SPECIES DIVERSITY AND ECOLOGY OF EPIPHYTIC LICHENS IN THE DRY DIPTEROCARP FOREST OF KHAO YAI NATIONAL PARK, THAILAND

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ความหลากหลายชนิด และนิเวศวิทยาของไลเคนอิงอาศัยในป่าเต็งรัง ในอุทยานแห่งชาติเขาใหญ่ ประเทศไทย

นายเวชศาสตร์ พลเยี่ยม

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
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Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อสำรวจความหลากหลายชนิด องค์ประกอบของชุมชีพและความต้องการที่อยู่อาศัยของไลเคนต่อที่พื้นที่เกาะอาศัยบนผิวเปลือกไม้ในสภาพป่าเต็งรัง อุทยานแห่งชาติเขาใหญ่ ทำการศึกษาความหลากหลายของไลเคนจากแปลงสำรวจขนาดเล็ก (ขนาด 10 ซม. x 10 ซม.) ที่วางบนผิวเปลือกไม้ (ที่ความสูง 1 ม. จากพื้นดิน) จำนวน 514 ต้น (27 ชนิด) เพื่อประเมินความมากชนิดและความชุกชุมของไลเคน การศึกษาพบไลเคนทั้งหมดจำนวน 175 ชนิด โดยพบไลเคนที่มีรูปแบบครัสโตสมากที่สุด คิดเป็นร้อยละ 89 ส่วนแบบโฟลิโอส สแควมูโลส และบิสซอยด์รวมกันคิดเป็นร้อยละ 11 การศึกษาครั้งนี้ไม่พบไลเคนที่มีรูปแบบฟรูทิโคส ไลเคนวงศ์ Graphidaceae มีความหลากหลายชนิดสูงที่สุด พบ 61 ชนิด รองลงมาคือวงศ์ Trypetheliaceae พบ 33 ชนิด ไลเคนสกุล *Graphis* มีความหลากหลายชนิดสูงที่สุด พบ 21 ชนิด และ *Astrothelium* พบ 14 ชนิด ในการสำรวจนี้พบไลเคนที่รายงานเป็นครั้งแรกของประเทศไทยจำนวน 28 ชนิด และ มีไลเคน 1 ชนิดในสกุล *Aptrootia* ที่คาดว่าเป็นชนิดใหม่ของโลก ต้นพืชที่พบไลเคนหลากหลายชนิดที่สุด ได้แก่ ต้นพันจำ (*Vatica odorata*) พบไลเคนได้ 86 ชนิด ในขณะที่ต้นยางเหียง (*Dipterocarpus obtusifolius*) มีจำนวนแทลลัสไลเคนเกาะอาศัยสูงที่สุด (4,446 แทลลัส และ ค่าความสำคัญ = 120.41) การศึกษานี้ชี้ให้เห็นว่าชนิดพืชเป็นปัจจัยสำคัญที่มีอิทธิพลต่อความหลากหลายชนิดและการกำหนดลักษณะชุมชีพของไลเคนในสภาพป่าเต็งรัง

การศึกษาชุมชีพของไลเคนที่เจริญบนพืชชนิดเด่นสองชนิด คือต้นยางเหียง (*Dipterocarpus obtusifolius*) และต้นรักใหญ่ (*Gluta usitata*) ประเมินจากจำนวนแทลลัสไลเคน การครอบครองพื้นที่ และความถี่ที่พบใน line intercepts ที่วางบนโคนต้น กลางต้น เรือนยอด และบนกิ่งของต้นไม้ พบว่าต้นรักใหญ่เป็นพืชที่ไลเคนหลากหลายชนิดเกาะอาศัยมากกว่ายางเหียง (พบไลเคนได้ 63 ชนิด) โดยมีไลเคน *Maronina corallifera* (ค่าความสำคัญ = 28.8) เป็นชนิดเด่น ในขณะที่ต้นยางเหียงมีไลเคนเกาะอาศัยจำนวน 54 ชนิด พบ *Bacidia* sp. 1 (ค่าความสำคัญ = 34.1) เป็นชนิดเด่น การศึกษานี้พบว่ามีไลเคน 31 ชนิด ที่สามารถเจริญได้บนพืชทั้ง 2 ชนิด ลักษณะผิวเปลือกไม้ ค่าพีเอชของเปลือกไม้ และความสามารถในการอุ้มน้ำของเปลือกไม้เป็นปัจจัยร่วมที่มีอิทธิพลอย่างมากต่อรูปแบบขององค์ประกอบชนิดไลเคนอย่างมีนัยสำคัญทางสถิติ ($p < 0.05$)

การศึกษาเพื่อประเมินโครงสร้างของประชากรโฟลิโอสไลเคนสองชนิด จากการสำรวจแทลลัสไลเคนตลอดลำต้นและบนกิ่งของพืช 20 ชนิด (จำนวน 198 ต้น) พบ *Parmotrema tinctorum* จำนวน 484 แทลลัส (คิดเป็น 3,227 แทลลัสต่อเฮกตาร์) และ *Pyxine coccifera* จำนวน 475 แทลลัส (คิดเป็น 3,167 แทลลัสต่อเฮกตาร์) โดยโครงสร้างหลักของประชากรไลเคนทั้งสองชนิดนี้จัดอยู่ในระยะกลางของช่วงวัยเจริญพันธุ์ พืชชนิดที่พบประชากรของ *Parmotrema tinctorum* ได้มาก (164 แทลลัส) ได้แก่ ต้นพันจำ ขณะที่ *Pyxine coccifera* พบได้มากบนต้นรักใหญ่ (119 แทลลัส) โดยมีพืชหลายชนิดที่ไม่พบประชากรของไลเคนทั้งสองชนิดนี้ การศึกษานี้บ่งชี้ว่าชนิดพืชมีความสำคัญต่อขนาดของประชากรไลเคน ดังนั้นการขยายพันธุ์โดยการย้ายปลูกแทลลัสไลเคนไปยังพืชที่เหมาะสมอาจจะช่วยเพิ่มขนาดประชากรในธรรมชาติได้ และสามารถเป็นแนวทางการเพิ่มผลผลิตไลเคนเพื่อเก็บเกี่ยวมาใช้ประโยชน์ต่อไปได้

สาขาวิชาชีววิทยา	ลายมือชื่อนักศึกษา ______
ปีการศึกษา 2565	ลายมือชื่ออาจารย์ที่ปรึกษา S. Watthana

WETCHASART POLYIAM : SPECIES DIVERSITY AND ECOLOGY OF EPIPHYTIC LICHENS IN THE DRY DIPTEROCARP FOREST OF KHAO YAI NATIONAL PARK, THAILAND. THESIS ADVISOR : ASST. PROF. SANTI WATTHANA, Ph.D. 184 PP.

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The purpose of this study is to explore the species diversity, community composition, and habitat requirements of lichens that live on the bark surface in the dry dipterocarp forest of Khao Yai National Park. The lichen diversity was assessed within the sampling grids (10 cm x 50 cm), which were placed on the trunk base (1 m above ground). All 514 trees (27 species) were evaluated for lichen richness and abundance. One hundred and seventy-five epiphytic lichen species were discovered, of which crustose growth forms accounted for approximately 89%, while foliose, squamulose, and byssoid growth forms accounted for 11%, whereas no fruticose growth form was observed. The crustose family Graphidaceae (61 species) exhibited the highest species diversity, followed by the Trypetheliaceae (33 species). The lichen genus *Graphis* comprises the most species (21 species), followed by *Astrothelium* (14 species). Twenty-eight species were new records for Thailand, and one lichen in the genus *Aptrootia* was described as a new species. *Vatica odorata* was the tree species with the maximum lichen richness, hosting 86 species, while *Dipterocarpus obtusifolius* had the highest abundance (4,446 thalli with IV = 120.41). This work indicated that tree species were an important factor influencing the species diversity and community composition of lichens in the dry dipterocarp forest.

The community of epiphytic lichens on *Dipterocarpus obtusifolius* and *Gluta usitata* was evaluated by thallus numbers, thalli cover, and intercept numbers found in the line intercepts that were placed on the trunk base, mid-trunk, canopy, and on branches. *Gluta usitata* housed the highest number of lichen taxa with 63 species, of which *Maronina corallifera* (IV = 28.8) was the most abundant. Whereas *Dipterocarpus obtusifolius* hosted 54 species, the dominant lichen was *Bacidia* sp. 1 (IV = 34.1). Thirty-one lichen species were observed on both tree hosts. The bark textures, pH, and water-holding capacity of the two tree species all statistically significantly impacted lichen compositions ($p < 0.05$).

The population structure of two foliose lichens was assessed for the lichen thalli throughout the stem and on the branches of 20 plant species (198 individuals). There were 484 thalli (3,227 thalli per hectare) of *Parmotrema tinctorum* found, and *Pyxine coccifera* 475 thalli were recorded (3,167 thalli per hectare). The main structure of these two lichen populations was classified as medium-adult size class. The *Vatica odorata* was the host species that supported a large population size of *Parmotrema tinctorum* (164 thalli), while *Pyxine coccifera* is more common on the *Gluta usitata* (119 thalli). There are many plant species where no populations of these two lichens have been found. This study indicates that plant species are essential for maintaining the size of lichen populations. In addition, propagation by transplanting thallus lichens to suitable plants may help increase population size in nature, and it can be a way to increase the production of lichens for harvesting and further use.

School of Biology

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Student's Signature ______________

Advisor's Signature ______________

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CHAPTER I

GENERAL INTRODUCTION

1.1 Background

Forest lichen and their natural habitats in Thailand

Thailand is known as a biodiversity-rich area in the world (6-10 % of the world's flora and fauna were estimated) and approximately 37,000 taxa of biota have been recorded (Baimai, 2010). The habitats of this biota could be varied in marine, freshwater, and land. On the land habitats, the high diversity present in the natural forests (Royal Forest Department, 2009). Thailand country is hosted for several types of forest, and 14 forest types were classified (Tawatchai Santisuk, 2006 as cited in Royal Forest Department, 2009). However, those forest types have been addressed into two major types of natural forest (evergreen and deciduous forests). Those two forest structures are occurred combined in different parts of the country from North to South and East to West.

The deciduous forest is the largest area coverage in the country (Royal Forest Department, 2009) and changes annually between rainy and hot seasons. That can view the dynamics of forest structures. Among the deciduous forests, the dry dipterocarp forest (DDF) is one of the most extreme habitats, especially with low moisture, poor soil, and frequency of forest fires. These characteristics of the forest are hazardous conditions for the life. Therefore, this forest type should promote the habitat for many specific flora and fauna that can tolerate or adapt well to the dynamic of the forest.

Lichen is known as a sensitive organism to environmental changes. Some of them may not survive within a minor change of environment. However, some lichens can survive and tolerate a major change in the forest which indicate something within the forest dynamics. That would be important to find out what lichens can have their properties to be permanent members of the DDF habitat.

The dry dipterocarp forest

The DDF is the seasonal forest that is distributed in many South-East Asia countries covering the eastern region of India, central Myanmar, Thailand, Laos, and Vietnam (Somsak Sukwong, 1982). In Thailand, the DDF is commonly found in the northern, north-eastern, western, and eastern of the country. The forest can be found in a variety of elevations, they may occur between 150 and 1,300 meters above sea level (m.a.s.l.). This forest type is characterized by hot and dry conditions or xeric forest, rainfall varies from 1,000 to 1,500 millimeters per year and has a long dry season of about 5-6 months. The typical forest fires are frequent in the dry season of the year (Somsak Sukwong, 1982; Sahunalu, 2009; FAO/RECOFTC, 2016). The forest fires are causing the annual dynamic of forest structures. The dynamic of DDF can be benefited the maintenance of the forest structures, which prevents the formation from progressing to a more evergreen (Stott, Goldammer, and Werner, 1990). Such conditions are suitable for some tree species to survive, especially the trees in the family Dipterocarpaceae that dominated the DDF (Somsak Sukwong, 1982).

Like the plants, lichens may be maintaining their community structure as related to the uniqueness of the DDF condition. Lichens are the indicator organism that reflected the character of the forests. Lichen richness, species that occurred, and their abundances are important characteristics that should be studied to understand the biological characteristics of lichens. Moreover, the requirement for suitable habitat and their specification of environments are interesting.

Study area

The selected sites for this study are in the DDF of Khao Yai National Park (KYNP). It encompasses the western part of the Phanom Donrak Mountain Range. The KYNP is the third largest national park of Thailand, covering an area of 2.165 km^2, situated between 14˚05' and 14˚15' N and 101˚05' and 101˚50' E, elevations range from below 100 to ca. 1,350 m.a.s.l. (Chayamarit and Puff, 2006). The forest types in KYNP were classifieds into five major types as summarized by Tem Smittinand (1977) and Chayamarit and Puff (2006) as 1) Tropical rain forest, being the majority covering the most area of the plateau (ca. 400 to 1,000 m.a.s.l.) 2) Mixed deciduous forest and 3)

Dry evergreen forest, found along the northern slopes between 400 and 600 m.a.s.l., 4) Lower montane rain forest, found ca. 1,000 upwards and occurring in the center of the national park area, and 5) Grassland or secondary forest, occurring at high elevations nearby the headquarter of the national park. Most of the grassland was affected by man and used for agricultural purposes before the national park was established. Recently the grassland has changed to a secondary forest. Based on the previous reports, there has not been DDF occurred in KYNP. However, after the Dong Pha Ya Yen-Khao Yai Forest Complex was declared a Natural World Heritage site in 2005. The areas of DDF were promoted at least on the map (Foundation for Khao Yai National Park, 2005). This forest type was found in very small patches, about 0.5% of the KYNP area (Napaporn Khao-min, 2018) which was distributed in the southern part of KYNP.

The selected sites for this study are in the DDF patches in the southern part of Khao Yai National Park at latitudes between 14˚11' and 14˚15' N and longitudes between 101˚29' and 101˚30' E, elevated between 100 and 600 m.a.s.l. The DDF patches can be found nearby a mixed deciduous forest, where the area was covered by sandy soil and rock. Moreover, DDF patches can occur nearby the bamboo forest and dry evergreen forests, where those forests were grouped in the clumps along the creeks or valleys. Even though the DDF patches are a small area in the national park, some DDF patches can be larger than 1 km^2 by visible estimation. So that the DDF patches would be important habitats for many specific flora, especially lichens.

The DDF patches for this study are slightly declining inclination of the slope from the peak of Lan Hin Dad area (a part of the Sa Mor Poon plateau) at about 600 to below 100 m.a.s.l. at the national park checks point no. 11 (Klong Pe Ka) and usually appears on the areas with a thin soil surface. The sandy soil is the major character of this forest type, and the soil always covers by a large sandy rock plate underneath. Sometimes DDF can be founded in an area with poor soil (clay with gray-brown color), where the small sandy rocks are abundant.

Climates

Khao Yai National Park has three seasons, hot, rainy, and cool seasons. The national park was facing the southwest monsoon, in the rainy season the area collected a large amount of rainfall between 2,000 and 4,000 mm/year depending on the area (Chayamarit and Puff, 2006). The rainfall volume was recorded from the weather station located at the measuring station point surrounded by evergreen forests. However, there was no weather station in the study area, and the climates at the study site may not be recorded in this work. The nearest weather station (Prachinburi Province) was used to referred for this study. The thirty-year climates (averaged between 1991 and 2020) at Prachinburi station was used here for the prediction of the trend of climates of study sites in DDF. Annual air temperature averaged 28.6 (8.5-42.9), rainfall 1,600-1,800 mm/year, and rain day 130-140 days (Thai Meteorological Department, unpublish data).

Vegetations

The vegetations found in the DDF of KYNP are generally deciduous trees with thick bark and small sizes, the canopy can be reached 5-15 m high. There were many tree species occurring as similar to other typical DDFs. The major tree species (63 %) was the *Dipterocarpus obtusifolius* Teijms. ex Miq. Other minor tree species found in less than 10 % of the observed trees such as *Corallia brachiata* (Lour.) Merr., *Dipterocarpus intricatus* Dyer, *Gluta usitata* (Wall.) Ding Hou, *Irvingia malayana* Oliv. ex A. Benn., *Parinari anamensis* Hance, *Sindora siamensis* Teijsm. & Miq., and *Vatica odorata* (Griff.) Sym. Since most areas were covered by large rocks space for shrub vegetation was not commonly found. Interestingly, the typical vegetation; *Vietnamosasa pusilla* (A.Cheval. & A. Camus) Hguyen which was commonly found in the other DDFs but was rarely seen in the study sites. Therefore, this forest seems to be different from a DDF located on the opposite side of the Phanom Donrak Mountain Range, at Sakaerat Environmental Research Station. The sampling trees of this study represented a unique DDF habitat of KYNP. The trees found in this forest may be related to lichen species, which were interesting to understand.

Lichens of the dry dipterocarp forest in Thailand

Among the several types of forest in Thailand, the DDF is one of the important habitats that facilitates many specific lichens (Wolseley and Aguirre-Hudson, 1991; 1997). Generally, physical factors in this forest type are low humidity, high light intensity, high temperature, and even of the forest fire. Host trees in DDF are the biological factor that can provide several types of microhabitats for the variation of lichen compositions. The DDF has been found abundant in northern, northeastern, and western Thailand. Some studies on lichen diversity were in the northern and western parts of the country. Wolseley and Aguirre-Hudson (1997) reported between 40 and 47 taxa of lichens from the sampling plots in the DDF sites at Doi Suthep National Park and Huay Kha Khaeng Wildlife Sanctuary, respectively. While Sujinda Bungwan and Wanaruk Saipunkaew (2018) found 40 taxa of lichen in the DDF of Doi Inthanon National Park. Whereas the exploration of lichen in DDF of the northeastern and central part of Thailand has been reported at similar diversity. About 41 species of lichens were recorded from Rongkhao conserved forest, Ubon Ratchathani Province (Hathaithip Suebsri and Pratyaprn Wanchai, 2021), only 31 species of lichens were reported from Sakaerat Environmental Research Station (A-mornrat Pitakpong, 2009; Nooduan Muangsan, Pongthep Suwanwaree, Duangkamol Maensiri, Taksin Artchawakom, and A-mornrat Pitakpong, 2015). A study of lichens at Khao Noi, Klong Peka, Khao Yai National Park reported 34 species (Sumrit Senglek and Kansri Boonpragob, 2015). However, all previous explorations have been done on the trunk base at less than 2 m above ground level. Thus, more lichen taxa on upper trunks and canopy have not been reported yet. These may result that many lichen species in the DDF of Thailand being unexplored. The need for quantitative observations in this forest type should be continued. At least on the whole part of the dominant trees and all tree species as possible. These covered the most diversity of lichens in the DDF.

This work focuses on the study of the epiphytic lichen diversity and their relationship to the phorophyte in the DDF of Khao Yai National Park, the central part of Thailand. This national park is situated not far from urban and industrial areas. The air pollution released from many activities around the park may affect directly lichens in the natural habitat. Study lichen in this work can be used for further application of air quality monitoring.

The research questions included in this study basically on 1) how many lichen species could be found in the DDF of study sites? 2) What lichen species are inhabitants in this DDF? 3) What are the characteristics of phorophytes and microhabitats in the DDF that epiphytic lichens prefer to colonize? 4) Do the dominant tree species play an important role in the most suitable host for lichens? and 5) What strategies that the dominant lichens use to maintain their population on the trees in the DDF?

1.2 Research Objectives

This work is to explore the lichen diversity, community composition, and population of some lichens in the DDF that consisted of KYNP. The study area is partially in the world heritage site of Dong Pha Ya Yen-Khao Yai Forest Complex, where a high diversity of biota was promoted. The area becomes very important when it plays the role of a vast ecosystem service for a large number of organisms and humans. Most of the people who live in the lowlands of the northeastern, central, and eastern parts of Thailand are served by this world heritage site ecosystem. Especially being an important source of the watershed, good quality air, as well as the tourism industry, etc. However, this world heritage may be pressured by the risk and threat of the organisms within this natural habitat. The urbanization, transportation, industrial sector, and misuse of agricultural land around the national park may be the most factor involving habitat loss or somehow directly influencing their organisms, especially sensitive organisms such as lichen. This work, therefore, focuses to understand the diversity, and community of lichens in this natural habitat and together coved to the new inside of study lichen population of two well-known species of tropical lichens. The three objectives of this work were including,

1. To examine species diversity and substrate preference of corticolous lichens in the DDF of central Thailand.

2. To examine species composition of lichens connected to habitat requirement on the dominant phorophytes in the DDF of central Thailand.

3. To examine the population structure and reproduction of two foliose lichens species and their ecological requirements in the DDF of central Thailand.

1.3 Scope and Limitations

Working under this research is mainly focused on the exploration of epiphytic lichens diversity, species composition, distribution pattern, and some ecological aspects related to phorophyte species. The investigations are conducted at the DDF in the central part of Thailand, at Khao Yai National Park. Fifteen study sites were located in five different elevation ranges of KYNP at 101-200, 201-300, 301-400, 401-500, and 501-600 m above sea level. Each study site has an area of 400 m^2 (20 m x 20 m), selected to be representative of the gradient in the dry dipterocarp forest type of the monsoon tropical forest.

The lichen taxa and environmental variables were investigated on tree barks. Lichen abundance access by the number of thalli, together with Important Value (IV) was used to summarize the common-rare status of each lichen species. The lichens data will be sampled in the sampling grids (size 10 cm x 10 cm with five contiguous grids) or the 50 cm of the line intercepts depending on research objectives. The environmental variables were also collected from the sample trees as referred to in the sampling grid positions.

In addition, the data set was standardized and analyzed by using several types of statistics, the correlation between lichens and environmental variables processing with multiple regressions depending on the research hypothesis. The multivariate analysis was used to analyze the community compositions.

The limitation of this research might be the field data collection. Time consumption and heterogeneity of lichen habitats (tree bole vs branches) can cause some problems in data collection. Uncontrol factors during working in the field may be happened such as forest fires in the dry season that can cause lichens and tree damage, together with heavy rain which was common in the tropics that can influence the data collection on the canopy. Moreover, the Covid-19 crisis during the exploration period (2020 - 2021) can be a large effect on most plans that the field data collection could not possible.

1.4 Expected Results

The data on lichen diversity was added to the Thai lichen checklist and new lichen taxa found in this work revealed the rich biodiversity of the country. The results reflected the importance of pristine habitats that show the need for intensive exploration and a conservation plan which should be set up for the specific area. The degree of lichen and host relationship is linked to the limiting factors on trees that lichens preferred. This result was important information that can be applied to design suitable habitats for cultivating or transplanting lichens. These were the benefit to produce lichens as living materials to evaluate the air quality indicator of industrial and city sites. From the conservation point of view, this requirement was more advantageous to conserve the threatened epiphytic lichen populations' *in-situ* habitat. This significant knowledge is likely far to success in Thailand or other South-East Asian countries.

1.5 List of Abbreviations

ave.	average
ca.	circa (about)
CCA	Canonical Correspondence Analysis
cm	centimeter
corr.	correlation
dbh	Diameter at breast height (cm)
DDF	dry dipterocarp forest
Ed. (Eds.)	editor (editors)
et al.	et alii; and others
etc	et cetera; and the others
e.g.	for example
ha	hectare
i.e.	id est (that is)
KYNP	Khao Yai National Park
m.a.s.l.	meter above sea level
m	meter (SI unit of length)

min	minimum
max	maximum
no.	number
p. (pp.)	page (pages)
sp.	species (usually a single species)
spp.	species (usually many species)
WC	Water holding capacity

1.6 References

A-mornrat Pitakpong. (2009). *The use of lichen as an indicator for environmental monitoring in Nakhon Ratchasrima municipality and Sakaerat Environmental Research Station.* (Master's thesis). Suranaree University of Technology, Nakhon Ratchasrima. Retrived from http://sutir.sut.ac.th:8080/jspui/handle/123456789/3355.

Baimai, V. (2010). Biodiversity in Thailand. *The Journal of the Royal Institute of Thailand, 10*, 107-114.

Chayamarit, K., and Puff, C. (2006). *Plants of Khao Yai National Park*. National Park office. National Park, Wildlife and Plant Conservation Department, Bangkok: Prachachon Co., Ltd.

FAO/RECOFTC. (2016). *Forest landscape restoration in Asia-Pacific forests*. Bangkok, Thailand. Retrived from https://www.recoftc.org/sites/default/files/publications/resources/recoftc-0000150-0001-en.pdf.

Foundation for Khao Yai National Park Protection. (2005). *Dong Phayayen-Khao Yai Forest Complex: Natural World Heritage Site*. Bangkok, Thailand.

Hathaithip Suebsri and Pratyaprn Wanchai. (2021). Species diversity of lichens in Rongkho conserved forest, Ubon Ratchathani University. *Burapha Science Journal, 26*(2), 941-954. Retrived from https://science.buu.ac.th/ojs246/index.php/sci/article/viewFile/3563/2997.

Napaporn Kao-mim. (2018). *Use of hyperspectral imaging system data from HJ - 1A satellite for forest types classification in Khao Yai National Park.* (Master's thesis). Kasetsart University. Bangkok. Retrived from http://www.thai-explore.net/file_upload/submitter/file_doc/7260315ae86a4341a4c50ade0907a6e04962.pdf.

Nooduan Muangsan, Pongthep Suwanwaree, Duangkamol Maensiri, Taksin Artchawakom, and A-mornrat Pitakpong. (2015). *Ecology and diversity of lichens in Sakaerat Environmental Research*. Suranaree University of Technology. Nakhon Ratchasima. Retrived from http://sutir.sut.ac.th:8080/sutir/bitstream/123456789/7410/2/Fulltext.pdf.

Royal Forest Department. (2009). *Forestry in Thailand*. Bangkok: Ministry of Natural Resources and Environment.

Sahunalu, P. (2009). Stand structure and species composition in a long-term dynamic plots of Sakaerat deciduous dipterocarp forest, northeastern Thailand. *Journal of Forest Management, 3*(6), 1-20.

Somsak Sukwong, S. (1982). Deciduous forest ecosystem in Thailand. *J. Natl. Res. Councla* Thailand*, 14*(1), 55-75.

