic conditions of Cibodas Botanical Garden exhibit a temperature range of 19.8–20.4°C and a relative humidity of 85–91.1%. During the period from August to December, precipitation levels are relatively high, making these months particularly suitable for lichen transplantation. The high humidity results in consistently moist tree trunk surfaces, which can support optimal thallus growth. Given these environmental conditions, it is hypothesized that *Pseudocyphellaria* has a long lifespan (Hutasuhut *et al*., 2021). This is supported by field observations, where the presence of thalli remains consistent over time, although their population size fluctuates annually.

From the explanation above, it can be inferred that the elements contributing to the success of the lichen transplant include the size of the talus surface to be transplanted, weather factors (the rainy season is a very suitable time to transplant), the structure of the tree trunk surface (textured tree structure is very suitable for Lobariaceae lichen), the age of the talus to be transplanted (if a new place is suitable for transplantation then the lichen will continue the generative phase, If it is not suitable then it will grow up, if it is not suitable it will grow in the vegetative phase) (Fatma *et al*., 2017). Based on temperature and humidity data, humidity plays a role compared to temperature. Therefore, it is recommended that transplantation be done in January to May because at that time it is in a more humid state so that the opportunity for transplant growth is faster. Weather conditions suitable for the growth of the thallus are the main factor in the successful attachment of the transplant to the natural substrate, conversely, if the weather conditions are not good, it can cause inhibition of the degeneration process of the transplanted diaspora.

CONCLUSION

The mapping results of the Lobariaceae family found Pseudocyphellaria consisting of four species, namely *Pseudocyphellaria* sp., *P. aurata*, *P. crocata* and *P. argyracea*. The highest number of *Pseudocyphellaria* thalli was recorded for *P. crocata*, indicating that this species exhibits superior adaptability compared to other thalli. The results of this lichen research are useful for the nation because they can be used as a reference for teaching materials at junior high, high school, and college levels, and can contribute to increasing learning resources for biodiversity. Additionally, this research provides valuable reference data on Lobariaceae lichens for relevant stakeholders at the Cibodas Botanical Garden, particularly the National Research and Innovation Agency.

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