Stott, P. A., Goldammer, J. G., and Werner, W. L. (1990). The role of fire in the tropical lowland deciduous forests of Asia. In J. Goldammer (Ed.), *Fire in the Tropical Biota* (pp. 32-44). Berlin: Ecological Studies, 84, Springer Verlag.

Sujinda Bungwan, and Wanaruk Saipunkaew, W. (2018). Corticolous lichen communities composition in *dominant* forests of Doi Inthanon National Park, Chiang Mai Province: Applications for long-term environmental change monitoring. *The KKU Science Journa 46*(4), 722-731. Retrived from https://ph01.tci-thaijo.org/index.php/KKUSciJ/article/view/249948.

Sumrit Senglek, and Kansri Boonpragob. (2015). The status of lichens in the deciduous dipterocarp forest at Khao Yai National Park. *Proceedings of the 9th Botanical Conference of Thailand.* (pp. 280-292). Bangkok, Thailand. Retrieved from http://www.lichen.ru.ac.th/images/data/ThaiJournal/2558_The%20status%20of%20lichens%20in%20a%20deciduous%20dipterocarp%20forest.pdf.

Tem Smitinand. (1977). *Plant of Khao Yai National Park*. Bangkok: New Thammada Press Ltd.

Thai Meteorological Department. (2022). *Climates of Prachinburi Province*. Retrieved from https://www.tmd.go.th/.

Wolseley, P. A., and Aguirre-Hudson, B. (1991). Lichens as indicators of environmental change in the tropical forest of Thailand. *Global Ecology and Biogeography Letters, 1*, 170-175.

Wolseley, P. A., and Aguirre-Hudson, B. (1997). Fire in tropical dry forests: corticalous lichens as indicators of recent ecological changes in Thailand. *Journal of Biogeography, 24*, 345-362.

CHAPTER II

SPECIES DIVERSITY AND SUBSTRATE PREFERENCE OF EPIPHYTIC LICHENS IN THE DRY DIPTEROCARP FOREST

2.1 Abstract

This work aims to explore the species diversity of lichens in the dry dipterocarp forest of Khao Yai National Park, in relation to the biotic factor of host species. Lichen diversity was performed within the sampling grids (size 10 cm x 10 cm). Five sampling grids were placed on the trunk base at 1 m above ground for each tree. All 514 trees (27 species) were investigated for lichen richness and abundance, together with environmental variables, including tree species, tree dbh, bark surface, bark lenticel, bark shedding, bark resin, water holding capacity of bark (wc), pH of bark, leaves area index, and elevation. There were 175 species of epiphytic lichens, approximately 89 % were crustose, while foliose, squamulose, and byssoid species shared 11 %. However, fruticose growth form was absent. The lichen taxa which were recorded as having the highest diversity belong to Graphidaceae (61 spp.), and the Trypetheliaceae (33 spp.) was the second most common family. The lichen genus *Graphis* (21 spp.) was the species-rich genera and followed by *Astrothelium* (14 spp.). This work found 28 new records for Thailand, and a lichen species was described as new to science. This lichen belongs to the genus *Aptrootia*. The tree species that supported the most lichen richness is *Vatica odorata*, which hosted 86 species. While *Dipterocarpus obtusifolius* is supported in the most abundance (4,446 thalli with IV = 120.41), this tree species has a high beta diversity, which indicates the high variation of lichen habitat found on this host species. Canonical Correspondence Analysis (CCA) indicated that bark surface was the most important factor directing the different lichen communities. Similar to CCA, PERMANOVA shows that the environmental variables which were significantly influenced species richness and abundance of lichens are bark surface, bark wc, tree dbh, bark lenticel, bark shedding, elevation, bark pH, and tree species. The indicator species of lichens that were selected indicate each environmental variable. Through

habitat acquisitions, the bark surface was shown as the most important factor that influenced lichen composition in this forest type the rough bark indicated by *Bacidia* sp.1, *Maronina corallifera* indicated for rough bark with scale, *Marcelaria bengulensis* indicated for smooth bark. The exploration of lichens in this work provided many aspects of the knowledge for managing our natural habitats. The DDF of KYNP can be evaluated as a high lichen diversity, the new exploration taxa can be added to the Thai lichen checklist, and the known important host species and their bark properties that are suitable for a high lichen richness and abundance could be covering the conservation strategies for maintaining the microhabitats for the lichens. The lichens as indicator species can be used as a tool to monitor environmental changes.

2.2 Introduction

Study of lichen diversity in Thailand

Thailand is known as the biodiversity-rich area in the world (6-10 % of the world's flora and fauna were estimated), there were approximately 37,000 taxa of biota have been recorded (Baimai, 2010). However, the exact number of lichen organisms could not be included in this number. Therefore, how many lichen species occurred in Thailand country are? It is an unclear answer recently. As we turn back to the old history of studying lichen in Thailand, over a hundred years ago, the first exploration of lichen diversity was started by european botanist (Vainio, 1909). Ninety-five species were recorded for that time. In the recent, a large increase in lichen diversity was projected, as a work by Buaruang, Boonpragob, Mongkolsuk, Sangvichien, Vongshewarat, Polyiam,...Lumbsch (2017), a total of 1,292 species of lichens were published in a checklist. After Buaruang et al., additional new lichen taxa were recently reported for the country (Luangsuphabool, Lumbsch, Piapukiew, and Sangvichien, 2018; Poengsungnoen, Buaruang, Vongshewarat, Sangvichien, Boonpragob, Mongkolsuk, and Lumbsch 2019; Poengsungnoen Vongshewarat, Buaruang, and Polyiam, 2022; Siringamram, Buaruang, Poengsungnoen, Polyiam, and Vongshewarat, 2022; Phraphuchamnong, Nelsen, Distefano, Mercado-Diaz, Parnmen, Rangsiruji, ...Lumbsch, 2022).

These may indicate that many lichen taxa belonging to the country are unexplored. Therefore, more investigation of lichen diversity is needed to complete the overall list of lichen species in this country. In addition, studies on the relationship between lichens and surrounding environments are important to understand their ecology, which challenges establishing the conservation strategy for the high diversity of lichen in Thailand.

Lichen and its environments

Lichens can survive in a wider range of climates, occurring in the very cool climate of Artic tundra and Antarctica. Some lichens can be grown in the hazardous habitat of high temperatures, such as on exposed rocks in the desert (Purvis, 2000). They could be a new colonist on the artificial or natural substratum. The bark of trees is a requirement for many lichens in the forest habitat.

The trees of tropical forests can host a large size of lichen community. There were several ten species to more than hundreds of species on a single leaf or a tree (Aptroot, 1997; Lücking and Matzer, 2001; Pinokiyo, Singh, and Singh, 2006). The relationship between epiphytic lichens and their host trees is contributed to qualifying the degree of phorophyte or host preferences that vary within suitable conditions. Generally, bark textures, bark moisture, the chemistry of bark, and bark pH were documented as the related factors that influenced epiphytic lichens (Barkman, 1958; Loppi and Freti, 2004; Hauck and Spribille, 2005; Cáceres, Lücking, and Rambold, 2007; Favero-Longo and Piervittori, 2010). Lichen diversity and species compositions are different within the variation of the host species, that bark properties may respond to the degree of phorophyte preferences of lichens (Loppi and Frati, 2004; Backlund, Jonsson, Strengbom, Frisch, and Thor, 2016; Marmor, Randlane, Juriado, and Sagg, 2017). The basic requirement and tolerance of lichens on tree bark are causing the specification (Brodo, 1973).

The understanding of the relationship between lichens and their phorophytes is our ordinary interest in lichen biology that was well documented in some areas of the temperate forests (Hale, 1955; Barkman, 1958; Adams and Risser, 1971; Brodo, 1973; Schmitt and Slack, 1990; Marmor et al., 2017) but few studies in new world tropical forest (Cáceres et al., 2007). Moreover, information on the relationship between lichens and their hosts is rare in the old-world tropical forest, such as in Thailand country. Some studies documented that the variation of tree species and bark properties affected the diversity and abundance of lichens (Boonpragob and Polyaim, 2007). This was a study in evergreen forests, however, the relationship between forest lichens and their phorophytes should be focused more on the deciduous forests, which are occupied in most areas of the country. The study involved the understanding of phorophyte to lichen diversity and abundance that the data can extend to more conservation efforts of our nature.

Objectives

This work was focused on exploring the lichen diversity in the dry dipterocarp forest type, which improved the knowledge of the diversity of lichen organisms in the study area which is important for the management of lichen conservation in the forest habitat. The main objective is to examine species diversity and substrate preference of corticolous lichens in the DDF of central Thailand.

Hypothesis

The lichen organisms are unrecognized in many natural habitats, and the unexplored species could be hidden in the pristine forest, therefor more investigation in this work could find more new species to the country and perhaps new to science. Besides the discovery of species diversity, the investigation of the requirement of lichen for their suitable habitats is also important, epiphytic lichens prefer the specific microhabitat on their phorophytes, which are referred to as biological factor, e.g., tree species, tree size (dbh), bark characteristics (texture or moisture) and pH of bark (Barkman, 1958). All of these, bark pH is a major factor influencing to diversity and species composition of lichens.

2.3 Review Literatures

What is lichen?

Lichen was found and described as bio-organisms over two hundred years ago. In 1867, the Swiss botanist, Simon Schwandener proposed the dual theory of lichen. The information found after study under the microscope that the lichens were composited organisms between fungi and algae or cyanobacteria. To associate a body with different organisms, lichens can formulate the thallus structures. The variety of the thallus structures can be seen by the function of the fungal partners. There are three major types of lichen growth forms, constructed by fungal hyphae, which are crustose, foliose, and fruticose. Several additional special types can be defined, which are related to one of three types, such as some crustose growth form, that thallus characterized by powdery, called “leprose lichen” or some foliose forming gelatinous cyanobacteria, called “gelatinous lichen”. There was the group of lichens called to follow the type of substratum, such as the lichens that grow on tree bark, which may be called “corticolous lichens”, on rock as “saxicolous lichens”, on plant leaves as “foliicolous lichens”, on mosses as “mussicolous lichens”, on wood as “lignicolous lichens” and on living trees as “epiphytic lichens” (Budel and Scheidegger, 2008).

Lichen diversity

Lichens are a member of the Kingdom Fungi, that this kingdom is known as the second largest group of organisms in the world. The lichen diversity was based on the fungal partner, this group of organisms is accepted as a high diversity. Hawksworth, Kirk, Sutton, and Pegler (1995) estimate the number of lichenized fungi as about 13,500 species worldwide. The complete world inventory is expected to total about 18,000 species (Sipman and Aptroot, 2001). The new approach to the number of lichenized fungi was published by Lücking, Hodkinson, and Leavitt (2016), they proposed that the accepted species is 19,387, these belonging to 995 genera, 115 families, 39 orders, and 8 classes. Recently, some new lichen species should be recognized and added to this number.

In Thailand, the lichen biota was evaluated as having a high diversity. In 2002 the first catalogue of Thai lichens was published, there were 554 species (Wolseley, Aguirre-

Hudson, and McCarthy, 2002). Fifteen years later the second checklist for Thai lichen was produced, and more than two times the species were presented (1,293 species) (Buaruang et al., 2017). After Buaruang, et al., there were continuously published many new lichens in the country (Luangsuphabool et al., 2018; Poengsungnoen et al., 2019; Suwannarach, Kumla, Satienperakul, Sungpalee, Hermhuk, Suttiprapan,...Lumyong, 2019; Poengsungnoen et al., 2022; Siringamram et al., 2022; Phraphuchamnong et al. 2022). That made the number of lichen taxa over 1,300 species recently. The total number of lichen species diversity in Thailand is unpredictable at this moment because there are some unexplored habitats for lichens distributed in several specific forests that need to be intensively investigated.

The environmental factors control lichen diversity

According to Barkman (1958) the term "epiphytic lichen" may refer to the organisms that live on plants or in the dead outer tissue of plants without drawing water or food from their living tissues. Following Ochsner (1928) as cited in Barkman (1958), the host plants could be called phorophytes. To colonize the phorophytes, the epiphytic lichens would survive depending on their phorophytes, together with other surrounding environmental factors. The knowledge of how epiphytic lichens can survive on their phorophytes, or environmental conditions is interesting.

Barkman (1958) pointed out that the three major possibility factors could influence epiphytic lichens. These are the abiotic environment, man, and vegetation. The abiotic environment may refer to macroclimate as wind, air humidity, and temperature. The abiotic may also refer to chemical compositions. Man can affect epiphytic lichens by changing the habitat structure or microclimate as followed by many activities such as deforestation, agriculture, and increase air pollution. The vegetation or phorophyte itself can influence microclimates in which epiphytic lichens grow, by creating different microhabitats for each lichen, that is direction of exposure, height above ground, inclination, and bark property. The biotic factors may include the animals who consume lichens as food, as medicine, and as shelter habitats. Another influencing factor may refer to the competition between lichens and other plants such as bryophytes, vascular epiphytes, and lianas (Barkman, 1985; James, Hawksworth, and Rose, 1977).

The influences of phorophyte on epiphytic lichens

Phorophyte property is an important factor for epiphytic lichens to select for their niches. Many reports indicated that the phorophyte is a major factor that has been close relation to lichen diversity and composition (Adams and Rissen, 1971; Brodo, 1973). Phorophyte properties may refer to host species, host age (related to tree size), bark structures, type and intensity of lenticel, type of nutrient and concentration in bark, pH of bark, water holding capacity, etc. (Barkman, 1958; Gardstein, Nadkarni, Krömer, Holz, and Nöske, 2003)

Tree species were the major comparison for the variations of lichen community in the natural habitat. As works by Upreti and Chatterjee (1999) compared lichen communities from two host species (belonging to *Quercus* and *Pinus*) and found that young trees supported the lichen communities dominated by crustose growth form, where the mature trees sustained the climax communities dominated by foliose and fruticose lichens. Loppi and Frati (2004) found that the diversity values measured on *Tilia* were on average 1.5 times higher than on *Quercus*. Boonpragob and Polyiam (2007) found different lichen communities on two dominant trees in the tropical rain forest, *Castanopsis* (smooth bark) dominated by crustose of Graphidaceae, whereas the *Dipterocarpus* (rough bark) dominated by crustose of Thelotremataceae. Backlund et al. (2016) pointed out that the epiphytic lichen species richness and species composition on the trunk of Pine and Spruce trees were different.

The other factors that are related to the host tree and influence epiphytic lichens such as host age, bark structure, and pH of bark. As reported by Caceres et al. (2007) found that the lichen communities are correlated to bark properties (bark pH, degree of bark shedding, density and size of bark lenticels, and presence of milk sap) and microclimates. Juriado, Liira, and Jaanus (2009) pointed out that tree-level variables (e.g. bark pH, bryophytes cover, and phorophyte species) explained the largest fraction of the variation in lichen species composition in the boreo-nemoral forest.

However, the site factors that may refer to forest structures can take place on the abiotic factor that influenced to lichen community. McCune, Rosentreter, Ponzetti, and Shaw (2000) found that the habitats of epiphytic lichens in conifer forest have induced by canopy structure and substrate characters. The epiphytic communities showed marked variation in height in the canopy, bark vs wood, degree of sheltering, and stem diameter. Komposch and Hafellner (2002) pointed out that tree height can affect the life form distribution of lichens, and that the foliose growth form the preferred upper region of the tree canopy, where the squamulose is frequent on the tree base. While crustose growth form dominated all height zones. Kelly, Donovan, Feehan, Murphy, Drangeid, and Marcano-Berti (2004) found that the environmental variables most closely correlated to variation in lichen community composition were the height above ground and horizontal gradient reflecting differences in forest structure.

Sampling of epiphytic lichen community

The problems of lichen behavior understanding in nature are concerning to many ecologists. Using the standard sampling techniques may help to learn the lichens community in some aspects of the study. The simple questions lichenologists want to know such as what those lichens are, where they are, how many of them, and why they associate with environments (Will-Wolf, Esseen, and Neitlich, 2002; McCune and Grace, 2002). There were several ways to approach the lichen community that had been posted to answer such previous questions, those ways so call "sampling" (McCune and Grace, 2002).

McCune and Lesica (1992) used three techniques to sample epiphytic lichens and compare the appropriate technique to capture lichens with meet the research goal. They suggested that a single large plot resulted in high species capture but low accuracy of cover estimates. Subsampling with many small plots, species capture was low, but the accuracy of cover estimated was higher for common species, this technique is appropriate when vegetation is relatively dense. Belt transects were intermediate in both species capture and accuracy of the cover estimate, this technique is suitable when sparse vegetation.

Sipman (1996) reviewed the sampling technique to study corticolous lichen diversity in tropical forests, based on the questions of how many species of lichen could be found and how complete inventory can be in the specific environment. He posted that lichen diversity much depended on the number of available microhabitats. Therefore, his advisement by using the sampling plot varying from 0.4-35 dm^2 is to be applied to investigate lichens on various parts of the common trees (tree base, lower trunk, upper trunk, inner canopy, outer canopy, etc.). These may represent the most diversity of corticolous lichen in available microhabitats and seem to be important in selecting the tree for the investigations.

Will-Wolf et al. (2002) suggested several ways to access the epiphytic lichen diversity and community compositions. They agree with the potential technique for sampling for the most lichens should be focused within the sampling plots. These are more quantified data sets that may cover the representative species of the specific habitat and have less bias. However, investigations technique can be applied depending on the research objectives.

Asta, Erhardt, Ferretti, Fornasier, Kirschbaum, Nimis, . . . Wirth (2002) used sampling grids to approach lichen diversity as an indicator of environment quality, by placing the sampling ladder on four aspects of the trunk base at 1.50 m above ground. Each sampling ladder has five 10 cm x 10 cm contiguous quadrats. Then they recorded lichen species in each sampling ladder and their frequency (number of quadrats in which lichens are found). Those allowed to calculate the Lichen Diversity Value (LDV). This LDV class level is used to evaluate the variation in environmental quality.

Gardstein et al. (2003) created the protocol for epiphytic observation in tropical rainforests by using several sizes of sampling plots. To cover the most diversity of epiphytes on trees, five zones on the tree were divided for lichen investigation. These were zone 1, which included the tree base (0-2 m above ground), zone 2, the tree trunk, zone 3, the base part of the branch, zone 4 included the second branches part, and zone 5 is the outer canopy. Investigation for zone 1-3 can use a 30 cm x 20 cm plot in four directions. Where zone 4-5 are elongated the length of the sampling plot as 60 cm (total surface depends on branch surface). However, the suggestions to work with an accumulation curve are important. These may allow deciding to scope how many trees is enough for investigation of the relation to species richness. The suitable number of sample trees was around 8 individuals.

Cáceres, Lücking, and Rambold (2008) found out the efficiency of sampling methods for an accurate estimate of species richness of corticolous microlichens in the rain forest. Among three techniques they found that the quantitative transect sampling yielded 3 times as much as non-quantitative opportunistic sampling found. The repetitive non-quantitative found 2 times of the number of species but only two-thirds of the number found in quantitative transect sampling. The quantitative transect sampling with subplots of size 20 cm x 60 cm was placed at the breast height of the phorophyte. They concluded that only 47 trees (16 species) can yield the most species of lichens in the forest (150 species or 3.19 sp./ tree).

Another simple technique to investigate the lichen community is lichen sampling by using the visualization technique. As studied by Reynole, Er, Winder, and Blanchon (2017) the distribution and the community of lichens in the mangrove forest of New Zealand were investigated. The lichens on a dominant tree species (*Avicennia marina* subsp. *australasica*) were carefully observed by visualized technique from the trunk base to the canopy. By this simple technique, they found 106 species of lichen taxa, these numbers made up 6 % of the total lichen diversity of the country.

Analysis of lichen community

An analysis of lichen diversity and community composition are measured by several types of numerical values. To understand how lichens can associate within favorable environments likely approached by many ecological indices, such as richness, abundance, evenness, etc. or evaluated by using diversity indices such as gamma diversity, alpha diversity, Shannon diversity, and Simpson diversity, etc. These were simply a measurement that was commonly used in lichen community study (Lücking, 1998; McCune and Grace, 2002; Will-Wolf, Geiser, Neitlich, and Reis, 2006).

Will-Wolf et al. (2002) suggested that the quantitative comparison of various indices related to lichen community composition with environmental variables can be structured in two general ways. They suggested that lichen community variables for a set of independent replicate plots can be compared with values of other variables using correlation or regression techniques. For the stratified structure dataset of the lichen community may be categories of the dataset that can be compared with summary values for other variables from the same plots and /or categories using ANOVA or similar techniques. However, multivariate analysis techniques are useful for investigating a pattern of variation, in different species composition and other community variables, and exploring the relationship of composition to multiple potential explanatory variables (McCune and Grace, 2002). Canonical Correspondence Analysis (CCA) is recommended for any species composition relation to the gradient of environmental variables (McCune and Grace, 2002; Cáceres et al., 2007)

Exploration of lichen diversity in Thailand

Lichens are among the micro-organisms that are found divers in Thailand. The importance of habitat variations provided a wide range of lichen distributions. There were increased by exploring based on general questions such as how many lichen species and where they are in Thailand. It still takes place the prior important questions that need to be answered. Although some part of those questions had been answered, the long history of study according to the first exploration of lichen diversity in Thailand have been done over a hundred years ago by European botanist (Vainio, 1909). Ninety-five species were recorded for that time. In the 20th century, many new lichen taxa were reported for one time and published in a paper. For example, Homchantara and Coppins (2002) reported 22 new species of the lichens family Thelotremataceae. Aptroot, Saipunkaew, Sipman, Sparrius, and Wolseley (2007), reported over 300 species of new records and new species in a paper. Papong, Bonpragob, and Lücking (2007) found a new species and 71 new records of foliicolous lichens in a national park.

In the recent, a large increase in lichen diversity is projected for Thailand. Buaruang et al. (2017) published a lichen checklist in Thailand, and a total of 1,292 species were recorded. However, after Buaruang et al. the additional of the new lichen taxa still presented to the country (Luangsuphabool et al., 2018; Poengsungnoen et al., 2019; Suwannarach et al., 2019; Poengsungnoen et al., 2022; Siringamram et al., 2022; Phraphuchamnong et al., 2022). This may indicate that many lichen taxa belonging to the country are unexplored. Therefore, more investigation of lichen diversity is needed to complete the overall list of lichen species in this country.

Previous studies on epiphytic lichen diversity were focused on the exploration of the forest floor (Wolseley and Aguirre-Hudson, 1997; Boonpragob, Homchantara, Coppins, McCarthy, and Wolseley, 1998; Aptroot et al., 2007). Thus, the inventory list of epiphytic lichen in the forest community is still far to complete. The unseen lichens, especially epiphytic lichens on the upper trunk and canopy strata of the forest are rare in the investigation. Although, such high levels on the trunk in some tropical forests were estimated to be suitable habitats for lichen richness (Sipman and Harries, 1989, Komposch and Hafellner, 2002). In a study by Boonpragob and Polyiam (2007) in the tropical rain forest at Khao Yai National Park, they found a high diversity of up to 270 taxa of lichens on six individuals of two host species, where the most lichen diversity occupied at canopy levels, but gradually decreased at lower levels on the trunk to ground level. The community composition was also different depending on tree heights. However, that report was investigated in the evergreen forest condition. On the other hand, there is no data on species diversity at the upper trunk and canopy levels of trees in deciduous forests.

A variety of forest types caused the complexity of the biotic and abiotic factors (Wolseley and Aguirre-Hudson, 1997; A-mornrat Pitakpong, 2009; Sujinda Bungwan and Wanaruk Saipunkaew, 2018). Among the several types of forest in Thailand, the deciduous dipterocarp forest type (DDF) is one of the important habitats that facilitates many specific lichens (Wolseley and Aguirre-Hudson, 1991; 1997). Generally, limiting factors in this forest type is low humidity, high light intensity, high temperature, and forest fire. Trees in this forest type might provide several types of microhabitats for the variation of lichen compositions.

The DDF has been found abundant in northern, northeastern, and western Thailand. Some studies on lichen diversity were in the northern and western parts of the country. Wolseley and Aguirre-Hudson (1997) reported between 40 and 47 taxa of lichens from the sampling plots in the DDF sites at Doi Suthep National Park and Huay Kha Khaeng Wildlife Sanctuary. While the exploration of lichen in northeastern and central parts has been reported at lower diversity. A-mornrat Pitakpong (2009) found

22 species of lichens at Sakaerat Environmental Research Station, and additional species were recorded at 31 species (Nooduan Muangsan et al., 2015). A team of lichenologists at Ramkhamhaeng University reported about 34 species of lichens in the same forest type at Khao Yai National Park (Ramkhamhaeng University, 2004; Sumruit Senglek and Kansri Boonpragob, 2015). However, the previous explorations have been done on a small area of DDF of KYNP and lichens were observed at the tree base. Thus, more lichen taxa on upper trunks and canopy have not been reported. These may indicate that many lichen species in the DDF of Thailand are unexplored. The need for quantitative observations in this forest type should be continued for all tree species as possible. At least on the whole part of the dominant trees. These could be covering the most diversity of lichens in the DDF of KYNP.

2.4 Materials and Methods

Site studies

The study sites (plots) were located along the nature trail from the base to the top of the mountain (about 7 km long) based on the appearance of DDF patches at five elevation ranges, in particular; 101-200, 201-300, 301-400, 401-500, 501-600 m.a.s.l. The details of each study site was shown in Table 2.1, distribution of the study sites (three sites for each elevation range) was plotted on the map (Figure 2.1). The general characteristic of study sites as DDF location, topography, geology, climates, and vegetation are summarized in chapter I (see also Figure 2.2).

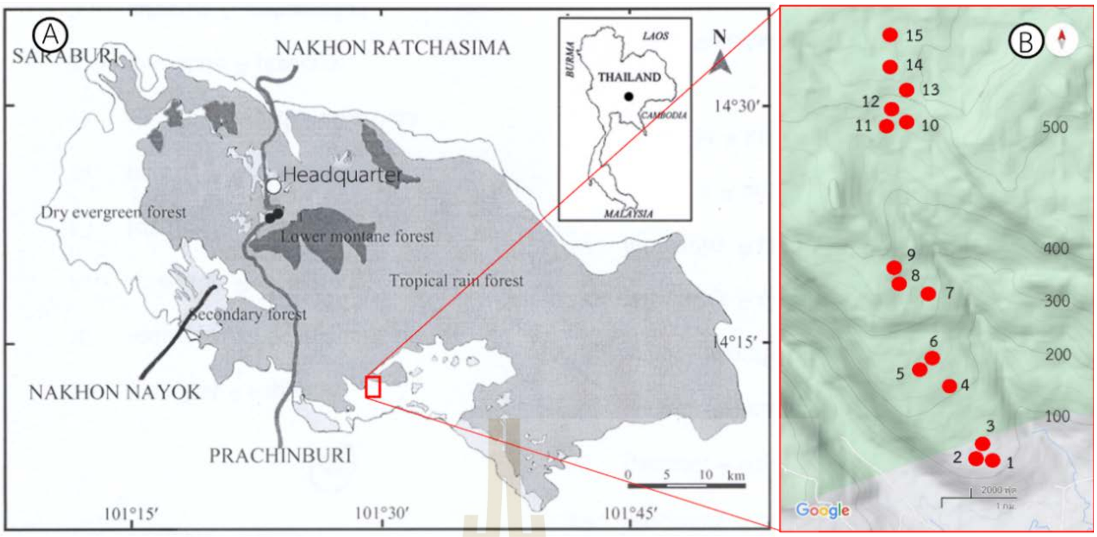

Figure 2.1 Map of KYNP and location of study sites in the DDF, (A: study sites are located at the southern part of KYNP, B: The red dots are the indicated each study site distributed at each elevation range of the contour map).

Note. The map was edited from Boonpragob and Polyiam (2007), and plotting of the study sites was applied on the contour map that consisted of the google map application.

Figure 2.2 Typical characteristics of the dry dipterocarp forest of Khao Yai National Park, (A-C: forest structures and vegetations of the study sites, D: *Dipterocarpus obtusifolius* the dominant tree species, E: tree trunk with eventually forest fires, and F: lichen community on a tree trunk).

Table 2.1 Positions and elevations of the study sites in DDF of KYNP.

Plot no	Elevation (m.a.s.l.)	Latitude	Longitude	No of sampling tree (species)	Mean tree dbh (min-max) (cm)	Leaf area index (min-max)
1	118	14°11'10" N	101° 29'52" E	37 (8)	12.9 (4.7-36.6)	1.19 (0.26-2.31)
2	125	14°11'11" N	101° 29'49" E	30 (9)	13.7 (4.5-27.3)	1.41 (0.35-2.48)
3	126	14°11'14" N	101° 29'47" E	31 (9)	13.6 (4.8-35.3)	1.45 (0.42-3.17)
4	253	14°11'51" N	101° 29'31" E	46 (8)	15.5 (6.4-44.0)	1.61 (0.02-3.1)
5	258	14°11'52" N	101° 29'28" E	30 (7)	17.5 (5.3-68.0)	1.69 (1.12-2.61)
6	214	14°11'54" N	101° 29'26" E	35 (5)	12.6 (4.2-26.5)	0.81 (0.03-1.84)
7	312	14°12'22" N	101° 29'25" E	46 (8)	10 (4.1-17.4)	0.96 (0.02-2.14)
8	376	14°12'23" N	101° 29'65" E	42 (6)	8.8 (4.0-23.0)	0.71 (0.17-1.48)
9	382	14°12'41" N	101° 29'17" E	39 (6)	25.1 (4.5-113.0)	1.50 (0.19-2.28)
10	471	14°13'34" N	101° 29'10" E	33 (5)	8.6 (4.8-2.0.5)	1.0 (0.45-1.58)
11	472	14°13'36" N	101° 29'80" E	25 (6)	9.2 (5.4-15.1)	0.8 (0.32-1.32)
12	484	14°13'37" N	101° 29'90" E	34 (5)	7.5 (4.5-13.4)	1.6 (0.49-2.75)
13	522	14.13'51" N	101° 29'12" E	23 (2)	14.4 (4.5-28.3)	1.50 (0.98-2.26)
14	538	14°14'40" N	101° 29'70" E	27 (5)	15.8 (4.3-51.0)	1.21 (0.23-2.37)
15	536	14°14'22" N	101° 29'20" E	36 (7)	7.8 (4.2-22.1)	1.51 (0.28-2.45)

Field sampling

The field work was started in January 2020 and finished in February 2022 (Field work was not possible during COVID-19 crisis). The field samplings were conducted within fifteen study sites (plots), each having an area of 400 m^2 (20 m x 20 m). The study sites were selected and referred to as the DDF patches (each DDF patch has a size ca. > 100 m in diameter) that were distributed along elevational gradients. The study sites were distributed from the foothill at 118 m.a.s.l. to the top of the hill at 538 m.a.s.l. The three study sites of each elevation range are distributed at least 50 m far from each other.

Environmental variable for lichens: Of the ten environmental variables measured for this study, most of the environmental variables were the tree variables. Within each study site, all trees with a diameter at breast high (dbh) larger than 4 cm (> 13 cm in circumference) were selected for lichen sampling. The tree data (environmental variables) are tree species, dbh, bark surface, bark shedding, present/ absent of lenticel, present/ absent of resin, Leaf area index of the plot, and elevations, which were recorded in the field. The small pieces of bark (size ca. 10 to 25 cm^2) of the sampling trees were collected to measure for bark pH and water holding capacity of bark in the laboratory.

Several characteristics of the environmental variables include 1) tree species, all trees in study sites with dbh larger than 4 cm. were selected, and the tree species were identified in the field as possible, if not some specimens of trees were collected and identified by a botanist in the laboratory. 2) tree dbh, measured using the dbh measuring tape. 3) bark surfaces, the barks are characterized into three different characters these are rough bark, rough-with scale, and smooth bark (Figure 2.3). 4) bark shedding were three categories as bark not shed, sparsely shed (up to 3 cm in diameter), and bark regularly shed (more than 3 cm in diameter) (Figure 2.3). 5) bark with lenticel (present/ absent) (Figure 2.3). 6) bark with resin (present/ absent) (Figure 2.3). 7) pH of bark, this allowed measuring in the laboratory using a flat head electrode with a potable pH meter Model Phi 200 (Beckman Instrument Inc, USA). The bark samples were moisture with 0.25 M KCl, then the flat head electrode was measured directly to bark surfaces (Farmer, Bates, and Bell, 1990; Kricke, 2002). This method allows measuring for the pH values of bark surfaces. 8) water holding capacity of bark, the data was measured from the same bark as pH measurements. After measuring for bark pH, the bark pieces were storage in deionized water for 24 hours, then the bark was removed from the water and put on the tissue paper to absorb the drop of water outside the bark, then weighed for a wet weight of each bark piece. All bark pieces were dry in a hot oven for 24 hrs. at 105 °C to evaporate the moisture within the bark pieces, After that let the bark cool at room temperature for 1-2 hrs, then weighed the bark pieces for dry weight. The water holding capacity was calculated as compared to % dry weight (Hauck, Jung, and Runge, 2000). 9) Leaf area index (LAI), is measuring the area of leaves over a unit of the ground surface (This may indicate the relation of light intensity on the area of study sites), the LAI was measured at the center of the study sites using the Plant Canopy Analyzer, Model LAI-2000 (LI-COR, Inc.). 10) elevation ranges were measured using the Garmin GPS, GPSMAP 65s.

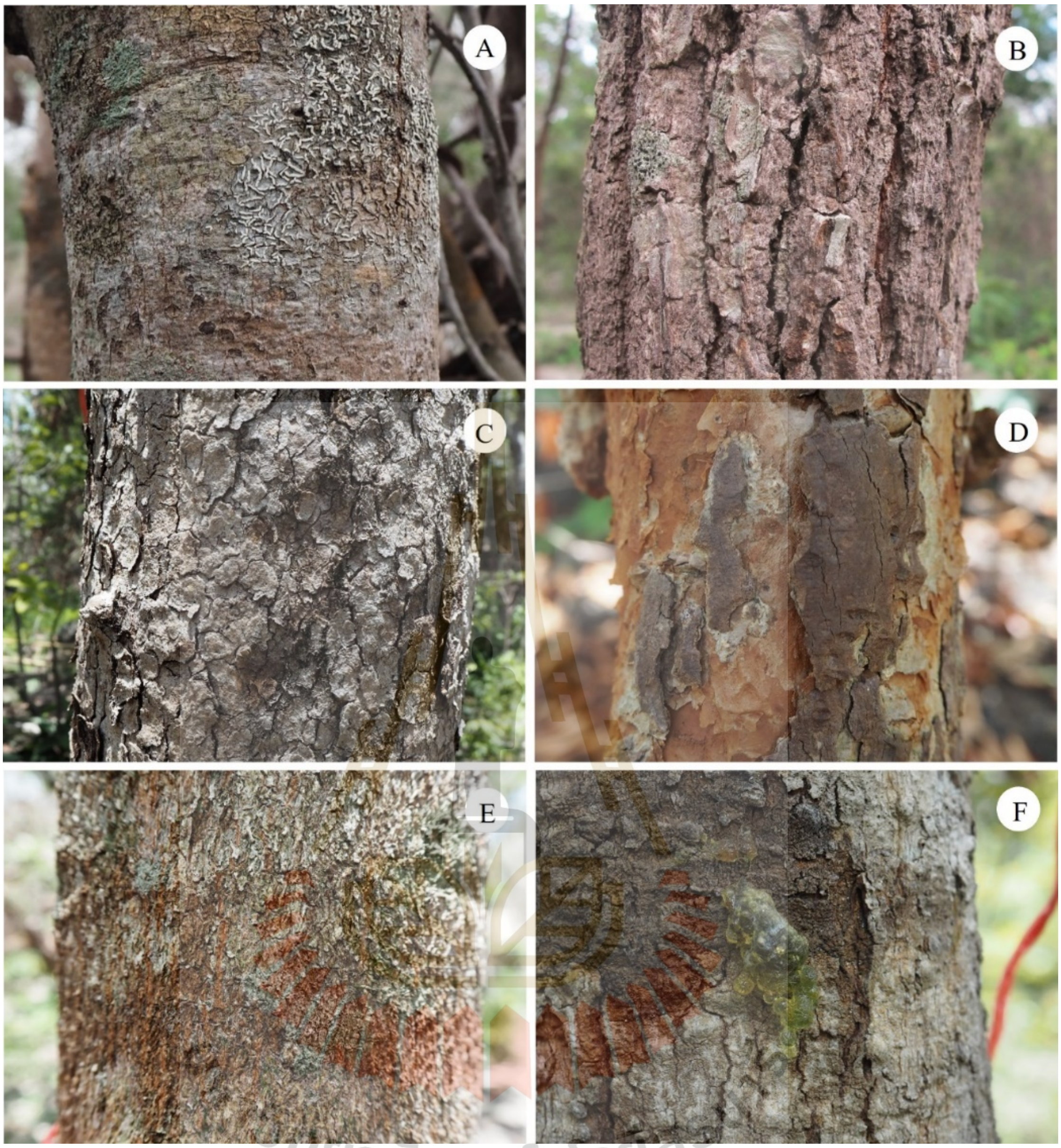

Figure 2.3 Bark characteristic of host trees in DDF of KYNP, (A: completely smooth bark of *Gluta usitata*, B: rough but not scaly bark, *Dipterocarpus obtusifolius*, C: rough bark with scaly, *Irvingia malayana*, D: bark with regularly shedding, *Syzygium antisepticum*, E: bark with abundance lenticel, *Corallia brachiata*, F: bark with resin, *Vatica odorata*)

Sampling of lichen diversity and community survey: The lichen data were investigated in the sampling grids as adapted from Asta et al. (2002), the five sampling grids size 10 cm x 10 cm were contagiously placed on the tree trunk at 1 m above ground level (Figure 2.4). Each sampling grid was placed on a tree direction with a high diversity of lichens visible. All selected trees in the study sites were recorded for their environmental variables as referred to in the sampling grid's position. The lichen taxa were identified as possible in the field, however, the voucher specimen for each lichen species were collected and extended identification was done in the laboratory at RAMK herbarium, Ramhkamhaeng University.

The data for lichen abundance was measured for each lichen species. Counting the number of thalli that occurred within the sampling grids was the frequency of each lichen on each tree (maximum = 5).

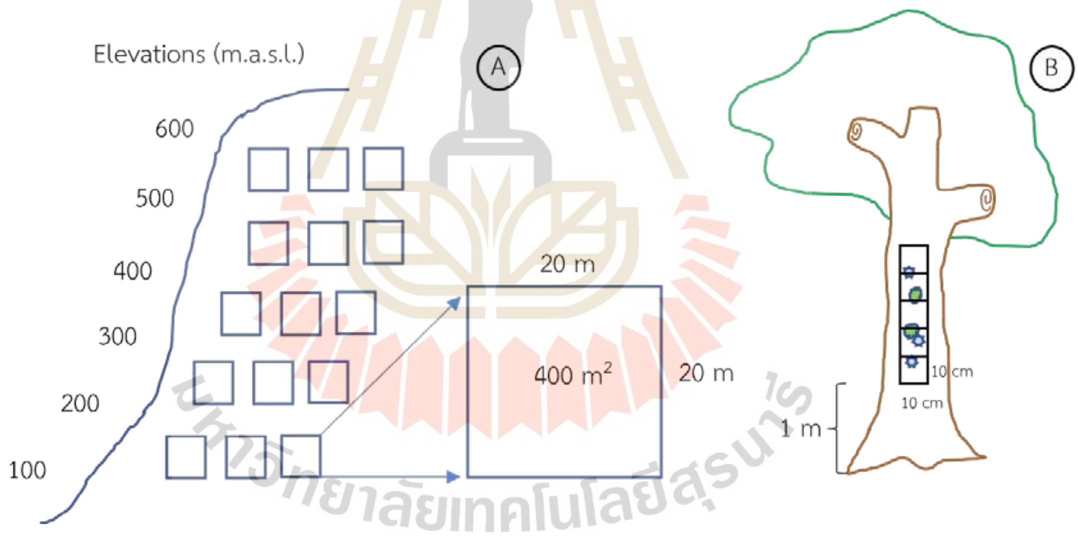

Figure 2.4 Drawing of sampling design for exploring the lichen diversity and community composition in the dry dipterocarp forest at Khao Yai National Park (A: the study sites are located at different elevation ranges of 100 to 600 m.a.s.l., each study site (400 m^2) is established for tree selection, B: the five sampling grids placed on the selected tree for lichen exploration.

Lichen identification

Lichen identifications were performed as follows the literature, such as Swinscow and Krog (1988); Awasthi (1991); Homchantara (1999); Kawinnat Noicharoen (2002); Papong, Boonpragob, and Lücking, 2012); Lücking, Archer and Aptroot (2009); Rivas Plata, Lücking, Sipman, Mangold, Kalb, and Lumbsch (2010); Aptroot and Lücking (2016); Poengsungnoen, Buaruang, Boonpragob, and Lumbsch (2021). Thallus, vegetative propagules, and ascomata morphologies were observed using the stereomicroscope (Olympus), Cross section of the thallus, fruiting body, and pycnidia were prepared under the Stereomicroscope by free hand section and investigated under the compound microscope (Olympus), these allowed to study thallus anatomy, type of photobionts, ascomata anatomy, as well as ascus, ascospore, and conidiospore characters. The secondary metabolites of lichens were examined by spot test technique, using a 10% of potassium hydroxide (K), sodium hypochlorite (C), paraphenylene diamine (P), and ultraviolet reaction (UV). However, thin layer chromatography was performed for some lichens that need to be identified by chemical characters (Orange, James, and White, 2010).

The specimens which are not possible to identify up to species level were indicated in genus level such as Genus name sp.1, 2, 3, etc. The sterile lichens which were not possible to identify for any genera level were studied based on thallus morphology, for instance, types of growth form, thallus corticate, thallus color, types of vegetative structures, and chemical test by spot test. These groups of lichens may name such as Unidentified crustose 1, 2, 3, etc.

An artificial key for the lichen genera and pictures of the taxa found in this study were provided (see Appendix E and Appendix F). Lichen identification was carried out at RAMK herbarium where the voucher specimens shall be kept as well.

Data analysis

Diversity and community of lichen: The analysis of species diversity was calculated for several measurements as follows Whittaker (1972). The three diversity values were measured as Gamma diversity (γ), which is the total number of species found on the host species or elevations, Alpha diversity (α), which is the average species richness per host species or elevations, and Beta diversity (β) is species turn over or compositional heterogeneity of species diversity across the sampling unit (host species or elevations), where the Beta diversity was calculated by the formula as γ/α (McCune and Grace, 2002, Berryman and McCune, 2006).

More analysis on species diversity was measured for the Shannon-Wiener index (H'). This diversity index can be used to compare the diversity between the sites (see McCune and Grace, 2002). This Shannon-Wiener index allowed evaluation of the richness of the lichens between habitats as well. The abundance of lichen was evaluated by the number of individuals. This value is commonly used to evaluate the lichen composition analysis (Will-Wolf et al., 2002). In addition, lichen similarity between elevation ranges was calculated by using Sorensen coefficient as follows Hawksworth and Seaward (1977).

The common–rare status of lichen was evaluated by the Important Value (IV). The IV was calculated from the sum of relative abundance (number of thalli) and relative frequency (number of grids) (Pinokiyo et al., 2008). The common-rare status of each lichen species in this study was divided into 4 categories, these are very common (IV= >3), common (IV= 1.1-3), rare (IV= 0.1-1), and extremely rare (IV= <0.1).

Lichen species composition and community measurements were analyzed using multivariate analysis. The Canonical Correspondence Analysis (CCA) was selected to assess the gradients in species composition (abundance) and their ecological relationship. The data set was managed in Microsoft Excel; the data matrices were prepared separately in two excel worksheets. The main matrix was the host species in columns and lichen species in rows, the second matrix was the host species in columns and environmental variables in rows. Within the data set, to decrease the noise of analysis, the tree sample that found only one lichen species, and the lichen species which recorded less than two individuals were excluded from the analysis. The outlier of the data matrix was analyzed within the statistical package, and they were excluded from the analysis as well. A total of 125 lichen taxa and 258 hosts (20 species) with nine environmental variables were included in the analysis.

A total of the variance explanation was calculated from CCA axes 1, 2, and 3. Pearson's correlation coefficients were calculated to compare the explanatory variables (dbh, bark surfaces, bark shedding, bark lenticel, bark resin, pH bark, water holding capacity, LAI, and elevations) and response variables (lichen abundance). The Monte Carlo permutation test (999 permutations, $p < 0.05$) was used to assess the statistical significant of relationships between lichen species and environmental variables (Ter Braak and Smilauer, 2002; McCune and Grace, 2002; Wegrzyn, Kolodziejczk, Falowshka, Wezyk, Zieba-Kulawik, and Szostak, …Wietrzyk-Pełka, 2020). The analyses were performed using PC-ORDS Ver. 5.10 (McCune and Grace, 2002).

Lichen indicator values: Indicator analysis was used to describe the species' relationships to environmental categories (McCune and Grace, 2002; Will-Wolf et al., 2002), and is commonly used to analyze the preference or specification of lichens to their suitable environments. Although the environments for lichens are complex, they can reflect the biotic or abiotic state of the environment where they live. Therefore, the determination of the lichen species as an indicator of their specific environments is important to understand the ecosystem functions (Will-Wolf et al., 2002). The indicator values were analyzed using the package "indicspecies" in R program (De Cáceres, 2022; De Cáceres, Jansen, and Dell, 2022). The analysis required prior classification of the site into the environmental variables. The different in lichen occurrence and abundance among the environmental variables were tested using the non-parametric multivariate statistic test. This work used the Permutation multivariate analysis of variance (PERMANOVA) to compare the groups of environments and test the null hypothesis that the dispersion of all groups is equivalent ($p < 0.05$). The analysis is based on Bray Curtis distance using the function "adonis 2" with 999 permutations in R.

For the data set of indicator species is determined using the species occurrence and abundance values from a set of each environmental variable. After classifying the same sites into site groups, that may represent the environmental variable types, The two data elements in an indicator species analysis were 1) the community data matrix; and 2) the vector that describes the classification of environmental variables. The analysis was run using the function "multipatt" that include in the "indicspecies" package in R version 4.3.2.1 (R Core Team, 2022).

2.5 Results and Discussions

Lichen diversity in the DDF of KYNP

A total of 175 taxa (60 genera, 21 families, and 15 unidentified crustose) of lichens were found in the DDF of KYNP (Figure 2.5, Table 1A, and Appendix F). They were crustose, foliose, squamulose, and byssoid growth forms. Where the most lichens inhabitant in the study sites were crustose growth forms (88.6 % or 155 species). Followed by foliose, squamulose, and byssoid growth forms (accounted for 9.7, 1.1, and 0.6 % respectively). This work divided the lichens into 10 functional groups of growth forms and reproductive structures, to address the characteristics of lichen which were flavor in this forest habitat. It was found that crustose with perithecia have the highest numbers of 43 species. The crustose with lirellate apothecia were subsequently lower, followed by crustose with perithecoid-apothecia, crustose with sterile stage, crustose with disc-like apothecia, foliose with green algae, crustose with irregular disc apothecia, foliose with cyanobacteria, squamulose and byssoid, those accounted for 36, 25, 20, 19, 13, 12, 4, 2, and 1 species respectively (Figure 2.6 and Table 1A).

Lichen diversity among the genera and family levels

The diversity of lichen that occurs in the DDF of KYNP was high in species diversity, and at genus and family levels. The most genera that gathered the highest diversity was *Graphis* (21 species), followed by *Astrothelium*, *Ocellularia*, *Thelotrema*, *Arthonia*, and *Phaeographis* which were more than or equal to five species recorded. However, another fifty-five genera have been found in less than five of the species (Figure 2.7 and Table 2.2). Whereas the diversity of lichen among family levels which occurred in DDF showed the highest diversity that belonged to Graphidaceae (61 species), subsequently lower by Trypetheliaceae, Caliciaceae, Arthoniaceae, Parmeliaceae, Lecanoraceae, Coccocarpiaceae, Monoblastiaceae, Pertusariaceae, Ramalinaceae, accounted for 34, 15, 15, 11, 11, 7, 4, 4, 4, 4 species respectively. While the rest family found only 1 species, these were Candelariaceae, Chrysothrichaceae, Coenogoniaceae, Fusidaceae, Mycoporaceae, Porinaceae, Pyrenulaceae, Ramboldiaceae, and Stereocaulaceae. However, this work found many sterile lichens (15 taxa) which were not possible to specify into family or genera levels, they need more information on further classifications (Figure 2.8 and Table 1A).

Newly lichens recorded for Thailand

A new species of lichen found in this work is belonging to the genus *Aptrootia* (Lücking, Cking, Sipman, UmaÑA, Chaves, and Lumbsch, 2007). This genus is also reported for the first time to Thailand (Buaruang et al., 2017). A few specimens were collected from the dominant tree species (*Dipterocarpus obtusifolius*), and this lichen may be specific to the host that consisted of DDF. According to Buaruang et al., the twenty-eight lichen species were classified into the new record taxa for Thailand (see Table 1A and Appendix F). All the new lichen taxa found can be an evaluation that this forest type is one of the important habitats, and the DDF of KYNP can have a high potential to support the species richness of lichens. However, there were many unidentified taxa, and these lichens need more careful identifications, perhaps more specimens are needed, and further study on identification could find out the name, for all new lichens recorded in this work can be improved to the Thai lichen checklist.

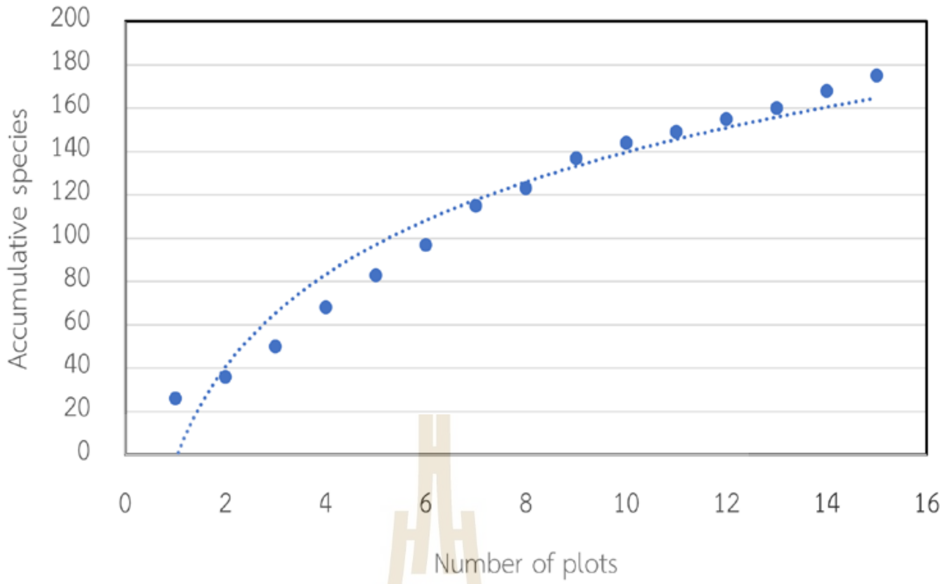

Figure 2.5 Species accumulation curve of the lichen within the sampling plots of the DDF of KYNP.

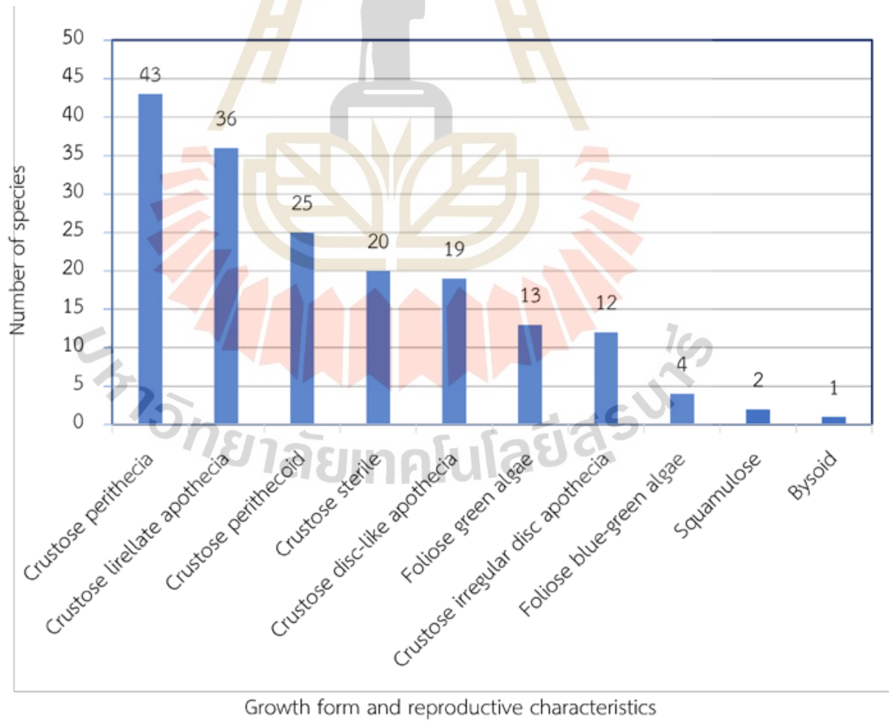

Figure 2.6 Species richness of lichen within each growth form and reproductive characteristics recorded from the DDF of KYNP.

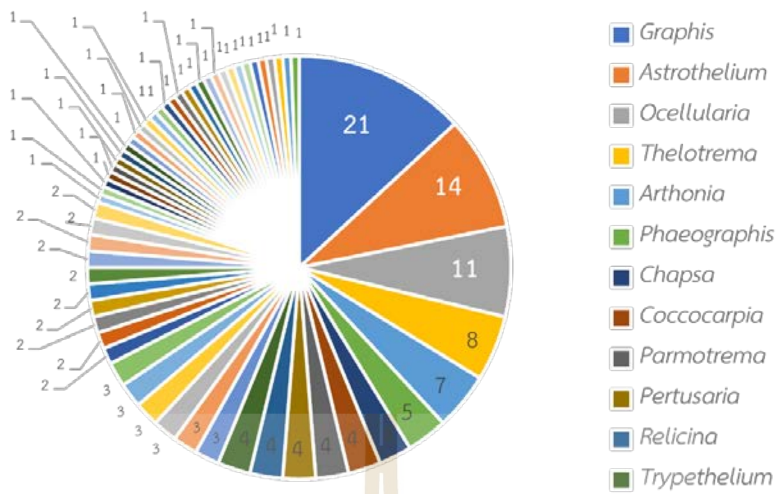

Figure 2.7 Proportion of species diversity of lichen within genera recorded from the DDF of KYNP. (Lichen name showing only the genera which found the highest number of species)

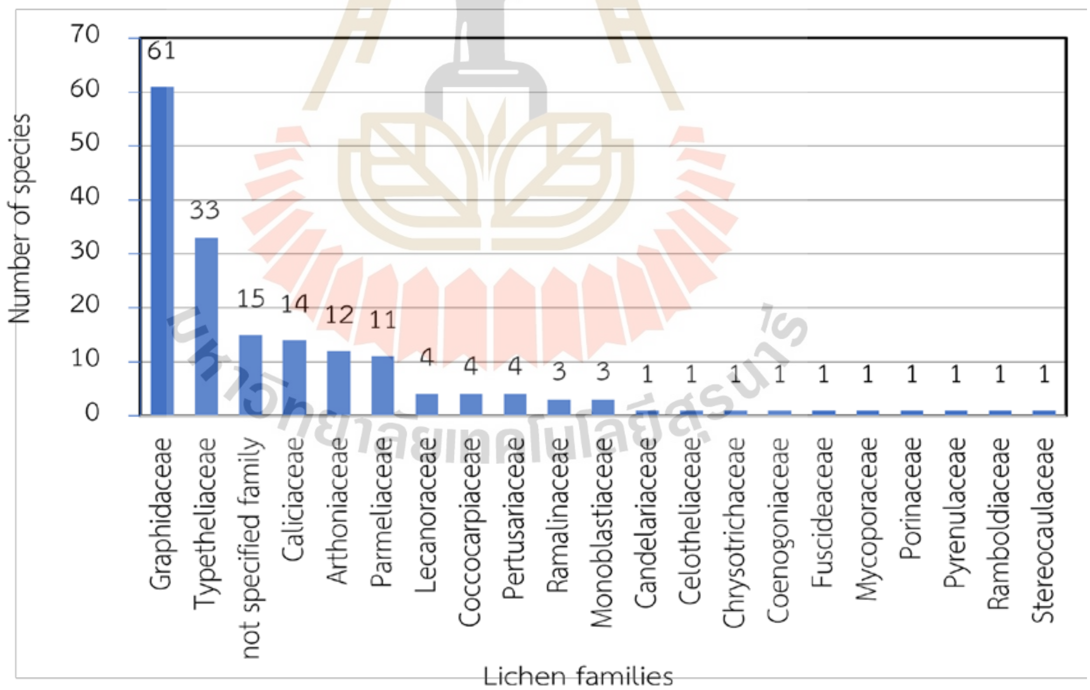

Figure 2.8 Species richness of lichen within each growth form and reproductive characteristics recorded from the DDF of KYNP.

Table 2.2 The list of lichen genera and the number of species recorded from the DDF of KYNP.

Lichen genera	no of species	Lichen genera	no of species	Lichen genera	no of species
Graphis	21	*Gassicurtia*	2	*Lepraria*	1
Astrothelium	14	*Hafellia*	2	*Marcelaria*	1
Ocellularia	11	*Nigrovothelium*	2	*Maronea*	1
Thelotrema	8	*Polymeridium*	2	*Maronina*	1
Arthonia	7	*Sarcographa*	2	*Mycomicrothelia*	1
Phaeographis	5	*Stirtonia*	2	*Mycoporum*	1
Chapsa	4	*Viridothelium*	2	*Myriotrema*	1
Coccocarpia	4	*Aptrootia*	1	*Pallidogramme*	1
Parmotrema	4	*Bacidia*	1	*Parmelinella*	1
Pertusaria	4	*Bulbothrix*	1	*Phyllopsora*	1
Relicina	4	*Candelariella*	1	*Porina*	1
Trypethelium	4	*Celothelium*	1	*Pseudopyrenula*	1
Amandinea	3	*Chrysothrix*	1	*Pyrenula*	1
Anisomeridium	3	*Coenogonium*	1	*Pyxine*	1
Bathelium	3	*Crocynia*	1	*Ramboldia*	1
Cratiria	3	*Cruentotrema*	1	*Stigmatochromma*	1
Lecanora	3	*Cryptothecia*	1	*Thelenella*	1
Platygramme	3	*Diorygma*	1	*Vainionora*	1
Arthothelium	2	*Dyplolabia*	1	Unidentified crustose	15
Dictyomeridium	2	*Fissurina*	1		
Dirinaria	2	*Glyphis*	1	Total no. of species	175

Species richness and abundance of lichens in different habitats in the DDF of KYNP

Species richness of lichen in different elevation gradients: The lichen richness can be evaluated in several types of ways, the number of species found (γ-diversity) can reflect the rich of the species in their habitats. This work found that the most lichen taxa (87 species) recorded between 301 and 400 m.a.s.l., and slightly lower (70-80 species) at 201-300, 501-600, and 401-500 m.a.s.l. This work found that the lowest diversity (50 species) of lichen recorded from 101-200 m.a.s.l. (Figure 2.9, Figure 2.10, and Table 2.3).

When averaging the number of species on the sampling unit (α-diversity), there was a similar pattern of change found in the α-diversity compared to γ-diversity within each elevation range. The highest alpha diversity was found at 301-400 m.a.s.l. and slightly lower at 201-300, 501-600, and 401-500 m.a.s.l. but less than half was recorded from 101-200 m.a.s.l., accounting for 3.3, 3.2, 3.1, 2.9, and 1.4 respectively (Figure 2.10 and Table 2.3).

The Shannon-Wiener index (H') were shown that the elevation ranges between 101 and 600 m.a.s.l. have similar values in H' (ranges from 4.1-4.4). However, the average of H' for this forest type is 5.9, this value indicated the high diversity of lichen could be evaluated (Figure 2.10 and Table 2.3).

Species abundance of lichens in different elevation gradients: Lichen abundances were evaluated by the number of thalli (see Table 3B and Table 4B). In some cases, they can be evaluated by the calculation of Important Value (IV) (see Table 1A). At different elevation ranges the lichen abundances were high, with the most lichen abundances found at 301-400 m.a.s.l, and subsequently lower at 201-300, 501-600, 401-500 m.a.s.l. Where the lower abundance was found in 101-200 m.a.s.l. (Figure 2.11)

The common-rare status of lichen reflected the abundance of the species in the DDF. Four categories of common-rare status of each lichens species can be evaluated here. (see Table 1A and Appendix F)

The very common species (IV = > 3), this group of lichens were found easily in this forest type, however, some of them perhaps specific to host species. The very common lichens of this DDF were 14 species, these are *Bacidia* sp.1, *Maronina corallifera*, *Amandinea efflorescens*, *Lepraria* sp.1, *Gassicurtia* sp.1, *Cratiria obscurior*, *Chrysothrix xanthina*, *Thelotrema monosporum*, *Phaeographis brasiliensis*, *Relicina rahengensis*, *Marcelaria benguelensis*, *Graphis streblocarpa*, *Bulbothrix queenslandica*, and *Relicina malaccensis*. The IV values accounted for 32.92, 21.69, 17.76, 14.98, 9.85, 8.69, 7.22, 4.98, 4.69, 3.81, 3.63, 3.59, 3.19, and 3.09 respectively.

The common species (IV = 1.1-3) were 18 species found in this status, such as *Parmotrema tinctorum*, *Polymeridium quinqueseptatum*, *Dirinaria picta*, *Chapsa indica*, and *Dyplolabia afzelii*, the IV values accounted for 2.47, 2.17, 2.04, 1.56, and 1.51 respectively.

The rare species (IV = 0.1-1) was the most group of lichen status occupied in this DDF. There were 98 species recorded, the lichens in this group such as *Ocellularia exuta*, *Bathelium madreporiforme*, *Astrothelium subdiscretum*, *Nigrovothelium tropicum*, *Candellariella sorediosa*, the IV values were 0.91, 0.9, 0.83, 0.8, 0.75, respectively. The newly described taxa *Aptrootia* sp.1 is recognized in this group as well (IV = 0.49).

The extremely rare species (IV < 0.1), this group of lichens found only one or a few thalli or found only on an individual tree. They were 45 species recorded, for example, *Anisomeridium polycarpum*, *Cruentotrema kurandense*, *Phyllopsora corallina*, *Celothelium aciculiferum*, and *Pseudopyrenula endoxanthoides*, all of these species have IV values less than 0.07. However, some species of lichen found in this group become very common in other forest types such as *Sarcographa labyrinthica*, which was a very common species of the tropical rain forest of the same national park (Boonpragob and Polyiam, 2007). This may indicate that the DDF is not suitable habitat for this lichen species.

Table 2.3 Diversity indices of epiphytic lichens occurred in different elevations in the DDF of KYNP.

habitats	No. of sampling tree	γ-diversity (no of species)	α-diversity species/sample tree (±SD)	β-diversity	H'	IV
site 1	37	28	1.3 (±1.4)	21.5	3.1	5.6
site 2	30	22	1.4 (±1.4)	15.7	2.9	6.1
site 3	31	27	1.5 (±1.5)	18.0	3.1	5.8
101-200 m.a.s.l.	98	50	1.4 (±1.4)	37.9	4.1	17.5
site 4	46	44	2.4 (±1.7)	18.3	3.2	17.9
site 5	30	36	2.9 (±2.4)	12.4	3.2	13.2
site 6	35	47	4.4 (±2.2)	10.7	3.5	23.1
201-300 m.a.s.l.	111	80	3.2 (±2.3)	25.6	4.4	54.2
site 7	46	54	3.2 (±2.0)	16.9	3.5	21.9
site 8	42	39	3.6 (±2.0)	10.8	3.1	23.4
site 9	39	44	3.0 (±2.2)	14.7	3.3	14.5
301-400 m.a.s.l.	127	87	3.3 (±2.2)	27.3	4.4	59.8
site 10	33	40	2.2 (±2.9)	18.2	3.3	8.4
site 11	25	44	3.0 (±2.0)	14.7	3.2	9.5
site 12	34	38	3.4 (±2.0)	11.2	3.1	15.8
401-500 m.a.s.l.	92	70	2.9 (±2.5)	24.8	4.3	33.7
site 13	23	23	2.7 (±1.6)	8.5	2.6	7.6
site 14	27	44	3.4 (±2.3)	12.9	3.6	12.8
site 15	36	48	2.8 (±2.3)	17.1	3.5	14.4
501-600 m.a.s.l.	86	78	3.1 (±2.3)	25.2	4.4	34.8
in the DDF of KYNP	514	175	2.8 (±2.2)	63.4	5.9	

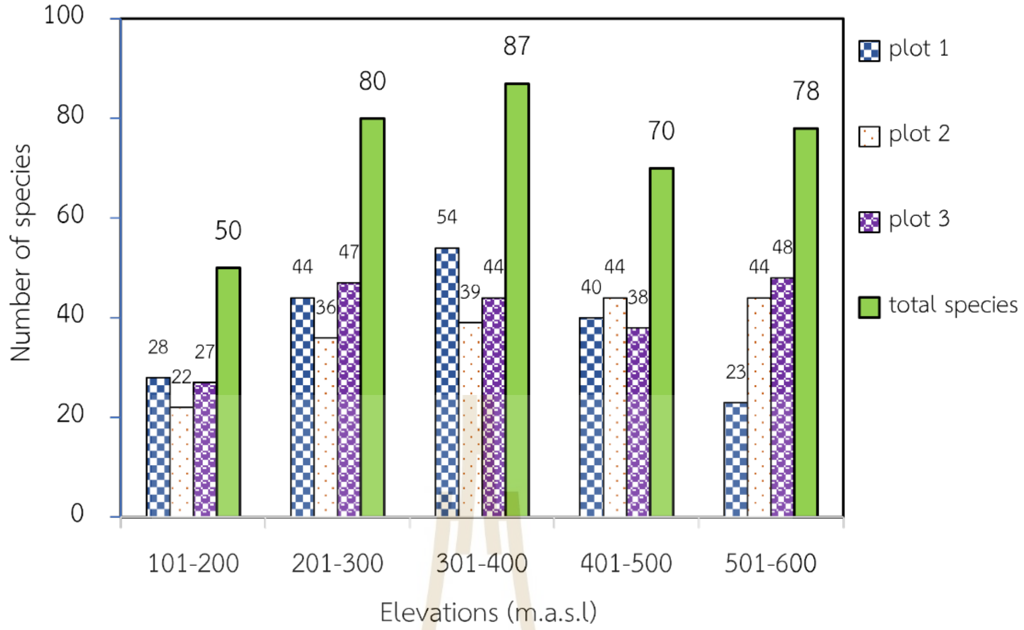

Figure 2.9 The species richness of lichen recorded from each elevation ranges in the DDF of KYNP.

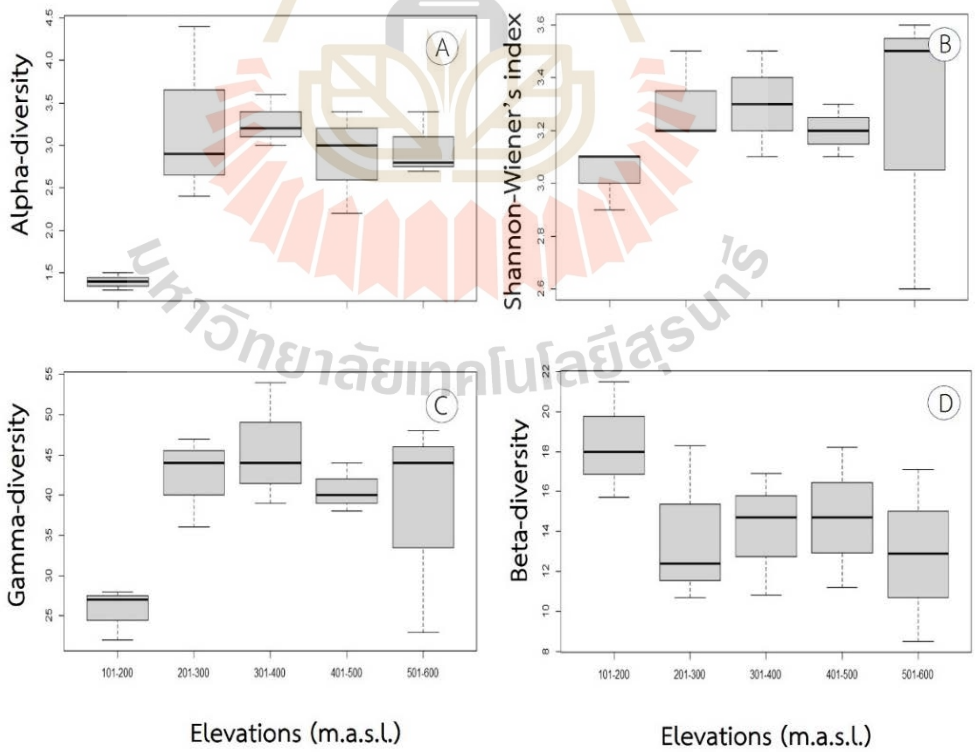

Figure 2.10 Lichen richness and diversity indices of the sampling plots in the DDF of KYNP.

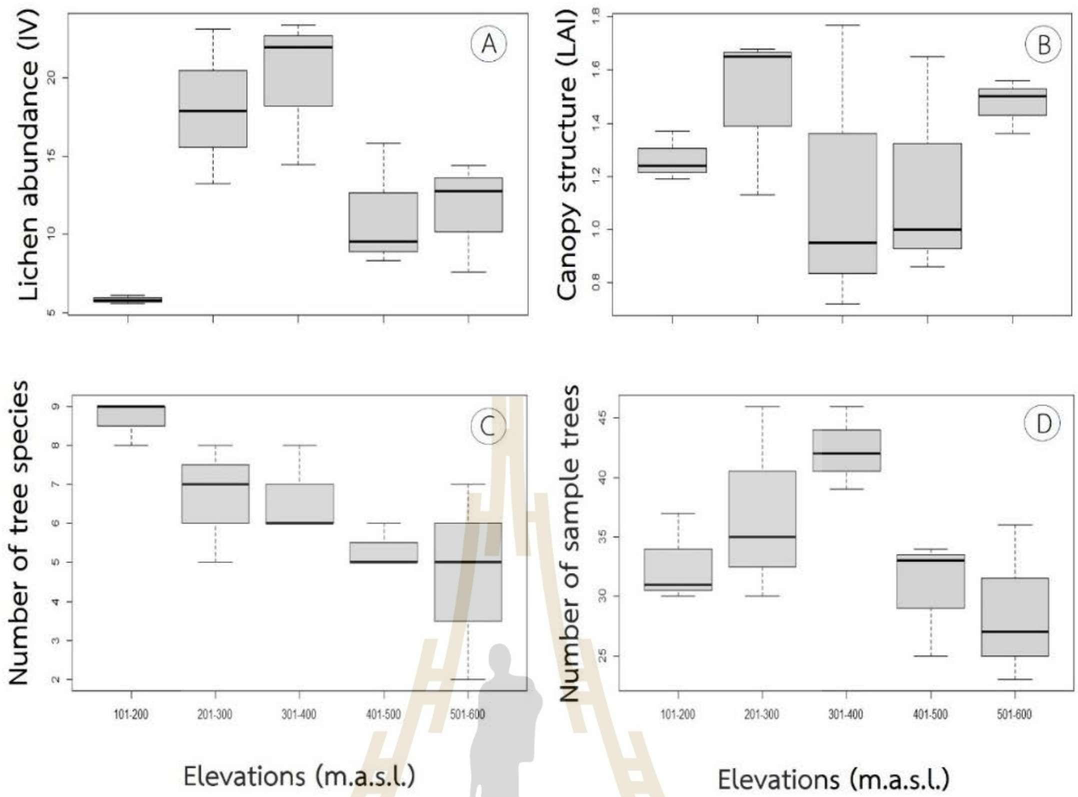

Figure 2.11 Lichen abundance, canopy structures, and sample tree variables in the DDF of KYNP.

Similarity of lichen species between elevations: The similarity of lichen species among five elevation ranges based on Sorensen Coefficient was shown in Table 2.4

The most similarity of lichen species was found between the elevations that have close to each other. They recorded the highest similarity (53 %) of lichens between 401-500 and 501-600 m.a.s.l., whereas the lowest similarity (33.6 %) was found between 101-200 and 501-600 m.a.s.l. However, other similarities of lichens in between elevation ranges were calculated at between 42-52 % (see Table 2.5). These results may indicate that the elevation influences the lichen distribution in the DDF of KYNP.

Table 2.4 Similarity (Sorensen's coefficient) of lichen species between elevation ranges (m.a.s.l.) in the DDF of KYNP.

Elevation ranges	101-200	201-300	301-400	401-500	501-600
101-200		50.37 (34 spp.)	41.96 (30 spp.)	43.20 (27 spp.)	33.59 (22 spp.)
201-300			48.84 (42 spp.)	50.65 (39 spp.)	51.25 (41 spp.)
301-400				51.85 (42 spp.)	50.00 (42 spp.)
401-500					53.33 (40 spp.)
501-600					

Host preference of lichens in the DDF of KYNP

Species richness and occurrence of lichens on different host species: Host species are important for lichen diversity and species compositions. However, the number of sampling trees in DDF did not equal on each tree species. Some tree species were common and dominated in this forest type, but some species were very rare (only one individual was sampled for 10 tree species). This was the character of the DDF of KYNP that the forest may not support many tree species as found in other forests. However, all host tree species have their characteristics that can provide the substratum for many lichens. Most of the tree species found in the DDF are characterized by a thick bark, these may be the defending strategies of trees against forest fire damage during the dry season.

There were 514 sampling trees explored for lichen richness and abundance, those trees belong to 27 taxa, (23 known taxa and 4 unidentified taxa) (the number of sample trees for each species is presented in Table 2.5). The most tree species found in the study sites were the *Dipterocarpus obtusifolius*, this tree has a large proportion (322 individuals, 63 %) of the tree sample. Other tree species that were sampled, accounted for 0.2-6.4 % of the proportions (Table 2.5).

The lichen richness recorded from each tree species varies from 1 to 86 species (gamma diversity), the highest number of lichen species was recorded on *Vatica odorata* subsequently by *Dipterocarpus obtusifolius* (accounted for 86 and 70 species, respectively). It seems that the trees of Dipterocarpaceae are important for lichens to inhabit. Satya, Uppreti, and Nayaka, (2005) pointed out that the tree in the family Dipterocapaceae; *Shorea robusta* was an excellent host for lichen growth in India. They found the lichen composition were different even with different age of the trees, young tree with smooth bark supported the *Chrysothrix candellaris* and pyrenolichens, while the old tree (with rough bark) was dominated by foliose growth form (Collemioid, Parmelioid, and Physcioid) with some crustose of *Buellia*, *Pertusaria*, and *Graphis*.

As a comparison between the two favor host species for lichen richness, the *Vatica odorata* has a smooth bark character, it has a higher pH, and water holding capacity of bark (averaged 4.1 and 71.9 %, respectively). but the *Dipterocarpus obtusifolius* has a rough bark with lower values of pH, and water holding capacity of bark (averaged 3.3 and 65.4 %, respectively) (see Table 1B). It was supported that most lichen species are different on both host species (only 22 species or 28.2% of similarity found). Besides the species diversity, the species abundant also show very surprising that the most abundant lichens found only on the *Dipterocarpus* tree but not occurred on any *Vatica* tree, these abundant lichens are *Amandinea efflorescens, Bacidia* sp.1, *Gassicurtia* sp.1, and *Lepraria* sp.1. Contrastingly, the lichen species that are occurred only on the *Vatica* seems to be the pyrenolichens, these, for example, *Macelaria benguelensis, Nigrovothelium tropicum* and some species of the *Astrothelium* (Table 3B and Table 4B). This was suggested that the bark properties of different host species may play an important role in creating different favorable habitats for each lichen (Upreti and Chatterjee, 1999).

Most of the tree species hosted for lichen less than half of the favor one at between 1 and 46 species. However, there were two host species that could not find lichen growing on the trunk base (Table 2.5 and Figure 2.12). Those two host species are *Lagerstroemia* sp.A, and *Memecylon scutellatum*. The two host species are characterized by inconstantly bark surfaces that are not permanently substrate for lichens. The *Lagerstroemia* sp.A has bark with a smooth and shiny bark surface, the outer surface often shedding. This character of bark is not benefit for the reproductive part of lichen to attach and colonized. However, if the reproductive part of lichen can be colonized, the new thalli may not survive as long as bark shedding. For the *Memecylon scutellatum,* bark characterized by flaky substrate, and fallen apart bark pieces are common. This is not the permanent habitat for lichens. However, the lichens that sometimes grow on this tree species are the leprose growth form such as the leprariod lichens (field observation by the author). This type of lichen has a loose thallus as a bark character, this is a benefit for leparoid lichens in a dispersion strategy.

The average of lichen diversity within the sampling tree shows a different value depending on tree species, which ranged from 0.1 to 6.0 of alpha diversity. The highest alpha diversity found form *Vatica odorata* (α diversity = 6.0). Other tree species provided different alpha diversity as shown in Table 2.5.

The beta diversity is indicated by the heterogeneity of the lichen host, which was found a high value from the *Dipterocarpus obtusifolius* (β diversity = 33.2). While most trees found, have beta diversities at lower than half of which found in the former tree species, they could have more homogeneity of the substrata than the *D. obtusifolius* (Table 2.5)

Table 2.5 Summary the lichen richness and abundance on each tree species which occupied in the DDF of KYNP.

No.	Host species	Number of sample trees	number of lichen thalli	Average no. of thalli/tree	Diversity Measures			IV
					γ	α (±SD)	β	
1	*Acronychia pedunculata*	3	25	8.3	6	2.0 (±3.5)	3.0	0.71
2	*Corallia brachiata*	19	388	20.4	39	4.8 (±2.3)	8.4	12.16
3	*Cratoxylum formosum*	1	9	9.0	2	2.0	1.0	0.29
4	*Dalbergia chochinchinensis*	4	64	12.8	14	4.5 (±4.4)	3.1	1.29
5	*Dellinia obovata*	1	7	7.0	2	2.0	1.0	0.37
6	*Diospyros* sp.A	2	17	8.5	4	2.5 (±2.1)	1.6	0.62
7	*Dipterocarpus intricatus*	21	262	12.5	23	3.0 (±1.4)	7.7	8.08
8	*Dipterocarpus obtusifolius*	322	4,446	13.8	70	2.3 (±1.6)	33.2	120.41
9	*Garcinia cowa*	1	9	9.0	2	2.0	1.0	0.26
10	*Gluta usitata*	30	382	12.7	46	3.9 (±1.9)	11.9	12.13
11	*Irvingia malayana*	16	154	9.6	20	1.7 (±2.0)	12.1	3.96
12	*Lagerstroemia* sp.A	1	-	-	-	-	-	-
13	*Melodorum fruticosum*	5	27	5.4	9	2.0 (±2.0)	4.5	1.09
14	*Memecylon scutellatum*	1	-	-	-	-	-	-
15	*Neonauclea purpurea*	1	17	17.0	5	5.0	1.0	0.60
16	*Ochna intergerima*	7	71	10.1	12	2.1 (±2.0)	5.6	2.13
17	*Parinari anamensis*	8	188	23.5	18	3.8 (±1.7)	4.8	4.90
18	*Schima wallichii*	1	57	57.0	5	5.0	1.0	1.25
19	*Shorea roxbergii*	4	91	22.8	13	3.8 (±2.9)	3.5	2.36
20	*Sindora siamensis*	8	69	8.6	11	2.0 (±1.1)	5.5	2.21
21	*Syzygium antisepticum*	8	5	0.6	1	0.1 (±0.4)	8.3	0.78
22	*Syzygium* sp.A	8	48	6.0	14	2.5 (±2.1)	5.6	0.82
23	*Vatica odorata*	33	575	17.4	86	6.0 (±3.3)	14.2	19.60
24	unknown A	1	9	9.0	2	2.0	1.0	0.29
25	unknown B	1	9	9.0	2	2.0	1.0	0.29
26	unknown C	1	16	16.0	1	1.0	1.0	0.36
27	unknown D (Ebenaceae)	6	88	14.7	17	4.0 (±2.4)	4.3	3.05
	Overall	514	7,033	13.7	175			

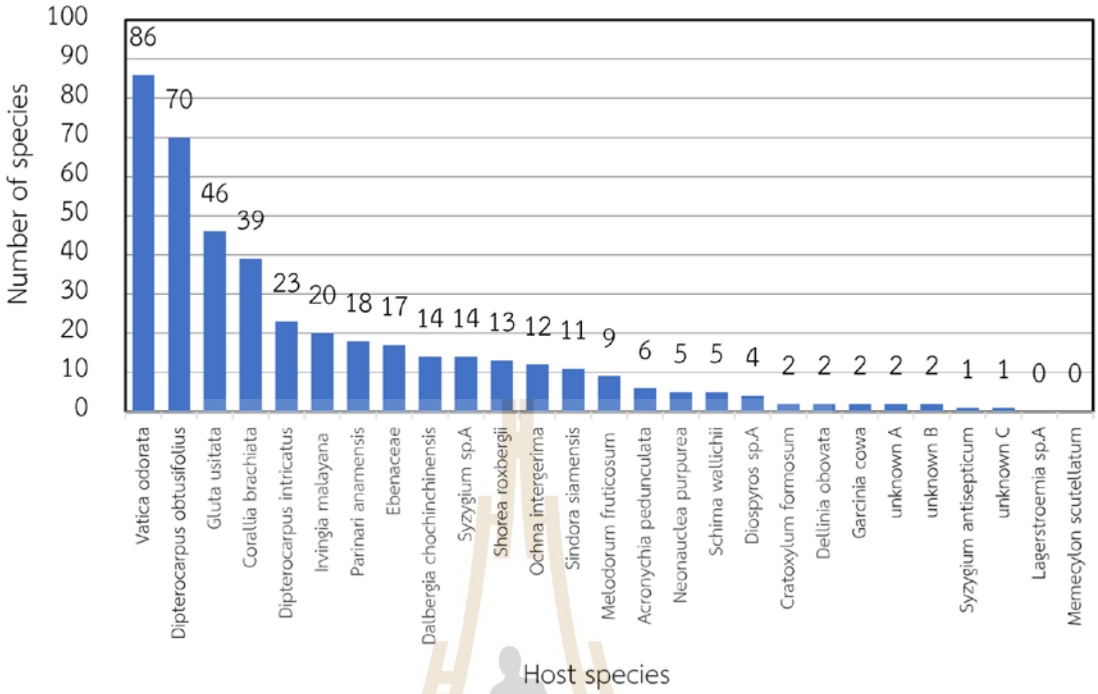

Figure 2.12 Lichen richness on various tree species in the dry dipterocarp forest of KYNP.

Ordination of lichen community on the variation of tree species in the DDF of KYNP: The direct gradient analysis of lichens to their environmental variables by CCA showed the distinct group according to tree species (Figure 2.13). The most favorable tree species that found a high number of lichen specie was *Vatica odorata*, its form a group on the right side of axis 2 and was mostly distributed at the upper side of axis 1. The second most favor host was *Dipterocarpus obtusifolious* this host species was grouped on the left side of axis 2 and have a wide distribution along this axis above and below axis 1. Other common host species for lichens such as *Gluta usitata* and *Corallia brachiata* mostly formed the groups on the right side of axis 2 and below axis 1. Grouping of the ordinations of tree species may be influenced by several environmental factors, and the bark surface showed the highest correlation with axis 1 (Figure 2.13, Table 5C, and Table 6C). In the DDF of KYNP, the most common tree species found in study sites and the most favor host for lichens are the trees in the family Dipterocarpaceae, these are *Vatica odorata* and *Dipterocarpus obtusifolious*. The two host species have a thick and hard bark which was constant for lichen inhabitants. However, the two tree species have different textures of bark, as the *Vatica odorata* has smooth bark, but *Dipterocarpus obtusifolious* has a rough bark with distinct deep cervices (see Figure 2.3). Other two host species, *Gluta usitata* and *Corallia brachiata* may be grouped correlated to bark water holding capacity and the presence of bark lenticel (Figure 2.13, Table 3C and Table 6C).

Lichen species that are found on the two host species grouping separately with referred to their host species. Most of the lichen species ordinated in the center of the graph may be found overlapping in the variation of environmental variables. On the other hand, lichens in DDF can be survived or tolerated minor changes in environments. However, many lichens that are not grouped in the center or distributed separately in the graph could favor other host trees (Figure 2.14, Table 4C).

Influence of environmental variations and lichen diversity: Several factors of environmental variables affected lichen diversity (Table 2.6). The PERMANOVA result shows that among the ten environmental variables, the bark surfaces of the trees were the most factor that influenced significantly on lichen diversity ($F = 7.0899$, $p = 0.001$). Other factors that can have a significantly influenced on lichen diversity were the bark water holding capacity ($F = 3.0007$, $p = 0.001$), tree dbh ($F = 2.9235$, $p = 0.001$), bark lenticel ($F = 2.6883$, $p = 0.002$), bark shedding ($F = 2.2696$, $p = 0.002$), elevations ($F = 2.0872$, $p = 0.004$), bark pH ($F = 1.9400$, $p = 0.006$), and host tree species ($F = 1.7540$, $p = 0.001$). The environmental variables shown above were recognized as the most factors found influenced directly to lichens in other forest types (Cáceres et al., 2007).

However, two factors that were found not significantly influenced lichen diversity in the DDF are the leave area index and the presence of bark resin. This may be explained by the tree in the DDF of KYNP are not high as found in other forest types and the life form of trees are deciduous trees, therefore within this forest type, the lichens have no limited uptake of the radiation that important for their photosynthesis process. This result was found to contrast with a work by Boonpragob and Polyiam (2007), that the light along the trunks of trees in the tropical rain forest was an important factor to control species richness, species composition, and abundance below the canopy.

The present of resin may not be influenced lichen diversity because the lichen may take place on the bark as a permanent epiphyte, but the resin of bark usually occurred for short periods on trees, and resin is always present when the tree bark was damaged, however, in this work, the resin was recorded on some trees of the *Dipterocarpus obtusifolius* and *Vatica odorata*, that those trees species are known as the most flavor for high lichens diversity in this DDF.

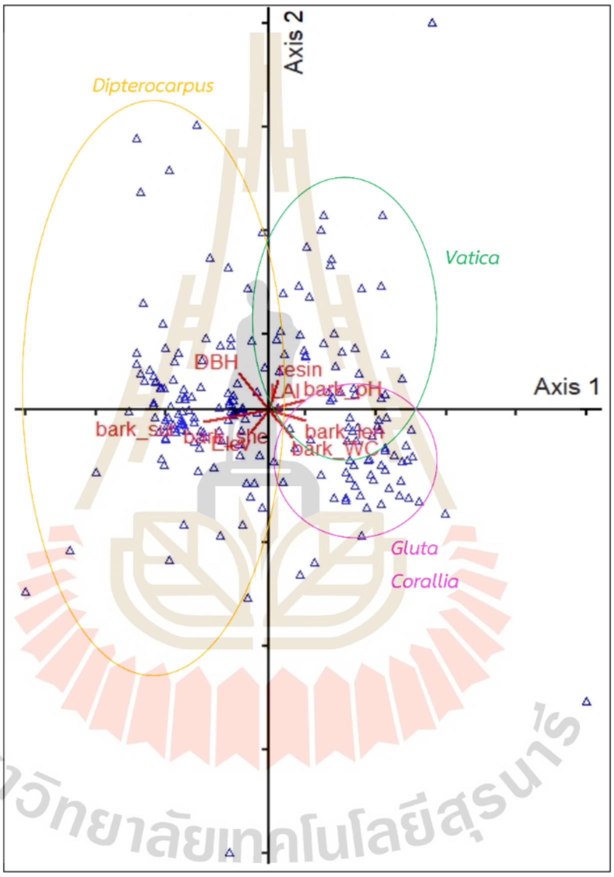

Figure 2.13 Canonical Correspondence Analysis (CCA) plot of studied tree samples. The circular line indicated the groups of major tree species that supported a high lichen diversity in the DDF of KYNP.

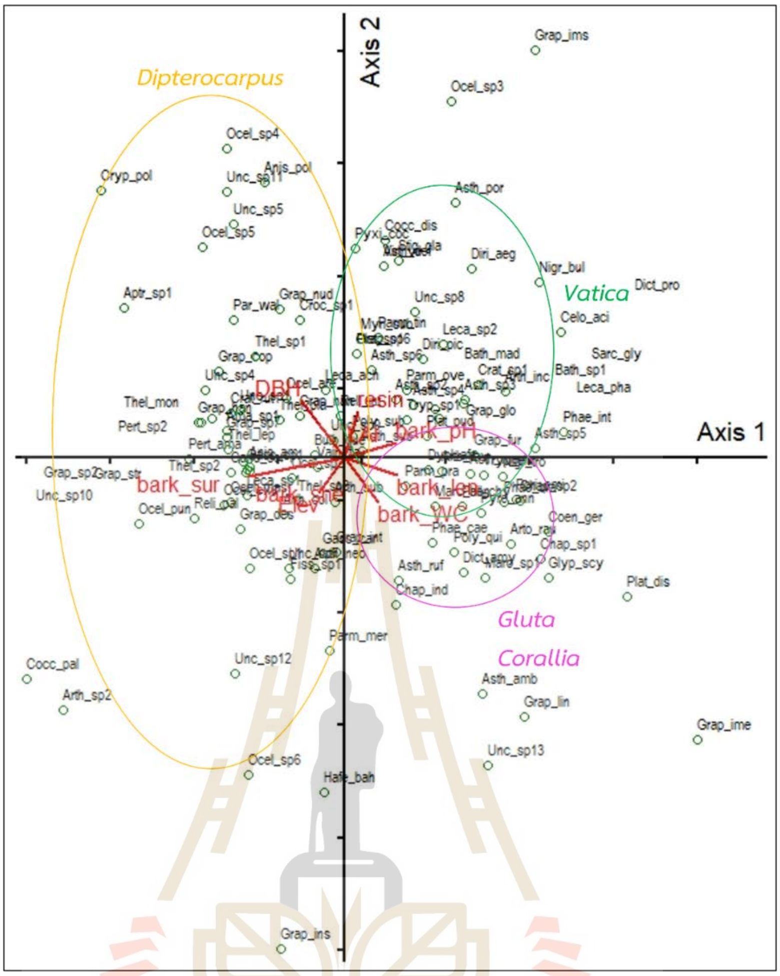

Figure 2.14 Canonical Correspondence Analysis (CCA) plot of lichen samples. The circular line indicated the groups of major tree species that supported a high lichen diversity in the DDF of KYNP.

Table 2.6 PERMANOVA summary of environmental variables that influenced lichen diversity (Bray Curtis Distances).

Environmental variables	df	Sum of squares	Mean square	F ratio	p-values
bark_surface	1	3.234	0.02695	7.0899	0.001
bark_WC	1	1.391	0.01159	3.0007	0.001
tree_dbh	1	1.355	0.01129	2.9235	0.001
bark_lenticel	1	1.247	0.01039	2.6883	0.002
bark_shedding	1	1.055	0.00879	2.2696	0.002
elevation	1	0.971	0.00809	2.0872	0.004
bark_pH	1	0.903	0.00752	1.9400	0.006
host_species	21	16.203	0.13500	1.7540	0.001
LAI	1	0.696	0.00580	1.4941	0.053
bark_resin	1	0.627	0.00522	1.3441	0.101

Indicator species for environment variables in the DDF of KYNP

In this work, the indicator species of lichen for their specification of environmental variables are determined using the species occurrence (175 species) and abundance values (number of thalli) from a set of each environmental variable. The environmental factor that uses to be evaluated for indicator species is the bark surface. As follow the results of PERMANOVA analysis (Table 2.6), it was clear that the bark surface of trees in the DDF plays an important role on control the lichen diversity in this forest type. Therefore, finding the lichen that can be indicated by each bark surface characteristic was discussed here. After analyses for indicator species of lichens using a statistical package, there were 34 species of lichen have been selected to indicate several characters of barks. Which were found 31 species can be indicated for one group of barks type, whereas three species indicated for two groups of bark types (Table 2.7)

The indicator species for the rough bark, four species of lichen indicate this type of bark, *Bacidia* sp. 1 has the highest correlation (corr. = 0.415, p = 0.001), other lichen species that can be evaluated as indicator species for the rough bark are *Lepraria* sp.1 (corr. = 0.260, p = 0.001), *Thelotrema monosporum* (corr. = 0.191, p = 0.001), all three lichens have a highly significant to be the indicator species for this bark type. Those three lichens are commonly found on the bark of *Dipterocarpus obtusifolius*, and another tree with related to rough bark character.

Indicator species for rough with scaly bark, there were five species indicated for this bark type, such as *Maronina corallifera* (corr. = 0.243, p = 0.002) and *Cratiria obscurior* (corr. = 0.181, p = 0.004). The trees which were found for this bark category such as *Irvingia malayana* and *Ochna intergerima*.

Indicator species for smooth bark, there were 22 species of lichen indicated for this bark type, such as *Marcelaria bengulensis* (corr. = 0.31, p = 0.001), *Dyplolabia afzelii* (corr. = 0.278, p = 0.001), *Pallidogramme chrysenteron* (corr. = 0.225, p = 0.001), *Phaeographis caesioradians* (corr. = 0.2, p = 0.001), and *Bathelium madreporiforme* (corr. = 0.195, p = 0.001). The tree with smooth bark such as *Gluta usitata*.

Indicator species for rough and bark with scale. The *Amandinea efflorescens* (corr. = 0.175, p = 0.009) is only one selected species. This lichen can be found in many tree species.

Indicator species for rough with scale and smooth bark, there were two lichen species found. These are *Phaeographis brasiliensis* (corr. = 0.21, p = 0.001) and *Polymeridium quinqueseptatum* (corr, = 0.149, p = 0.02). Those lichens are commonly found on the smooth bark of *Gluta usitata,* and *Vatica odorata*. However, some thalli are also found on bark on small scale such as *Corallia brachiata*.

The lichens that could be indicated for another aspect of environmental variables for this work are presented in Appendix D, they can be a high potential species to monitor the environmental changes in the future. To use lichen as indicator species for a set of environments, the lichen species should be carefully selected as a suitable indicator for specific environments. However, using the group of lichens as a monitoring tool is recommended (McCune et al., 2000; Will-Wolf et al., 2002; Berryman and McCune, 2006; Munzi, Ravera, and Caneva, 2007).

Table 2.7 The selected lichen species that indicated 5 types of bark characteristics of the phorophytes in the DDF of KYNP (see more species in Appendix D).

Lichens	Statistically significant	
	correlation	p-value
Indicator species of rough bark (4 species)		
Bacidia sp.1	0.415	0.001
Lepraria sp.1	0.260	0.001
Thelotrema monosporum	0.191	0.001
Gassicurtia sp.1	0.156	0.026
Indicator species of rough-scaly bark (5 species)		
Maronina corallifera	0.243	0.002
Cratiria obscurior	0.181	0.004
Chapsa indica	0.167	0.011
Unidentified crustose sp.7	0.133	0.044
Thelotrema lepademersum	0.124	0.038
Indicator species of smooth bark (22 species)		
Marcelaria benguelensis	0.310	0.001
Dyplolabia afzelii	0.278	0.001
Pallidogramme chrysenteron	0.225	0.001
Phaeographis caesioradians	0.200	0.001
Bathelium madreporiformie	0.195	0.001
Arthonia subvelata	0.166	0.011
Graphis gloriosensis	0.152	0.014
Nigrovothelium tropicum	0.148	0.016
Dirinaria aegialita	0.147	0.016
Astrothelium porosum	0.144	0.008
Parmotrema tinctorum	0.142	0.033
Dirinaria picta	0.131	0.031
Platygramme pudica	0.131	0.031
Nigrovothelium bullatum	0.128	0.018
Hafellia bahiana	0.124	0.047
Relicina intertexta	0.124	0.037
Trypethelium eluteriae	0.124	0.023
Platygramme sp.1	0.122	0.049
Graphis furcata	0.121	0.031
Phaeographis intricans	0.121	0.029
Maronea sp.1	0.118	0.032
Astrothelium meristosporum	0.106	0.047

Table 2.7 The selected lichen species that indicated 5 types of bark characteristics of the phorophytes in the DDF of KYNP (Continued).

Lichens	Statistically significant	
	correlation	p-value
Indicator *species* of rough+rough-scaly bark (1 species)		
Amandinea efflorescens	0.175	0.009
Indicator species of rough-scaly+smooth bark (2 species)		
Phaeographis brasiliensis	0.210	0.001
Polymeridium quinqueseptatum	0.149	0.020

2.6 Conclusions

The results of this study can be concluded as follows:

1. The DDF of KYNP supports a high diversity of lichens (175 species) compared to the previous works in the same forest type of several study areas. There are more than 3 times higher than the previous recorded.

2. This work found a lichen species that are described as new to science, this lichen belongs to the genus *Aptrootia*, and this genus is described as the first time for Thailand. And the twenty-eight species were new records to Thailand. Together are making a new list of Thai lichens. This may reflect the quantitative investigations are needed for another forest.

3. The most common lichens fond in the DDF of KYNP are *Bacidia* sp.1, *Maronina corallifera,* and *Amandinea efflorescens*, they could estimate as a high abundance.

4. A large proportion of lichens in the DDF of KYNP is crustose growth form (89 %), with a small proportion for foliose, squamulose, and byssoid, but no fruticose lichen was found. This was indicated that the forest still dynamic in the pioneer stage of community succession of lichen biota.

5. The important tree species that supported a high diversity of lichen in the DDF of KYNP are *Vatica odorata*, and *Dipterocarpus obtusifolius*.

6. Lichen can be used as indicator species for environmental variations, many species can have a high potential to indicate the set of environments in the DDF.

2.7 References

Adams, D. B., and Risser, P. G. (1971). The effect of host specificity on the interspecific associations of bark lichens. *The Bryologist, 74*(4), 451-457. doi:10.2307/3241304.

A-mornrat Pitakpong. (2009). *The use of lichen as an indicator for environmental monitoring in Nakhon Ratchasrima municipality and Sakaerat Environmental Research Station.* (Master's thesis). Suranaree University of Technology, Nakhon Ratchasrima. Retrived from http://sutir.sut.ac.th:8080/jspui/handle/123456789/3355.

Anjali, D. B., Mohabe, S., Reddy, A. M., and Nayaka, S. (2015). Antimicrobial activities of 2-Propanol crude extract from lichen *Parmotrema tinctorum* (Despr.ex. Nyl.) Hale, collected from Eastern Ghats, India. *Current Research in Environmental & Applied Mycology*, *5(3)*, 160-168. doi: 10.5943/cream/5/3/1.

Aptroot, A. (1997). Lichen biodiversity in Papua New Guinea, with the report of 173 species on one tree. *Bibliotheca Lichenologica, 68*, 203-213.

Aptroot, A., and Lücking, R. (2016). A revisionary synopsis of the Trypetheliaceae (Ascomycota: Trypetheliaes. *The Lichenologist, 48*(6), 763-982.

Aptroot, A., Saipunkaew, W., Sipman, H. J. M., Sparrius, L. B., and Wolseley, P. A. (2007). New lichens from Thailand, mainly microlichens from Chiang Mai. *Fungal Diversity, 24*, 75-134.

Asta, J., Erhardt, W., Ferretti, M., Fornasier, F., Kirschbaum, U., Nimis, P. L., . . . Wirth, V. (2002). Mapping lichen diversity as an indicator of environmental quality. In P. L. Nimis, C. Scheidegger, & P. A. Wolseley (Eds.), *Monitoring with lichens-Monitoring lichens* (pp. 273-279). Dordrecht: Springer Netherlands.

Awasthi, D. D. (1991). A key to the microlichens of India, Nepal and Sri Lanka. *Bibliotheca Lichenologica, 40*, 1-339.

Bäcklund, S., Jönsson, M., Strengbom, J., Frisch, A., and Thor, G. (2016). A pine is a pine and a spruce is a spruce-The effect of tree species and stand age on epiphytic lichen communities. *PLoS One, 11*(1), e0147004.

Baimai, V. (2010). Biodiversity in Thailand. *The Journal of the Royal Institute of Thailand, 10*, 107-114.

Barkman, J. J. (1958). *Phytosociology and ecology of cryptogamic epiphytes*. Assen, Natherland: Van Gorcum, Assen.

Berryman, S., and McCune, B. (2006). Estimating epiphytic macrolichen biomass from topography, stand structure and lichen community data. *Journal of Vegetation Science, 17*(2), 157-170.

Boonpragob, K., Homchantara, N., Coppins, B. J., McCarthy, P. M., and Wolseley, P. A. (1998). An introduction to the lichen flora of Khao Yai National Park, Thailand. *Botanical Journal of Scotland, 50*, 209-219.

Boonpragob, K., and Polyiam, W. (2007). Ecological groups of lichens along environmental gradients on two different host tree species in the tropical rain forest at Khao Yai National Park. *Bibliotheca Lichenologica, 96*, 25-48.

Brodo, I. M. (1973). Substrate ecology. In V. Ahmadjian & M. E. Hale (Eds.), *The lichens* (pp. 401-441). New York: Academic Press.

Buaruang, K., Boonpragob, K., Mongkolsuk, P., Sangvichien, E., Vongshewarat, K., Polyiam, W., . . . Lumbsch, H. T. (2017). A new checklist of lichenized fungi occurring in Thailand. *MycoKeys, 23*, 1–91.

Büdel, B., and Scheidegger, C. (2008). Thallus morphology and anatomy. In T. H. Nash III (Ed.), *Lichen biology* (pp. 40-68). Cambridge: Cambridge University Press.

Cáceres, M. E. S., Lücking, R., and Rambold, G. (2007). Phorophyte specificity and environmental parameters versus stochasticity as determinants for species composition of corticolous crustose lichen communities in the Atlantic rain forest of northeastern Brazil. *Mycological Progress, 6*, 117-136.

Cáceres, M. E. S., Lücking, R., and Rambold, G. (2008). Efficiency of sampling methods for accurate estimation of species richness of corticolous microlichens in the Atlantic rainforest of northeastern Brazil. *Biodiversity and Conservation, 17*(6), 1285-1301.

De Cáceres, M. (2022). Indicator species analysis using 'indicspecies'. Retrieved from https://cran.r-project.org/web/packages/indicspecies/vignettes/IndicatorSpeciesAnalysis.html.

De Cáceres, M., Jansen, F., and Dell, N. (2022). *Relationship between species and groups of sites. R package version 1.7. 12*.

Farmer, A. M., Bates, J. W., and Bell, J. N. B. (1990). A comparison of methods for the measurement of bark PH. *The Lichenologist, 22*(2), 191-194.

Favero-Longo, S. E., and Piervittori, R. (2010). Lichen-plant interactions. *Journal of Plant Interactions, 5*(3), 163-177.

Gradstein, S., Nadkarni, N., Krömer, T., Holz, I., and Nöske, N. (2003). A protocol for rapid and representative sampling of vascular and non-vascular epiphyte diversity of tropical rain forests. *Selbyana, 24*, 105-111.

Hale, M. E. (1955). Phytosociology of corticolous cryptogams in the upland forests of southern Wisconsin. *Ecology, 36*(1), 45-63.

Hauck, M., Jung, R., and Runge, M. (2000). Does water-holding capacity of bark have an influence on lichen performance in dieback-affected spruce forests? *The Lichenologist, 32*(4), 407-409.

Hauck, M., and Spribille, T. (2005). The significance of precipitation and substrate chemistry for epiphytic lichen diversity in spruce-fir forests of the Salish Mountains, northwestern Montana. *Flora-Morphology, Distribution, Functional Ecology of Plants, 200*(6), 547-562.

Hawksworth, D. L., Kirk, P. M., Sutton, B. C., and Pegler, D. N. (1995). *Ainsworth and Bisby's Dictionary of the fungi*. Wallingford: CAB International.

Hawksworth, D. L., and Seaward, M. R. (1977). *Lichenology in the British Isles, 1568-1975*: Richmond Pub. Co.

Homchantara, N. (1999). *The taxonomic and ecological aspects of the Thelotremataceae in southeast Asia.* (Doctoral dissertation). Liverpool John Moores University, Liverpool.

Homchantara, N., and Coppins, B. J. (2002). New species of the lichen family Thelotremataceae in SE Asia. *The Lichenologist, 34*(2), 113-140.

James, P. W., Hawksworth, D. L., and Rose, F. (1977). Lichen communities in the British Isles: a preliminary conspectus. In M. R. D. Seaward (Ed.), *Lichen ecology*. London etc.: Academic Press.

Johansson, P., and Ehrlén, J. (2003). Influence of habitat quantity, quality and isolation on the distribution and abundance of two epiphytic lichens. *Journal of Ecology*, 213-221.

Jüriado, I., and Liira, J. (2010). Threatened forest lichen-its past, present and future in Estonia. *Forestry Studies, 53*, 15-24.

Kawinnat Noicharoen. (2002). *Biodiversity of foliose and fruticose lichens at Khao Yai National Park.* (Master's thesis). Ramkhamhaeng University, Bangkok.

Kelly, D. L., O'Donovan, G., Feehan, J., Murphy, S., Drangeid, S. O., and Marcano-Berti, L. (2004). The epiphyte communities of a montane rain forest in the Andes of Venezuela: patterns in the distribution of the flora. *Journal of Tropical Ecology, 20*(6), 643-666.

Komposch, H., and Hafellner, J. (2002). Life form diversity of lichenized fungi in an Amazon lowland rainforest. *Bibliotheca Lichenologica, 82*, 311-326.

Kricke, R. (2002). Measuring bark pH. In P. L. Nimis, C. Scheidegger, & P. A. Wolseley (Eds.), *Monitoring with lichens-Monitoring lichens* (pp. 333-336). Netherland: Kluwer Academic Publishers.

Loppi, S., and Frati, L. (2004). Influence of tree substrate on the diversity of epiphytic lichens: comparison between *Tilia platyphyllos* and *Quercus ilex* (Central Italy). *The Bryologist, 107*(3), 340-344.

Luangsuphabool, T., Lumbsch, H. T., Piapukiew, J., and Sangvichien, E. (2018). *Architrypethelium murisporum* (Ascomycota, Trypetheliaceae), a remarkable new lichen species from Thailand challenging ascospore septation as an indicator of phylogenetic relationships. *MycoKeys, 34*, 25-34.

Lücking, R. (1998). Ecology of foliicolous lichens at the Botarrama trail (Costa Rica), a neotropical rain forest site. II. Patterns of diversity and area cover and their dependence on microclimate and phorophyte species. *Ecotropica, 4*, 1–24.

Lücking, R., Archer, A. W., and Aptroot, A. (2009). A world-wide key to the genus *Graphis* (Ostropales; Graphidaceae). *The Lichenologist, 41*(4), 363-452.

Lücking, R., Cking, Sipman, H., UmaÑA, L., Chaves, J.-L., and Lumbsch, H. T. (2007). *Aptrootia* (Dothideomycetes: Trypetheliaceae), a new genus of pyrenocarpous lichens for *Thelenella terricola*. *The Lichenologist, 39*, 187-193.

Lücking, R., Hodkinson, B. P., and Leavitt, S. D. (2016). The 2016 classification of lichenized fungi in the Ascomycota and Basidiomycota-Approaching one thousand genera. *The Bryologist, 119*(4), 361-416.

Lücking, R., and Matzer, M. (2001). High foliicolous lichen alpha-diversity on individual leaves in Costa Rica and Amazonian Ecuador. *Biodiversity & Conservation, 10*(12), 2139-2152.

Lücking, R., Rivas Plata, E., Chaves, J. L., Umaña, L., and Sipman, H. J. (2009). How many tropical lichens are there... really? *Bibliotheca Lichenologica, 100*, 399-418.

Marmor, L., Randlane, T., Jüriado, I., and Saag, A. (2017). Host tree preferences of red-listed epiphytic lichens in Estonia. *Baltic Forestry, 23*(2), 364-373.

McCune, B., and Grace, J. B. (2002). *Analysis of Ecological Communities*. MjM Software Design. Gleneden Beach, Oregon, USA.

McCune, B., and Lesica, P. (1992). The trade-off between species capture and quantitative accuracy in ecological inventory of lichens and bryophytes in forests in Montana. *The Bryologist*, 296-304.

McCune, B., Rosentreter, R., Ponzetti, J. M., and Shaw, D. C. (2000). Epiphyte habitats in an old conifer forest in western Washington, USA. *The Bryologist, 103*(3), 417-427.

Munzi, S., Ravera, S., and Caneva, G. (2007). Epiphytic lichens as indicators of environmental quality in Rome. *Environmental Pollution, 146*(2), 350-358.

Nooduan Muangsan, Pongthep Suwanwaree, Duangkamol Maensiri, Taksin Artchawakom, and A-mornrat Pitakpong. (2015). *Ecology and diversity of lichens in Sakaerat Environmental Research*. Suranaree University of Technology. Nakhon Ratchasima. Retrived from http://sutir.sut.ac.th:8080/sutir/bitstream/123456789/7410/2/Fulltext.pdf.

Orange, A., James, P. W., and White, F. J. (2010). *Microchemical methods for the identification of lichens* (2^{nd} ed.). London: British Lichen Society.

Papong, K., Boonpragob, K., and Lücking, R. (2007). New species and new records of foliicolous lichens from Thailand. *Lichenologist, 39*, 47-56.

Papong, K., Nayaka, S., and Lumbsch, H. T. (2012). Two new species and a new record of *Lecanora* sensu stricto (Lecanoraceae, Ascomycota) from India. *Phytotaxa, 68*(1), 24–28-24–28.

Phraphuchamnong, P., Nelsen, M. P., Distefano, I., Mercado-Diaz, J. A., Parnmen, S., Rangsiruji, A., . . . Lumbsch, H. T. (2022). A new species of *Megalaria*

(Ramalinaceae, Ascomycota) from Thailand, and recognition of subgenus *Catillochroma*. *MycoKeys, 93*, 149-163.

Pinokiyo, A., Singh, K. P., and Singh, J. S. (2008). Diversity and distribution of lichens in relation to altitude within a protected biodiversity hot spot, north-east India. *The Lichenologist, 40*(1), 47-62.

Poengsungnoen, V., Buaruang, K., Boonpragob, K., and Lumbsch, H. T. (2021). A key to the identification of the genera of lichenized fungi occurring in Thailand. *Mycotaxon, 136*(2), 409-444.

Poengsungnoen, V., Buaruang, K., Vongshewarat, K., Sangvichien, E., Boonpragob, K., Mongkolsuk, P., and Lumbsch, H. T. (2019). Three new crustose lichens from Thailand. *The Bryologist, 122*(3), 451-456.

Poengsungnoen, V., Meethong, U., Buaruang, K., Boonpragob, K., and Lumbsch, H. T. (2022). New records of corticolous and foliicolous lichens from Thailand. *Herzogia, 35*(2), 621-629.

Poengsungnoen, V., Vongshewarat, K., Buaruang, K., and Polyiam, W. (2022). The lichen genus *Diploschistes* Norman (Graphidaceae) in Thailand. *Thai Journal of Botany, 14*(1), 31-37.

Purvis, O. W. (2000). *Lichens*. London: Natural History Museum and Washington: Smithsonian Institution.

R Core Team, R. (2013). *R: A language and environment for statistical computing*. Retrieved from http://R-project.org.

Ramkhamhaeng University. (2004). *Biodiversity of Lichens at Khao Yai National Park in Thailand*. Thailand: Bangkok, Thailand: Office of Natural Resources and Environmental Policy and Planning.

Reynolds, C. L., Er, O. A., Winder, L., and Blanchon, D. J. (2017). Distribution and community composition of lichens on mature mangroves (*Avicennia marina* subsp. *australasica* (Walp.) J. Everett) in New Zealand. *PLoS One, 12*(6), e0180525.

Rivas Plata, E., Lücking, R., Sipman, H. J. M., Mangold, A., Kalb, K., and Lumbsch, H. T. (2010). A world-wide key to the thelotremoid Graphidaceae, exculding the *Ocellularia-Myriotrema-Stegobolus* clade. *The Lichenologist, 42*(2), 139-185.

Satya, Uppreti, D. K., and Nayaka, S. (2005). *Shorea robusta* – an exellent host tree for lichen growth in India. *Current Science, 89*(4), 594-595.

Schmitt, C. K., and Slack, N. G. (1990). Host specificity of epiphytic lichens and bryophytes: a comparison of the Adirondack Mountains (New York) and the Southern Blue Ridge Mountains (North Carolina). *Bryologist*, 257-274.

Sipman, H. J. M. (1996). Corticolous lichens. In S. R. Gradstein, P. Hietz, R. Lücking, A. Lücking, H. J. M. Sipman, H. F. M. Vester, J. H. D. Wolf, & E. Gardette (Eds.). How to sample the epiphytic diversity of tropical rain forests. *Ecotropica* (Vol. 2, pp. 66-67).

Sipman, H. J. M., and Aptroot, A. (2001). Where are the missing lichens? *Mycological Research, 105*(12), 1433-1439.

Sipman, H. J. M., and Harris, R. C. (1989). Lichens. In H. Lieth & M. J. A. Werger (Eds.), *Ecosystem of the world 14B - Tropical rain forest ecosystems, biogeographical and ecological studies* (pp. 303-309). Amsterdam, Netherlands: Elsevier.

Siringamram, S., Buaruang, K., Poengsungnoen, V., Polyiam, W., and Vongshewarat, K. (2022). Notes on the lichen genus *Arthothelium* A. Massal. (Arthoniaceae) in Thailand. *Thai Journal of Botany, 14*, 39-44.

Sujinda Bungwan, and Wanaruk Saipunkaew, W. (2018). Corticolous lichen communities composition in *dominant* forests of Doi Inthanon National Park, Chiang Mai Province: Applications for long-term environmental change monitoring. *The KKU Science Journa 46*(4), 722-731. Retrived from https://ph01.tci-thaijo.org/index.php/KKUSciJ/article/view/249948.

Suwannarach, N., Kumla, J., Satienperakul, K., Sungpalee, W., Hermhuk, S., Suttiprapan, P., . . . Lumyong, S. (2019). *Sulzbacheromyces yunnanensis*, a new record for Thailand. *Mycotaxon, 134*(1), 215-219.

Swinscow, T. D. V., and Krog, H. (1988). *Macrolichens of East Africa*. London: British Museum (Natural History).

Ter Braak, C. J., and Smilauer, P. (2002). *CANOCO reference manual and CanoDraw for Windows user's guide: software for canonical community ordination*. Ithaca, New York.

Upreti, D., and Chatterjee, S. (1999). Epiphytic lichens on *Quercus* and *Pinus* trees in three forest stands in Pithoragarh district, Kumaon Himalayas-India. *Tropical Ecology, 40*(1), 41-49.

Vainio, E. A. (1909). Lichenes. In Schmidt, J. (ed.) Flora of Koh Chang; Contribution to the knowledge of the vegetation of the Gulf of Siam. *Botanisk Tidssskrift, 29*, 104-105.

Węgrzyn, M. H., Kołodziejczyk, J., Fałowska, P., Wężyk, P., Zięba-Kulawik, K., Szostak, M., . . . Wietrzyk-Pełka, P. (2020). Influence of the environmental factors on the species composition of lichen Scots pine forests as a guide to maintain the community (Bory Tucholskie National Park, Poland). *Global Ecology and Conservation, 22*, e01017.

Whittaker, R. H. (1972). Evolution and measurement of species diversity. *Taxon, 21*(2-3), 213-251.

Will-Wolf, S., Esseen, P. A., and Neitlich, P. (2002). Monitoring biodiversity and ecosystem function: Forests. In P. L. Nimis, C. Scheidegger, & P. A. Wolseley (Eds.), *Monitoring with lichens-Monitoring lichens* (pp. 203-222). Netherland: Kluwer Academic Publishers.

Will-Wolf, S., Geiser, L. H., Neitlich, P., and Reis, A. H. (2006). Forest lichen communities and environment-how consistent are relationships across scales? *Journal of Vegetation Science, 17*(2), 171-184.

Wolseley, P. A., and Aguirre-Hudson, B. (1991). Lichens as indicators of environmental change in the tropical forest of Thailand. *Global Ecology and Biogeography Letters, 1*, 170-175.

Wolseley, P. A., and Aguirre-Hudson, B. (1997). Fire in tropical dry forests: corticolous lichens as indicators of recent ecological changes in Thailand. *Journal of Biogeography, 24*, 345-362.

Wolseley, P. A., Aguirre-Hudson, B., and McCarthy, P. M. (2002). Catalogue of the lichens of Thailand. *Bulletin of the Natural History Museum, London (Botany), 32*, 13-59.

CHAPTER III

COMMUNITY OF EPIPHYTIC LICHENS ON TWO ABUNDANT PHOROPHYTE, (*DIPTEROCARPUS OBTUSIFOLIUS* AND *GLUTA USITATA*) IN THE DRY DIPTEROCARP FOREST OF CENTRAL THAILAND

3.1 Abstract

The study of the community of epiphytic lichens on dominant phorophytes aimed to determine which factors influence the diversity of epiphytic lichen communities under the different biotic and abiotic factors. The experiments were conducted on two dominant tree species: *Dipterocarpus obtusifolius* and *Gluta usitata*. Fifty centimeters of the line intercepts were placed vertically on tree trunks and first branches. All lichen specimens found in line intercept were identified and codded. Thallus numbers, thalli cover, and intercept numbers were recorded for each lichen species. Tree sizes were divided into three size classes as referred to the diameter at the breast height (dbh) for small size class (≤ 5 cm in dam>), medium size class (5.1-10 cm in diam.), and large size class (> 10 cm in diam). The positions on the trees were classified into trunk base, mid-trunk, and canopy. The value of bark pH and bark water holding capacity were recorded. The diversity of lichens, lichen abundance, thallus cover, and community compositions was analyzed by various computing programs. *Gluta usitata* housed the highest number of lichen taxa with 63 species which had *Maronina corallifera* (IV = 28.8) as the most abundant lichen. Whereas *Dipterocarpus obtusifolius* supported 54 species with *Bacidia* sp. 1 (IV = 34.1) as the dominant lichen. Thirty-one lichen species were observed on both tree hosts. The lichen diversity rising significantly related to the increasing of tree size classes. The highest lichen species were found on the trunk base, followed by branches. The differences in textures, pH, and water holding capacity of the bark of two dominant tree species were strongly affected to lichen compositions. *Dipterocarpus obtusifolius* and *Gluta usitata* were the most important

trees for maintaining the lichen community which had different microhabitats that supported the wide ranges of habitat for lichens in the DDF.

3.2 Introduction

The species diversity of epiphytic lichens may be significantly influenced by host tree characteristics such as substrate stability, bark texture, pH, water holding capacity, tree diameter, and tree age (Spier, van Dobben, and van Dort. 2010, Soto, Lücking, and Bolaños, 2012). A connection between host tree species and epiphytic lichen diversity has also been found in studies conducted in temperate forests (Kubiak and Osyczka, 2020; Ozturk Oran, Üniversitesi, Fakülesi, and Bölümü, 2011; Király, Nascimbene, Tinya, and Ódor, 2013). Spier et al., 2010) reported that the most significant element affecting lichen colonization was the type of tree, whereas bark pH plays a less significant role. However, the bark pH and water holding capacity and tree diameter were reported as the key determinants of lichen occurrence (Kubiak and Osyczka, 2020). On the other hand, there hasn't been evidence of this association in humid tropical forests (Soto et al., 2012). The composition of the lichen community is strongly associated with DBH and tree species, although the amount of fissuring had no discernible influence and pH was not a very important factor for the lichen community (McDonald, Woundenberg, Dorin, Adcock, McMullin, and Cottenie, 2017). Ozturk et al. (2011) examined *Quercus* taxa in Turkey which typically have high bark pH values, nitrophytes species were more frequently found on barks than acidophytes species.

There are many studies on the relationship between epiphytic lichen communities and phorophytes have been documented in temperate forests (Barkman, 1958; Adams and Rissen, 1971; Brodo 1973; Favero-Longo and Piervittori, 2010), and neotropical forests (Cáceres et al., 2007) However, rarely in the information on the relationship of lichens and their phorophytes in the paleotropical forest. However, there was some study that discovered the basic information of habitat acquisition for the forest lichens in the tropical forest of Thailand, (Wolseley and Aguirre-Hudson, 1997, Boonpragob and Polyaim, 2007). That used to help in the understanding of some aspects of the lichen community. However, the need to study the relationship between lichens and hosts is currently important, at least to serve the information for the conservation planning of lichen biodiversity.

This study compared the lichen community of two dominant tree species that were commonly found in the dry dipterocarp forest of Khao Yai National Park, where the study areas were situated in a part of the natural world heritage site at Don Phayayen-Khao Yai Forest Complex.

Objective

This work aimed to examine the species composition of lichens connected to habitat requirements on the dominant phorophytes in the DDF of central Thailand.

Hypothesis

The microhabitats on the phorophyte provide various suitable conditions for lichens (Boonpragob and Polyiam, 2007). The two dominant phorophytes in the dry dipterocarp forest, *Dipterocarpus obtusifolius* Teijms. ex Miq. and *Gluta usitata* (Wall.) Ding Hou facilitates different lichens species depending on branch or trunk diameter, high above the ground or zone on the tree.

3.3 Review Literatures

Trees or phorophytes in the forest are proven to be the most important habitat for lichen diversity. As recorded by Aptroot (1997) that a large number of lichens over 170 taxa inhabitants on a single tree in Papua New Guinea. This showed the importance of the tree to support the epiphytic community. The phorophyte property is an important factor for epiphytic lichens to select for their niches. Many reports indicated that the phorophyte is a major factor that has been close relation to lichen diversity and composition (Adams and Rissen, 1971; Brodo, 1973). Phorophyte properties may refer to host species, host age (related to tree size), bark structures, type and intensity of lenticel, type of nutrient and concentration in bark, pH of bark, water holding capacity, etc. (Barkman, 1958; Gardstein et al., 2003) Some research found out that the chemistry of bark can influence to epiphytic lichens. Hauck and Runge (2002) found the cover of *Hypogymnia physodes* was decreased with increasing concentration of many elements in stem flow and bark, similar to lichen cover, the total number of lichen species per sample tree also declined. Hauck and Spribille (2005) indicated that the cover of several lichen species was limited by high manganese (Mn) concentrations in barks or by high ratios of manganese (Mn) to calcium (Ca), magnesium (Mg) and iron (Fe).

Loppi and Frati (2004) found that the diversity values measured on *Tilia* were on average 1.5 times higher than on *Quercus*, which influx of light in winter is the most important factor for determining differences in the biodiversity of epiphytic lichens on *Tilia* and *Quercus*. Upreti and Chatterjee (1999) compared lichen communities from two phorophyte species (belonging to *Quercus* and *Pinus*) and found that bark-moisture and externally derived moisture influenced the growth of epiphytic lichens, young-trees supported the lichen communities dominated by crustose growth form, where the mature-trees sustained the climax communities dominated by foliose and fruticose lichens.

McCune et al. (2000) studied the epiphytic habitats in an old conifer forest and found that the habitats of epiphytic lichens in conifer forest have induced by canopy structure and substrate characters. The epiphytic communities showed marked variation with respect to height in the canopy, bark vs wood, degree of sheltering, and stem diameter. While Kelly et al. (2004) found that the environmental variables most closely correlated to variation in lichen community composition were the height above ground and horizontal gradient reflecting differences in forest structure.

Cáceres et al. (2007) studied the effect of phorophyte and environmental factors to determine the composition of the corticolous crustose lichen community in tropical rainforests. They found that the lichen communities are correlated to bark properties (bark pH, degree of bark shedding, density and size of bark lenticels, and presence of milk sap) and microclimates.

Juriado et al. (2009) pointed out that trees level variables (e.g. bark pH, bryophytes cover, and phorophyte species) explained the largest fraction of the variation in lichen species composition in the boreo-nemoral forest on the North-Estonian limestone escarpment.

Backlund et al. (2016) reported that the epiphytic lichen species richness and species composition on the trunk of Pine and Spruce trees are different. That was explained by canopy closure and habitat availability. However, the result showed that there was no difference in lichen richness between non-native *Pinus contorta* and the native *Pinus sylvestris*.

Boonpragob and Polyiam (2007) proposed the lichen groups as referred to several ecological aspects of two dominant tree species of the tropical rain forest. They constructed the nine ecological groups of lichens as varied with ecological gradients. The tree species play an important role to influence the lichen compositions. In addition, the substrate, light regime, relative humidity, and temperature play an important role in the group constructions related to the vertical gradient of the environments.

3.4 Materials and Methods

Site studies

The study sites for this work are selected from different altitudes between 100 and 600 m.a.s.l, latitudes between 14°11' and 14°15' N, and longitudes between 101°29' and 101°30' E. The topography, vegetation, and climates were summarized in Chapter I and Chapter II of this thesis.

Field sampling

Lichen data and environmental variables: two dominant phorophyte species selected for this study were *Dipterocarpus obtusifolius* and *Gluta usitata*. The selected trees were divided into three size classes as referred to the diameter at breast height (dbh), small size class (≤ 5 cm in dim.), medium size class (5.1-10 cm in diam.), large size class (> 10 cm in diam) (the detail of the trees is summary in Table 3.1).

Lichen data was collected by using the line intercept technique (Will-Wolf et al., 2002; Callaway, Reinhart, Moore, Moore, and Pennings, 2001). A fifty-centimeter length line with five intercepts and 10 cm intervals was used for lichen investigation (Figure 3.1). All lichen specimens attached to the line intercept were identified and coded, then the thalli number, thalli cover, and intercept numbers were recorded for each lichen species. On each tree individual, the line intercept had no limit on placing at any tree size classes, these were allowed to collect lichen within the same standard. The line intercepts were placed vertically in four directions (north, east, south, and west) and four parts of the trees, if possible, viz. the trunk base (< 2 m above ground), the mid-trunk (2-4 m above ground), the canopy (> 4 m above ground) and branch (1 m long of first branch). However, if the height of the trunk was lower than 2 meters, thus, the whole tree was referred to as lower trunk habitat. The lichen data will be collected, viz. lichen species, frequency, cover, and number of the thallus. The four parameters of environmental variables on two host species including tree size classes, and position on trees (lower trunk, mid-trunk, upper trunk, and branch) were measured. Moreover, bark pH and bark water holding capacity were measured in a similar method as mentioned in Chapter II.

Data analysis

The diversity of lichen was measured basically for gamma diversity (McCune and Grace, 2002) and compared for lichen diversity between phorophyte species, tree size classes, and positions on the tree. The abundance values of each lichen taxa were evaluated as Important Value (IV) or thallus cover (Pinokiyo et al., 2008; Will-Wolf et al., 2002). PERMANOVA was used to determine whether the explanatory variables (environmental variables) affected a responsible variable (species diversity) using “adonis2” function in R version 4.3.2.1 (R Core Team, 2022). The data set was analyzed by using ordination and classification techniques. Lichen community on two host species were analyzed using Canonical Correspondence Analysis (CCA) based on the abundance value (thallus cover) of species score against environmental variable or sample score, these were conducted by using the program PC-ORD 5.10 (McCune and Mefford, 2006).

Table 3.1 Characteristics of two dominant phorophytes for lichens in DDF of KYNP.

Tree size class	dbh (cm)	No of tree	Mean pH (min-max)	Mean WC (min-max)	Bark texture
Dipterocarpus obtusifolius					
Small	1.5-4.7	19	3.4 (2.9-4.4)	79.5 (41.5-113.3)	rough
Medium	5-10	11	3 (2-4)	56 (39-96)	rough
Large	14.9-34	20	3.1 (2.14-4.9)	63.3 (23-360)	rough
Gluta usitata					
Small	1.5-4.5	14	4.3 (3.9-4.7)	124.6 (68.1-185.7)	smooth
Medium	5.5-10	9	4.2 (3.5-5.4)	132.3 (11.8-318.1)	smooth
Large	11-38	12	3.6 (3 – 4.6)	84.2 (22.2-139.9)	smooth-rough

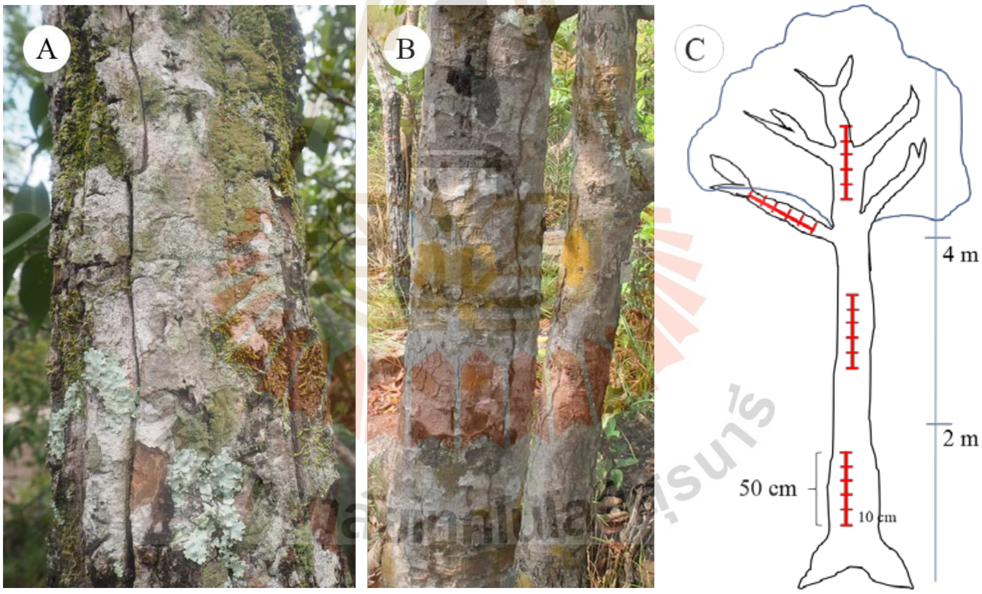

Figure 3.1 Sampling design for lichen community on the dominant phorophytes in the dry dipterocarp forest at Khao Yai National Park, (A-B: bark characteristics of two phorophytes [*Dipterocarpus obtusifolius* and *Gluta usitata*] and lichen communities which found in the study sites and, C: the 50 cm line intercepts placed vertically on the trunk and branch of selecting trees for lichen exploration).

3.5 Results and Discussions

Lichen richness and abundance on two host species

A total of 86 species of lichens were documented for both *Dipterocarpus obtusifolius* and *Gluta usitata* (Figure 3.2 and Table 3.2).

Gluta usitata supported the highest number of lichen taxa, recorded for 63 species (73.3%) (with 32 species found only on this host species). The most abundant lichens found on this host species were *Maronina corallifera* (IV = 28.8), *Macellaria benguelensis*, and *Cratiria obscurior* (IV = 13.29 and 13.19 respectively), etc. (Table 3.2).

Dipterocarpus obtusifolius supported 54 species of lichens (62.8 %), with 23 species found only on this host tree, the most abundant of lichens found on this tree species were *Bacidia* sp. 1 (IV = 34.1), and lesser abundances for *Amandinea efflorescens*, *Maronina corallifera*, *Cratiria obscurior*, and *Relichinopsis rahengensis,* Important values accounted for 22.50, 14.82, 12.05, 11.04 respectively (Table 3.2).

Similar lichens on two host species were documented for 31 species (36 %) (see Figure 3.2 and Table 3.2). They can use these two characteristics of bark as a suitable substratum. The lichens were found on two hosts such as *Amandinea efflorescens*, *Arthonia collectiva*, *Cartiria obscurior*, *Bulbothrix queenslandica*, *Chrysothrix xanthina*, and *Graphis streblocarpa* (Table 3.2). Those lichens can have a wide range of distribution on several types of substrates, they could adapt well to another substratum in this forest type at KYNP, and they could propose as the common species. These common species can have the potential to maintain the community structures of lichen in the DDF.

However, some lichen species found on two phorophytes may not have the potential of common species. To decide the common-rare status of lichen, there are some ideas to discuss. The lichens, found from two common tree species, perhaps common in other national parks that served the habitat as DDF environments, for example, the two foliose lichens of the family Parmeliaceae; *Relicina rahengensis* that was accepted as a “characteristic species for the DDF” (Wolseley and Aguirre-Hudson, 1997), this species have high IV recorded from both tree species (IV = 7.12 and 11.04) (Table 3.2). It can be found in a wider natural habitat in the DDF of several national parks in Thailand (Titiporn Pooprang, 2001; Wolseley et al., 2002; Nooduan Muangsan et al., 2015, Buaruang et al., 2017), This species can be a true common. Contrasting with the lichen *Relicina palmata*, that found on both two host species as well, it has a low IV (0.26-4.78). This lichen previously reports only from Khao Yai National Park (Noicharoen, Polyiam, Boonpragob, Elix, and Wolseley, 2003), but never report from another Thai national park, this lichen is still at risk on population size limited. Therefore, being occupied by two dominant hosts doesn't mean being common in a wide range of habitats. From this work using IV as abundance values to indicate the common-rare status could be suggested for each lichen.

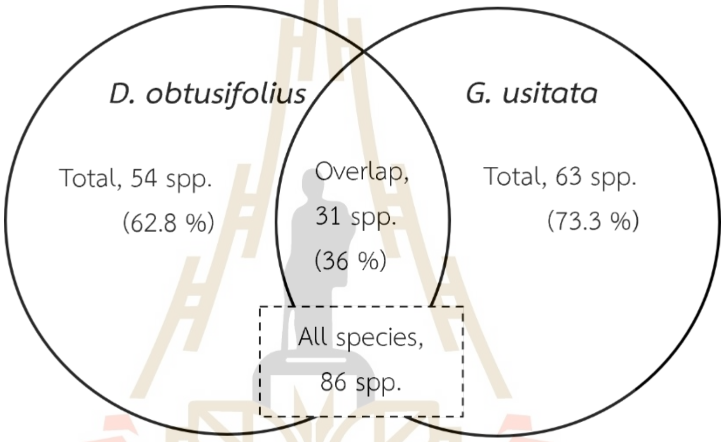

Figure 3.2 Proportion of lichen diversity on two host species in the DDF of KYNP.

Occurrence of lichen species on two common host species

Lichen vs tree size class: the bark habitats are important for the forest lichens. In this work, the three different size class of the lichen host was divided (usually tree sizes are reflected by the tree age) into the small, medium, and large size classes. It was found that the lichen diversity rising significantly related to the increase of tree size classes ($p= 0.001$). This similar trend was found in both two host species (Figure 3.3 and Table 3.3).

The tree with small size class: the small size class of *Dipterocarpus obtusifolius* supported 23 species, while *Gluta usitata* supported 9 species of lichens.

The lichens that are found on the small size class of tree can be referred to as the initial stage of the community succession. Those lichens are commonly found, such as *Amandinea efflorescens*, *Bacidia* sp.1, and *Chrysothrix xanthina*. They may play an important role in the pioneer organisms for the new bark surfaces. This was clear that lichens with crustose growth form dominated the small trees in this forest type. The three common crustose lichens found in this work are characterized by thallus having loose cortex, and two of these produce numerous soredia as vegetative propagules. These were benefits for lichens on a successful dispersion strategy, they can have a rapid colonization process after forest fires. This character of the lichen community changes was discussed previously by Wolseley and Aguirre-Hudson (1997). The tree with a small size (young tree) supported many crustose lichens. Similar results were studied by Upreti and Chatterjee (1999), who found that the young-trees dominated by lichen with crustose growth form.

Some foliose lichens were found in the small tree sizes class such as *Bulbothrix queenslandica* and *Parmotrema tinctorum*, there were produced isidia as vegetative propagule, It was indicated that dispersal by the asexual reproduction may be important for lichens to establish the pioneer stage of lichen communities in the DDF.

The tree with medium size class: the *Dipterocarpus obtusifolius* hosted 28 species of lichens, whereas the *Gluta usitata* hosted 24 species of lichens. Most of the lichen found on the medium size class of tree are still in crustose growth form. However, many foliose lichens can be established in this tree size class such as *Dirinaria aegialita*. It seems that foliose lichens can colonize the tree of *Dipterocarpus obtusifolius* rapidly.

The tree with large size class: the *Dipterocarpus obtusifolius* supported 42 species of lichens, whereas the *Gluta usitata* hosted 63 species. The lichens that are found on the large-size class of trees are still dominated by crustose growth form. However, the foliose growth form was also recorded from the large tree. This could be indicated that the successional stage of lichen communities in this forest type is to be approved. This result was clear that the large size of trees is important. They can have the potential of hosting a high diversity of lichens (Figure 3.3 and Table 3.2).

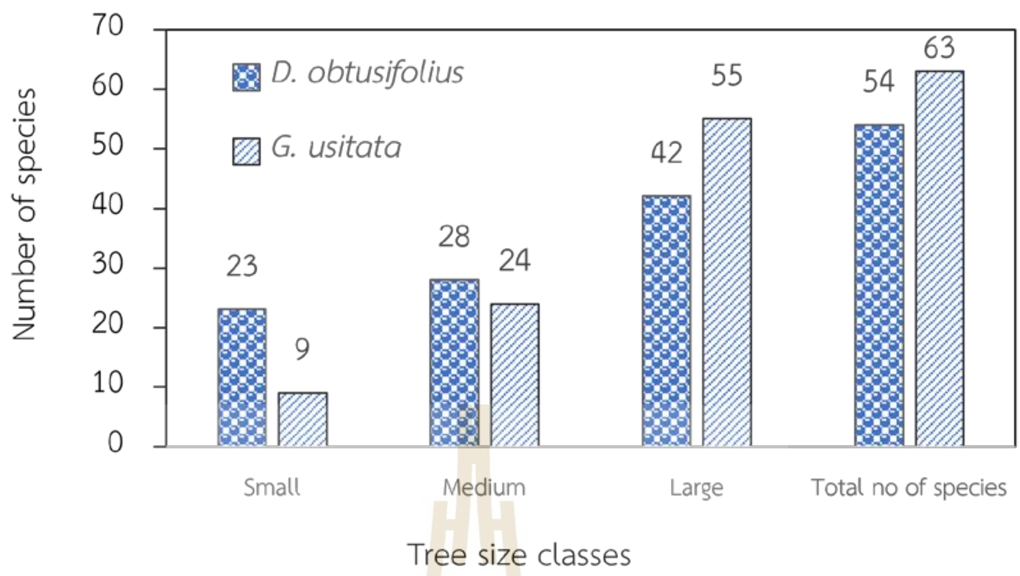

Figure 3.3 Number of lichen species on the different size classes of two host species

Upreti and Chatterjee (1999) pointed out that mature trees are usually supported foliose and fruticose lichens, which succeed in the climax community.

This work found some lichens that were occupied on all trees size classes, such as *Amandinea efflorescens*, *Maronina corallifera*, *Relicina rahengensis,* etc. they could adapt well in this forest type, and they can maintain their population within this forest community. Those lichens could support the most diverse of the forest which is an important point to cover the stability of the forest function.

Lichens at different position on the tree

Each habitat on a tree is usually important, the bark of trees can provide several types of microhabitats for the lichens. Vertical stratifications are the point of discussion here (Figure 3.4 and Table 3.2).

The trunk base of trees: This position is the favorite habitat for many lichens, they can be found in a high number of species more than half of the total species that are found on each host species (43 sp. on *Dipterocarpus obtusifolius*, 42 sp. on *Gluta usitata*). Most of the lichen found on this high level is crustose growth form. They could have an experience with forest fire damage. However, the lichen that occurred

Table 3.2 List of lichen taxa that occurred on different size classes of two host species and their important values.

no.	Lichens	*D. obtusifolius*			IV	*G. usitata*			IV
		S	M	L		S	M	L	
1	*Amandicea efflorescens*	b	m,c,br	b,m,c,br	22.5			b,m,c	5.49
2	*Amandinea* sp.2	b	b		0.62			m,c,br	2.66
3	*Amandinea* sp.3				-			c	1.4
4	*Aptrootia* sp.1			m	0.15				-
5	*Arthonia collectiva*		b, m	m, c	3.61		b,m	b,m	5.77
6	*Art. propingue*	b			0.15				-
7	*Arthonia recedens*			b, br	0.31	b		m,c	4.08
8	*Astrothelium condoricum*		b		0.31		b,m		1.28
9	*Ast. disjunctum*				-			m	0.77
10	*Ast. duplicatum*				-		m		1.02
11	*Ast. flavum*	b			0.15				-
12	*Ast. keralensis*				-			b	0.63
13	*Ast. meristosporum*				-			b	0.26
14	*Ast. subdiscretum*				-		b,m,br	br	3.64
15	*Astrothelium* sp.2			br, c	0.31				-
16	*Astrothelium* sp.7				-			b,c	2.26
17	*Astrothelium* sp.8				-			m	1
18	*Astrothelium* sp.10			c	0.31				-
19	*Astrothelium* sp.14				-			c	4.55
20	*Astrothelium* sp.15			c	0.68				-
21	*Bacidia* sp.1	b,br	b,c,m	b,m,c,br	34.1			br	0.77
22	*Bathelium madreporiforme*				-	b	m,br	m,c,br	8.49
23	*Bulbothrix queenslandica*	b	b, m	c, br	3.87			b,m,c	4.72
24	*Candellariella sorediosa*	b	b	b, m	2.32				-
25	*Chapsa velata*				-		b		0.63
26	*Chapsa* sp.1				-			m	0.37
27	*Chapsa* sp.2				-			m	0.89
28	*Chrysothrix xanthina*	b	m	c	1.08		b,m	b,m	8.44
29	*Cococarpia pellita*				-			b	0.51
30	*Cratiria obscurior*	b,br	b,m,c,br	c	12.05		b,m,br	m,br	13.1
31	*Cratira rutilans*	b		m, br	3.17	b			1.79
32	*Cratiria* sp.1	b	b		0.31				-
33	*Cratiria* sp.2		b		0.15				-
34	*Crocynia* sp.1				0.15				-
35	*Diorygma* sp.1				-			m	0.26

Table 3.2 List of lichen taxa that occurred on different size classes of two host species and their important values. (Continued).

no.	Lichens	*D. obtusifolius*			IV	*G. usitata*			IV
		S	M	L		S	M	L	
36	*Dirinaria aegialita*		m	m, c	0.77		m	b,m,c	1.4
37	*Dir. picta*				-		b	b,c,br	3.33
38	*Dyplolabia afzelii*				-	b	b,m,br	m,c,br	6.61
39	*Enterographa* sp.1	b			0.15				-
40	*Gassicurtia* sp.1	b,br	b,m,c,br	b,c,m	9.91		b,m	b,m,c,	8.43
41	*Graphis albissima*				-			br	0.26
42	*Gra. dendrogramma*				0.62	b	b,m	br	-
43	*Gra. draceanea*	b			-				1.65
44	*Gra. handelii*	br	b,m		3.39				-
45	*Gra. nuda*			m,c	1.93		b		0.89
46	*Gra. streblocarpa*			b,m,br	3.09		m	b,m	2.56
47	*Graphis* sp.1				-			m	0.51
48	*Hafelia bahina*	b		b,m,c,	8.04			br	2.81
49	*Haf. subnexa*	b		br	1.31			m	0.51
50	*Lecanora achroa*				-			b	0.26
51	*Lecanora* sp.2			b,c,br	1.16			br	0.26
52	*Leparia* sp.1		b	b,m	4.18				-
53	*Macelaria benguelensis*			c,m	0.92		b,m,br	b,m,c,	13.29
54	*Maronia* sp.1				-			c	0.26
55	*Maronina corallifera*	b,br	b,m,br	b,m,c,	14.82	b	b,m	b,m,c,	28.8
56	*Mycoporum deplanatum*				-	b			3.33
57	*Myriotrema subconforme*				-			b,m,br	2.26
58	*Myriotrema* sp.1			m	0.23				-
59	*Ocellularia arecae*			b,m,c,	8.11				-
60	*Oce. eumorpha*				-			b	0.51
61	*Oce. exuta*		b,m	b,m,br	6.11			b,m	3.33
62	*Oce. punctulata*	b		m	1				-
63	*Pallidogramme chlorocarpoides*				-		b		0.37
64	*Pal. chrysenteron*		b	c	0.46		b	m,c	1.91
65	*Parmelinella wallichiana*			br	0.15				-
66	*Parmotrema tinctorum*	b	br	br	1.38		b	m,br	0.65
67	*Pertusaria amara*		b	b,mc,b	3.47				-
68	*Pertusaria* sp.3		b,m	m,c,br	2.62				-
69	*Phaeographis brassiliensis*			c,m	0.69	b	b,br	m,br	6.56
70	*Pha. caesioradians*				-	b	b,m	b,c,br	7.13
71	*Phaeographis* sp.1	b			0.46				-
72	*Phaeographis* sp.2				-			m	0.26

Table 3.2 List of lichen taxa that occurred on different size classes of two host species and their important values. (Continued).

no.	Lichens	*D. obtusifolius*			IV	*G. usitata*			IV
		S	M	L		S	M	L	
73	*Platygramme pudica*		m	b,c,br	1.99		b	m,br	2.05
74	*Polymeridium*				-		b,m	b,m,c	3.7
75	*Pol. subcineriun*	b	b,c,m	m,c,br	7.3				-
76	*Pyxine coccifera*		b	br	0.93			b,m,br	6.12
77	*Ramboldia russula*				-			c	0.26
78	*Relicina intertexta*			br	0.85			m	1.79
79	*Rel. malaccensis*				-			br	0.26
80	*Rel. palmata*			b,m,c	4.78			b	0.26
81	*Rel. rahengensis*		m	b,m,c,br	11.04			m,c,br	7.28
82	*Thelotrema conferendum*			b,m,c,br	4.11			b	1.14
83	*The. monosporum*		b	b,m,br	4.5			b	2.54
84	*Trypethelium eluteriae*		b		0.15				-
85	*Vainionora flavidorufa*	b	m	m,c,br	2.86			b,c	1.02
86	*Viridothelium virens*				-			m	0.63
	No of species	23	28	42		9	24	55	

Note. different habitats of lichens are indicated as follows, *Tree size classes*: S = tree with small size class, M = tree with medium size class, L = tree with large size class, *Position on tree*: b = trunk base, m = mid trunk, c = canopy, br = branch

at the trunk base may tolerate the forest fire. On the other hand, the forest fire may not give a strong burn in some parts of DDF areas. Because in some areas the forest floor is covered by a huge rock plate, the small shrub or grass did not occur nearby the stem. Therefore, in the dry season, the forest floor may not provide enough litter material for fire burning. It can be seen that the burning evidence on the tree trunk (black color on the bark surface) did not show in the higher zone of the trunk. Therefore, the forest fire may not destroy many lichens on the trunk base. In the case of forest fire causing damage to lichens, Wolseley and Aguirre-Hudson (1997) found that the large foliose lichens (*Parmotrema*) are often damaged by forest fire and the foliose which was closely appressed to the bark surface may survive in bark crevices.

The branch of trees: This habitat is the second favorite habitat for many lichens in this forest. They were recorded for 38 species on *Gluta usitata*, and 34 species on *Dipterocarpus obtusifolius.* It is not clear that some lichens are specific to branches' habitat, however, some lichens prefer the upper part of trees to colonized bark, such as the foliose, these are *Parmelinella wallichiana*, *Relicina intertexta*, *Relicina malaccensis*. To live on the upper part of trees or branches lichens can uptake more light intensity which is essential for the photosynthesis process. Moreover, lichens that grow on the branches can escape the heat from the forest fire underneath (Wolseley and Aguirre-Hudson, 1991).

Mid-trunk and upper trunk: Some lichens can be found on those two habitats, the fewer species found on those two levels were recorded from *Gluta usitata*. They did not have a specific character of habitat favorite. The mid-trunk and upper trunk habitats may not be suitable for many lichens, because on these two positions of the tree, the relative humidity may be low and the ambient may be getting dry fast during the active period in the morning. This change in micro-climates may be caused unsuitable microhabitats for many lichens. However, the vertical strata of lichen in DDF show a different character from lichens in TRF. That the light intensity is a limiting factor for later forest types. Boonpragob and Polyiam (2007) found that a high diversity of lichens occurred on the canopy and a dramatic decrease in mid-trunk and trunk bases. However, the distribution of lichen along the trunk of the tree in DDF may not be clear, as to what factor could control their favorite habitats because forest fire may be another important factor that did not observe in this work.

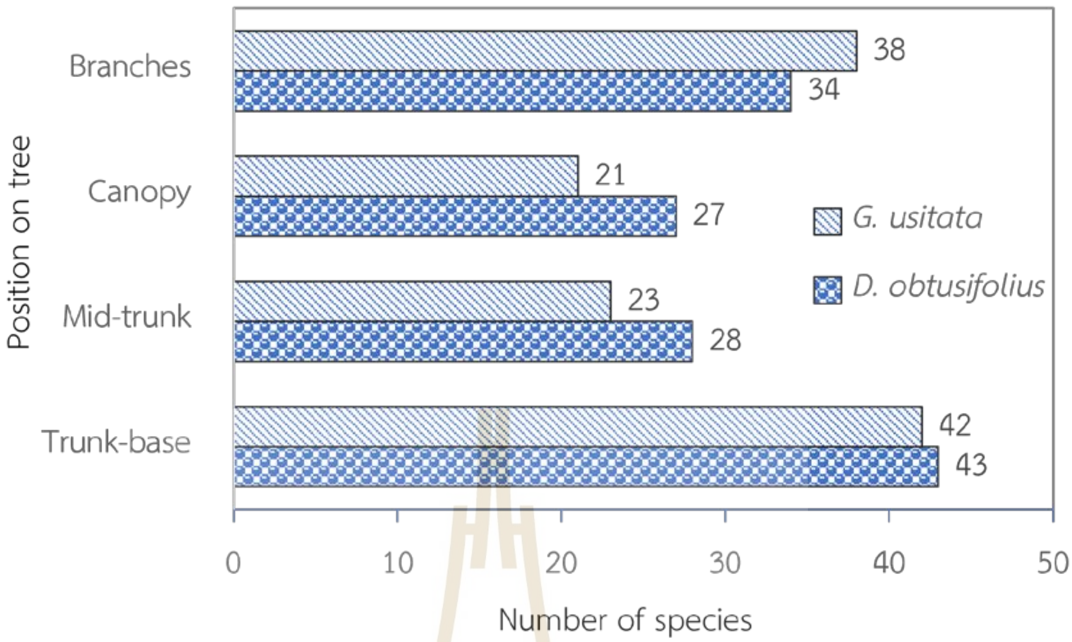

Figure 3.4 Number of lichen species on different positions of two host species.

Ordination of lichen community on the dominant tree species

In the ordination diagram, it was very clear that host tree species were grouped in a different direction of the graph. The *Dipterocarpus obtusifolius* was distributed on the right side above and below Axis 1, but *Gluta usitata* is distributed on the left side at the upper and lower Axis 1. It indicated that the differentiation between the phorophyte properties, that different tree species could have different bark textures that *Dipterocarpus obtusifolius* has a rough bark compared to *Gluta usitata*, pH of bark also show the different values that the former tree species have more acid bark than the later host species (see Table 3.1). This relation was show that the pH of the bark has a strong negative correlation to Axis 1.

Bark water holding capacity was shown a higher value in *Gluta* (higher nearly twice times). This is also found in a highly negative correlation in the graph. Those are the bark properties that could be distinguished in different characters. However, another factor of environmental variables such as tree size is also shown in differences in the position on the graph (Figure 3.5).

The lichen compositions are also clear grouping in the ordination graph. The distributions of lichens in the graph may be correlated to their hosts and various environmental factors. (The distribution and abundance of each lichen species was shown in Table 3.2 and for the abbreviation of lichen name see Table 1A). Similar characteristics of lichen compositions on the phorophytes have been found in other tropical forest, such as in Brazil, Cáceres et al. (2007) show that the lichen composition on trees is response correlated to differences in bark pH. Boonpragob and Polyiam, (2007) point out that the tree species in the tropical rain forest off Kha Yai National Park can be hosted for variation of lichens composition also in the same family (Graphidaceae), that the crustose with lirellate apothecia dominated on the smooth bark of *Castanopsis accuminatissima*, whereas, the crustose with perithecoid of discoid apothecia (former Thelotremataceae) preferred on the rough bark of *Dipterocarpus gracilis*. However, those two studies were investigated in the forest with a dense canopy.

However, in DDF, the forest is characterized by an open canopy, and there may be found differences in lichen compositions. In a study by Wolseley and Aguirre-Hudson (1997), they monitored the lichen community dynamic related to the forest fire in the DDF of the western and northern parts of Thailand. The common lichens found are foliose growth forms such as *Relicinopsis rahengensis* (as *Relicina rahengensis* in this work) and *Pyxine cocifera* which were accepted as the characteristic species of the forest with fire frequently. Although both two lichen species can be recorded in this work, the most common lichen in the DDF of KYNP should be different from the study in the DDF of the western and northern parts of that country. Where the major group of lichen in DDF of KYNP are the crustose growth forms, which include several genera such as *Bacidia*, *Maronina*, *Gassicurtia*, *Amandinea*, and *Phaeographis*.

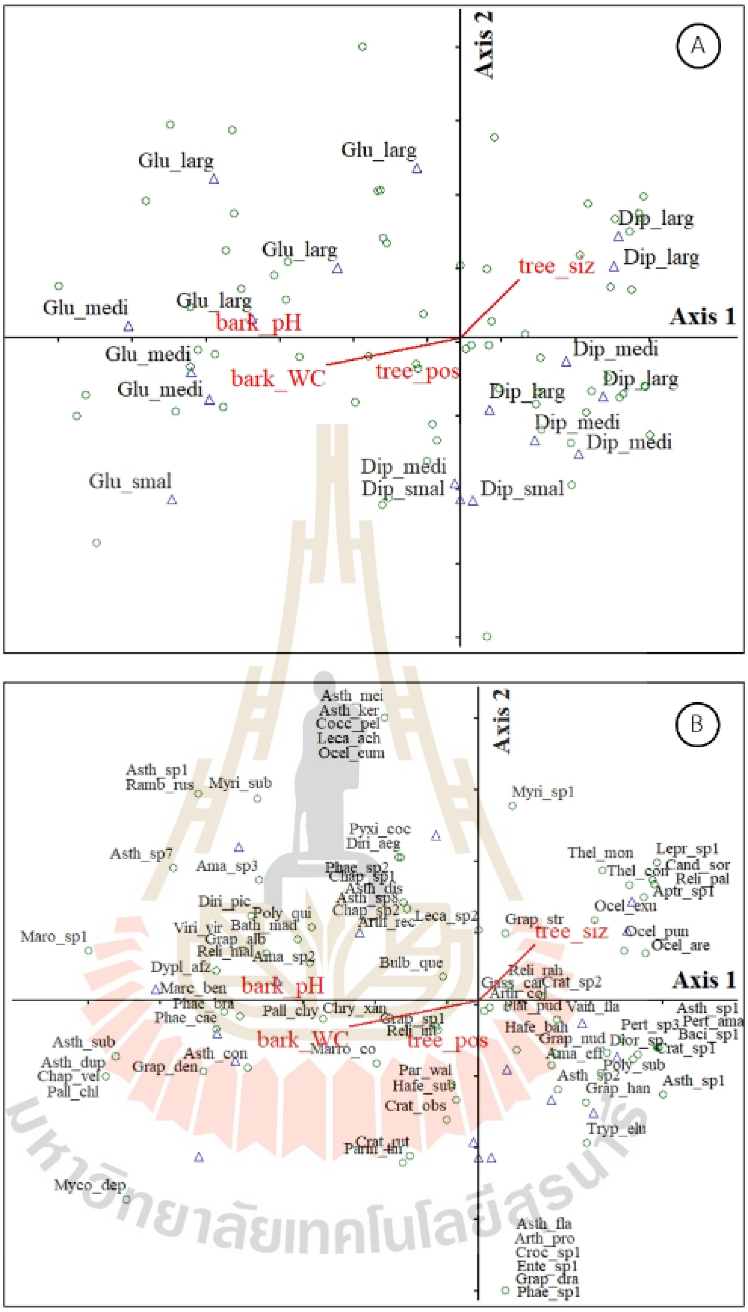

Figure 3.5 Canonical Correspondence Analysis (CCA) of the lichen community on the dominant host species in the DDF of KYNP (A: ordination of tree samples indicated by tree size classes, B: ordination of lichen species and correlation to host species, bark pH, bark water holding capacity, tree size, and positions on trees).

Lichen composition on the dominant tree species

The environmental variables that influenced lichen diversity are complexity (Barkman, 1958). All selecting biological factors on the two host species were shown a significant influence on lichens diversity. Following the result of PERMANOVA, it was clear that host tree species in DDF of KYNP was the most factor that drove the lichen diversity significantly (F = 5.7667, p = 0.001). Host trees were observed for different sizes from small to large (dbh ranges from 1.5 to 34.3 cm in *Dipterocarpus obtusifolius* and ranges from 1.5 to 38 cm in *Gluta usitata*). Those trees would have different bark textures, and bark properties on physical and chemical characteristics, that may directly be influenced to lichens. Therefore, the host species may be discussed as an overall indirect influence on lichens richness, but the environmental variables which belong to each host species could be the direct factor influencing lichens. Among all environmental variables measured in this work, the pH of bark could be the most factor influenced lichen (F = 2.5751, p = 0.002), followed by tree size (F = 2.3920, p = 0.001), water holding capacity (F = 1.7512, p = 0.004), and positions on trees (F = 1.5203, p = 0.003) (Table 3.3).

The bark pH of the two host species shows different values, the *Dipterocarpus obtusifolius* were more acidic bark (range from 2-4.9) than that found on *Gluta usitata* bark (range from 3-5.4) (Table 3.1). As found in many works the pH of bark can influence to epiphytic lichens community (Bates, 1992; Kermit and Guaslaa, 2001; Hauck and Runge, 2002; Nash, 2008). The lichens found in this forest, therefore, could be adapted for the acid bark, some of them may be referred to as the group of acidophile taxa.

Tree size classes can reflect tree ages, as small trees are probably younger than large trees, however, the tree age was not estimated in this work. The tree with a large size class should be provided a habitat longer for lichens, as the lichens usually take a long time to colonize the new bark. The lichen community was set up for a long period as the bark is exposed to the atmosphere. In the DDF of KYNP, it seems that the small tree (small size class) gathers the small number of lichen species, and increases with tree sizes (old tree). This is suggested by Seaward (2008) that with time, different lichen species and assemblages are subsumed by another lichen cover as a consequence of a particular succession. Therefore, large trees in DDF would be provided a large area for lichens to colonize on the bark surface.

The water-holding capacity is one of the lichen-plant interactions, that many lichens found on the *Gluta usitata*, which provided higher values of water-holding capacity compared to those recorded on *Dipterocarpus obtusifolius* (Table 3.1). Most species of lichens found in this forest type perhaps are preferred for the bark with high water-holding capacity. However, the most abundant species preferred the bark of *Dipterocarpus obtusifolius* such as *Bacidia* sp.1 (IV = 34.10) but rarely occurred on *Gluta usitata* (IV = 0.77), this lichen can be proved to indicate the bark of *Dipterocarpus obtusifolius* that typically present in the DDF (see Table 1D).

The position on trees is one of the selecting parameters used to interpret the relationship between lichens in their habitat. The lichens that are distributed on the tree in this forest type are commonly found on the trunk based (Figure 3.4 and Table 3.2), and gradually lower at mid-trunk and upper trunk or canopy. This finding is opposite from a study in the tropical rainforest type of the same national park by Boonpragob and Polyiam (2007) that found a higher diversity of lichens on the canopy level and subsequently lower at mid-trunk and tree base. Besides the species diversity, the variations of thallus growth form are to be found along three high. It was suggested by Komposch and Hafellner (2002), that foliose growth form preferred upper regions at the canopy, where the crustose growth form dominated all high zones.

However, the trees in the DDF of KYNP are not such tall trees, the appearance of lichen along the trunk which is related to environmental variables was interesting. More observations are important. However, it was clear that the abundance of lichens growing on the trunk base of the dominant tree species in the DDF of KYNP produced the soredia as a major vegetative propagule. This character was observed in another forest where forest fires are common, it could point out that soredia propagules are the benefit of lichen dispersal after a forest fire (Wolseley and Aguirre-Hudson, 1997). The common lichens which produced the mass of soredia found in this forest type such as *Amandinea efflorescens*, *Chrysothrix xanthina*, *Gassicurtia* sp.1, and *Lepraria* sp.1.

Table 3.3 Result of PERMANOVA test for the environmental variables that influenced lichen diversity on two dominant phorophytes in the DDF of KYNP.

Environmental variables	df	Sum of squares	Mean squares	F ratio	p-values
Host species	1	2.595	0.02976	5.7667	0.001
pH of bark	1	1.178	0.01351	2.5751	0.002
tree size class	2	2.175	0.02495	2.392	0.001
Water holding capacity of bark	1	0.805	0.00923	1.7512	0.004
positions on tree	3	2.087	0.02393	1.5203	0.003

3.6 Conclusions

This work observed lichen on the most common tree species in the DDF of KYNP, several results from these observations can be concluded as follows;

1. A high diversity of lichens was supported by the dominant tree species, that the major tree species can be hosted about half of the lichen species recorded for this forest type.

2. It was agreed with the result that the dominant tree species were the most important habitat to maintain the lichen community in this forest type.

3. The *Gluta usitata* (characterized by smooth bark) is more important for most lichens than the *Dipterocarpus obtusifolius* (characterized by rough bark), in case of supporting high diversity.

4. This work found that each tree species may play an important role in the favorite habitat for specific lichens.

5. The variations of bark texture, bark pH, and bark water holding capacities are proved to be the wide ranges habitat of lichens in DDF.

3.7 References

Adams, D. B., and Risser, P. G. (1971). The Effect of Host Specificity on the Interspecific Associations of Bark Lichens. *The Bryologist, 74*(4), 451-457. doi:10.2307/3241304.

Aptroot, A. (1997). Lichen biodiversity in Papua New Guinea, with the report of 173 species on one tree. *Bibliotheca Lichenologica, 68*, 203-213.

Bäcklund, S., Jönsson, M., Strengbom, J., Frisch, A., and Thor, G. (2016). A pine is a pine and a spruce is a spruce-The effect of tree species and stand age on epiphytic lichen communities. *PLoS One, 11*(1), e0147004. doi:10.1371/journal. pone.0147004.

Barkman, J. J. (1958). *Phytosociology and ecology of cryptogamic epiphytes*. Assen, Narherland: Van Gorcum.

Bates, J. (1992). Influence of chemical and physical factors on *Quercus* and *Fraxinus* epiphytes at Loch Sunart, western Scotland: a multivariate analysis. *Journal of Ecology*, 163-179.

Boonpragob, K., and Polyiam, W. (2007). Ecological groups of lichens along environmental gradients on two different host tree species in the tropical rain forest at Khao Yai National Park. *Bibliotheca Lichenologica, 96*, 25-48.

Brodo, I. M. (1973). Substrate ecology. In V. Ahmadjian & M. E. Hale (Eds.), *The lichens* (pp. 401-441). New York: Academic Press.

Buaruang, K., Boonpragob, K., Mongkolsuk, P., Sangvichien, E., Vongshewarat, K., Polyiam, W., . . . Lumbsch, H. T. (2017). A new checklist of lichenized fungi occurring in Thailand. *MycoKeys, 23*, 1-91. doi:https://doi.org/10.3897/ mycokeys.@.12666.

Cáceres, M., Lücking, R., and Rambold, G. (2007). Phorophyte specificity and environmental parameters versus stochasticity as determinants for species composition of corticolous crustose lichen communities in the Atlantic rain forest of northeastern Brazil. *Mycological Progress, 6*, 117-136. doi:10.1007/ s11557-007-0532-2.

Callaway, R. M., Reinhart, K. O., Moore, G. W., Moore, D. J., and Pennings, S. C. (2002). Epiphyte host preferences and host traits: mechanisms for species-specific interactions. *Oecologia, 132*(2), 221-230. doi:10.1007/s00442-002-0943-3.

Favero-Longo, S. E., and Piervittori, R. (2010). Lichen-plant interactions. *Journal of Plant Interactions, 5*(3), 163-177.

Gradstein, S., Nadkarni, N., Krömer, T., Holz, I., and Nöske, N. (2003). A protocol for rapid and representative sampling of vascular and non-vascular epiphyte diversity of tropical rain forests. *Selbyana, 24*, 105-111. doi:10.2307/41750962.

Hauck, M., and Runge, M. (2002). Stemflow chemistry and epiphytic lichen diversity in dieback-affected spruce forest of the Harz Mountains, Germany. *Flora-Morphology, Distribution, Functional Ecology of Plants, 197*(4), 250-261.

Hauck, M., and Spribille, T. (2005). The significance of precipitation and substrate chemistry for epiphytic lichen diversity in spruce-fir forests of the Salish Mountains, northwestern Montana. *Flora-Morphology, Distribution, Functional Ecology of Plants, 200*(6), 547-562.

Jüriado, I., Liira, J., and Jaanus, P. (2009). Diversity of epiphytic lichens in boreo-nemoral forests on the North-Estonian limestone escarpment: the effect of tree level factors and local environmental conditions. *The Lichenologist, 41*(1), 81-94.

Kelly, D. L., O'Donovan, G., Feehan, J., Murphy, S., Drangeid, S. O., and Marcano-Berti, L. (2004). The epiphyte communities of a montane rain forest in the Andes of Venezuela: patterns in the distribution of the flora. *Journal of Tropical Ecology, 20*(6), 643-666.

Kermit, T., and Gauslaa, Y. (2001). The vertical gradient of bark pH of twigs and macrolichens in a Picea abies canopy not affected by acid rain. *The Lichenologist, 33*(4), 353-359.

Király, I., Nascimbene, J., Tinya, F., and Ódor, P. (2013). Factors influencing epiphytic bryophyte and lichen species richness at different spatial scales in managed temperate forests. *Biodiversity and Conservation, 22*, 209-223.

Komposch, H., and Hafellner, J. (2002). Life form diversity of lichenized fungi in an Amazon lowland rainforest. *Bibliotheca Lichenologica, 82*, 311-326.

Kubiak, D., and Osyczka, P. (2020). Non-forested vs forest environments: The effect of habitat conditions on host tree parameters and the occurrence of associated epiphytic lichens. *Fungal Ecology, 47*, 100957. doi:https://doi.org/10.1016/j.funeco.2020. 100957.

Loppi, S., and Frati, L. (2004). Influence of tree substrate on the diversity of epiphytic lichens: comparison between *Tilia platyphyllos* and *Quercus ilex* (Central Italy). *The Bryologist, 107*(3), 340-344.

McCune, B., and Grace, J. (2002). *Analysis of Ecological Communities*. Gleneden Beach, Oregon: MjM Software Design.

McCune, B., and Mefford, M. J. (2006). *PC-ORD. Multivariate analysis of Ecological Data, Version 5.10 for Windows*: MjM Software.

McCune, B., Rosentreter, R., Ponzetti, J. M., and Shaw, D. C. (2000). Epiphyte habitats in an old conifer forest in western Washington, USA. *The Bryologist, 103*(3), 417-427.

McDonald, L., Woundenberg, M., Dorin, B., Adcock, A., McMullin, R., and Cottenie, K. (2017). The effects of bark quality on corticolous lichen community composition in urban parks of southern Ontario. *Botany, 95*. doi:10.1139/cjb-2017-0113.

Nash, T. H. (2008). Nitrogen, its metabolism and potential contribution to ecosystems. In T. H. Nash (Ed.), *Lichen biology* (2 ed., pp. 216-233). Cambridge: Cambridge University Press.

Noicharoen, K., Polyiam, W., Boonpragob, K., Elix, J. A., and Wolseley, P. A. (2003). New species of *Parmotrema* and *Relicina* (Ascomycota, Parmeliaceae) from Thailand. *Mycotaxon* 85: 325–330.

Nooduan Muangsan, Pongthep Suwanwaree, Duangkamol Maensiri, Taksin Artchawakom, and A-mornrat Pitakpong. (2015). *Ecology and diversity of lichens in Sakaerat Environmental Research*. Suranaree University of Technology. Nakhon Ratchasima. Retrived from http://sutir.sut.ac.th:8080/sutir/bitstream/123456789/7410/2/Fulltext.pdf.

Ozturk, S., Oran, S., Üniversitesi, U., Fakülesi, F.-E., and Bölümü, B. (2011). Investigations on the bark pH and epiphytic lichen diversity of *Quercus* taxa found in Marmara Region. *Journal of Applied Biological Sciences, 5*.

Pinokiyo, A., Singh, K. P., and Singh, J. S. (2008). Diversity and distribution of lichens in relation to altitude within a protected biodiversity hot spot, north-east India. *The Lichenologist, 40*(1), 47-62.

R Core Team, R. (2013). R: A language and environment for statistical computing. Retrieved from http://R-project.org.

Seaward, M. R. D. (2008). Environmental role of lichens. In T. H. Nash (Ed.), *Lichen biology* (2 ed., pp. 274-298). Cambridge: Cambridge University Press.

Soto, E., Lücking, R., and Bolaños, A. (2012). Especificidad de forófito y preferencias microambientales de los líquenes cortícolas en cinco forófitos del bosque premontano de finca Zíngara, Cali, Colombia. *Rev Biol Trop, 60*, 843-856. doi:10.15517/rbt.v60i2.4017.

Spier, L., van Dobben, H., and van Dort, K. (2010). Is bark pH more important than tree species in determining the composition of nitrophytic or acidophytic lichen floras? *Environmental Pollution, 158*(12), 3607-3611.doi:https://doi.org/10.1016 /j. envpol. 2010.08.008.

Tithiporn Pooprang. (2001). *Systematic study of the lichens family Parmeliaceae in Thailand.* (Master's thesis). Ramkhamhaeng University, Bangkok.

Upreti, D., and Chatterjee, S. (1999). Epiphytic lichens on *Quercus* and *Pinus* trees in three forest stands in Pithoragarh district, Kumaon Himalayas-India. *Tropical Ecology, 40*(1), 41-49.

Will-Wolf, S., Esseen, P. A., and Neitlich, P. (2002). Monitoring biodiversity and ecosystem function: Forests. In P. L. Nimis, C. Scheidegger, & P. A. Wolseley (Eds.), *Monitoring with lichens-Monitoring lichens* (pp. 203-222). Netherland: Kluwer Academic Publishers.

Wolseley, P. A., and Aguirre-Hudson, B. (1997). Fire in tropical dry forests: corticalous lichens as indicators of recent ecological changes in Thailand. *Journal of Biogeography, 24*, 345-362.

Wolseley, P. A., Aguirre-Hudson, B., and McCarthy, P. M. (2002). Catalogue of the lichens of Thailand. *Bulletin of the Natural History Museum, London (Botany), 32*, 13-59.

CHAPTER IV

POPULATION STRUCTURE AND LIFE STAGE CLASSES OF THE TWO FOLIOSE LICHENS IN THE DRY DIPTEROCARP FOREST OF CENTRAL THAILAND

4.1 Abstract

This work aims to examine the population structure and reproduction of two foliose lichen species and their ecological requirements in the DDF of central Thailand. By investigating the thallus individuals of two lichen species on whole tree trunks. The belt transects of 50 m x 2 m (100 m^2) were used to fix the study area into the same standard size at fifteen different study sites located between 101 and 600 m a.s.l. The thallus size of each lichen was measured at four main axes to calculate the thallus diameter. Investigating the reproductive parts of each thallus allowed the thallus to be divided into four life-stage classes: juvenile, small-adult, medium-adult, and large-adult. The results showed that the most stable population structure of these two lichen species was found in the medium-adult life-stage class. The total number of individual records indicated that two lichen species could be considered to have a small population (*Parmotrema tinctorum* was recorded for 484 individuals, estimated at 3,227 individuals per ha, and *Pyxine coccifera* was found for 475 individuals, about 3,167 individuals per ha). It was suggested that the gathering of two lichen species from nature for utilization might cause them at risk of extinction from nature. In this work, it was suggested that settlement of the permanent plots may be needed for the long-term monitoring of the population dynamics. This work can promote the idea that the DDF of KYNP should be selected for a permanent plot for lichen population monitoring in the DDF habitat.

4.2 Introduction

Lichens are mycobiont and photobiont partners' association organisms. They do create a new body called the thallus (Nash, 2008; Fahselt, 2008). Within this body, lichens can function to produce nutrients for their use, which benefits ecosystem enrichment (Konps, Nash, Boucher, and Schlesinger, 1999; Will-Wolf et al., 2002; Nash, 2008). There is a long history of human use of lichens, including silk dying, medicinal herbs, cosmetics and perfume, decoration, air pollution indicators, foods, and so on (Purvis, 2000; Devkota, Chaudhary, Werth, and Scheidegger, 2017; Yang, Devkota, Wang, and Scheidegger, 2017; Elkhateeb, El-Ghwas, and Daba, 2022). These are some benefits that people have earned from lichen in nature. However, the uncontrolled exploitation of lichens in nature caused the decline of the lichen population. Concerns about the reduction of our natural resources grow by the day. The demographic study of lichens has been in the spotlight recently, especially lichens that are at risk of extinction (Scheidegger and Werth, 2009; Scheidegger and Goward, 2002).

In Thailand, there may be many lichen species that are at risk of extinction. But those risk status assessments are not assessed. As a result, there is no data available for conservation management. This exploration focused on the study of the population structure of two lichen species that have different thallus morphologies. The lichens *Parmotrema tinctorum,* which has broadly lobed and large thallus, and *Pyxine coccifera,* which has narrowly lobed and small thallus were chosen. Former species are wildly used as living materials for studying the accumulation of air pollution and indicating air quality (Boonpeng et al., 2017; 2018). More applications: the natural substances of this lichen have been used as the raw material for making silk dyes (Wipawan Lekpet, 2021). The latter species is used to indicate the frequency of forest fires in dry deciduous forests (Wolseley and Aguirre-Hudson, 1997). All aspects of using lichens by humans may lead to the species being threatened. As a result, studying the population structure of lichens in nature is a highlight of conservation priority for biodiversity.

4.3 Review Literatures

A study on population structure is deeply into the ecological amplitude of the lichens. This gains a basic understanding of population status in natural habitats. The field data can help to identify the critical stage of the lichen life cycle, which is important for conservation management. However, demographic investigations of all stages of the life cycle are still rare and urgently needed for many epiphytic lichen populations (Scheidegger and Werth, 2009). Most studies were conducted on the rare or endangered species that occupy temperate regions such as *Lobaria pulmonaria*, *Erioderma pedicellatum*, and *Usnea longissima*. Scheidegger and Werth (2009) studied the natural history of *Lobaria pulmonaria* which provided knowledge on our understanding of population status connected to their conservation, which is a well-studied model (Scheidegger and Werth, 2009).

Scheidegger and Goward (2002) summarized the methods for monitoring lichens for the conservation of the red-list taxa, and suggested that know of the population size of the red-list species is important. The estimation of population size by counting the individuals within the fixed areas were used. In addition, several informations of population biology such as population demography, phenology, reproductive biology, and population ecology should be included.

Juriado and Liira (2010) found that the population of *Lobaria pulmonaria* which mainly occurs on mature hardwood trees in old forests shows a decline across Europe. Only in Estonia, 6% of *Lobaria pulmonaria* localities have become destroyed in the period from 1993 to 2010 due to clear-cutting; in 19% of localities, the species could be considered endangered, as it is affected by forest management activities. They pointed out that most of the endangered populations were also within woodland key habitats. In forest management and conservation planning, woodland key habitats should be preserved with surrounding buffer areas in order to avoid abrupt changes in environmental conditions and natural disturbance regimes. There is also a necessity to develop specific management methods to recover reforested wooded meadows, to ensure that species of semi-open habitats are retained, e.g. by reducing the density of spruce.

Nadyeina, Dymytrova, Naumovych, Postoyalkin, and Scheidegger (2014) studied the distribution and dispersal ecology of *Lobaria pulmonaria* in the largest primeval beech forest in Europe. They found that occupancy of *Lobaria pulmonaria* was related to altitude and canopy cover, whereas the species density was explained by habitat types and slope exposition. Population density is higher at the timberline than in the interior forest or on lowland meadows. This lichen preferred forest stands with loose or scattered canopy. On host trees, this lichen preferred tree trunk position at shaded sites, while juvenile thalli are more frequent on small trees, but mature thalli are predominantly found on trees of average or large sizes. Fertile individuals require specific environmental conditions, which are available at intermediate altitudes, related to sheltered light, and horizontal terraces on slopes with eastern exposition. They also found a high percentage of juvenile thalli in primeval beech forests.

Ignatenko and Tarasova (2017) studied the population structure of the lichen *Lobaria pulmonaria* in the middle boreal forests depending on the time-since-disturbance. They divided the population structure into seven functional groups with different life cycles. They found that the number of *Lobaria* thalli per hectare, the number of substrate units, the number of substrate types colonized by this lichen as well as the number of substrate types on which the lichen had completed its life cycle increased with time since disturbance.

Benesperi, Nascimbene, Lazzaro, Bianchi, Tepsich, Longinotti, and Giordani (2018) demonstrated that the successful conservation of the endangered forest lichen *Lobaria pulmonaria* requires knowledge of fine-scale population structure. They compared the relation of thallus size of this lichen and environmental variables, three stages of lichen as recruits, juvenile, and reproductive were classified. They found that the effect of habitat was significant only for adult thalli while the early life stages of the lichen were habitat-independent and were strictly associated with tree-level factors. A positive relationship between bryophyte cover and juvenile thalli was found as well.

In different latitudes, climate conditions, and vegetation components from the temperate regions and the tropical regions, a high diversity of lichen was found (Lücking et al., 2009). However, a study on the lichen population structure of the species is needed. Lack of understanding of the lichen population is projected to increase the risk. Rare or threatened species provide an insight into the conservation priorities of tropical species. A case study of the well-known species in population biology, *Lobaria pulmonaria* was previously found widespread in the temperate zones of North America, Europe, and Asia. The high potential of economic values and utilizations, such as using this lichen for medicinal purposes, Long periods of harvesting from natural habitats lead to this lichen's threatened status (Scheidegger and Goward, 2002; Scheidegger and Werth, 2009; Lõhmus and Lõhmus, 2019).

For the tropical lichens, similar to *Lobaria pulmonaria*, the lichen *Parmotrema tinctorum* is a widely distributed species in the tropical and subtropical zones (Swinscow and Krog, 1988; Brodo, Sharnoff, and Sharnoff, 2001). The distribution of this lichen species is well known, but the demography of the life stage has never been reported. The changing of environments, e.g., habitat degradation and loss, habitat fragmentation, increasing air pollution, and climate change, may influence the population density of this lichen. Besides these, overexploitation of the lichen population can be a serious problem that is influenced by human demand. There are some publications on using *Parmotrema tinctorum* for several purposes, such as dyes, antimicrobials, and air pollution monitoring (Ohmura Kawachi, Kasai, Sugiura, Ohtara, Kon, and Hamada, 2009; Casselman and Terada, 2012; Käffer, Lemos, Apel, Rocha, de Azevedo Martins, and Vargas, 2012; Anjali, Mohabe, Reddy, and Nyauaka, 2015; Boonpeng et al., 2017).

All aspects of using this lichen are based on lichen materials gathered from nature. Using this lichen without understanding population structure, can lead to the species being threatened. Another tropical lichen species that could be as important as *Parmotrema tinctorum*, the lichen *Pyxine coccifera* was known as the characteristic species of the DDF (Wolseley and Aguirre-Hudson, 1997). This lichen can be used as an indicator of forest fires. This lichen has information on its distribution (Wolseley et al., 2002; Monkolsuk Meesim, Poengsungnoen, and Kalb, 2012) but the population status is unknown. The two foliose lichens that are mentioned are examples of lichen taxa that know their distributions but lack population status in the country. Therefore, the study of the population structure of *Parmotrema tinctorum* and *Pyxine coccifera* in the forest is a priority conservation effort.

4.4 Materials and Methods

Site studies

The study sites (15 study sites) for this work are selected from different altitudes between 100 and 600 m.a.s.l and between 14°11' and 14°15' N and 101°29' and 101°30' E. The topography, vegetation, and climates were summarized in Chapter I and Chapter II of this thesis.

Selecting the lichens

This exploration focused on the study of the population structure of two lichen species that have different thallus morphology. The lichen *Parmotrema tinctorum* which has a broad lobe and large thallus and *Pyxine coccifera* which has a narrow lobe with small thallus were selected (see Figure 4 and Table 4.1).

Field sampling

The collection of *Parmotrema tinctorum* and *Pyxine coccifera* on the phorophytes was established along the belt transects of 50 m x 2 m (100 m^2), which were in the dry dipterocarp forest patches in each study site. All trees with dbh > 4 cm that are present along the belt transect were selected. All thalli of those two lichen species were explored in all selected trees. The occurrence of two lichen species (present or absent) on selected trees was recorded, together with thallus size (thallus diameter estimated by the average of the four axes of the thallus (see Hestmark, Skogesal, and Skullerud, 2005; Benesperi et al., 2018), the number of thallus in each life stage was counted. The life stages of the two lichen species were categorized into four stages at different ranges (see Table 4.2).

The phorophyte characteristics, such as tree species, tree size (dbh), height above ground, and directions on the tree where lichens are present (the angle against north, N=0°) were recorded.

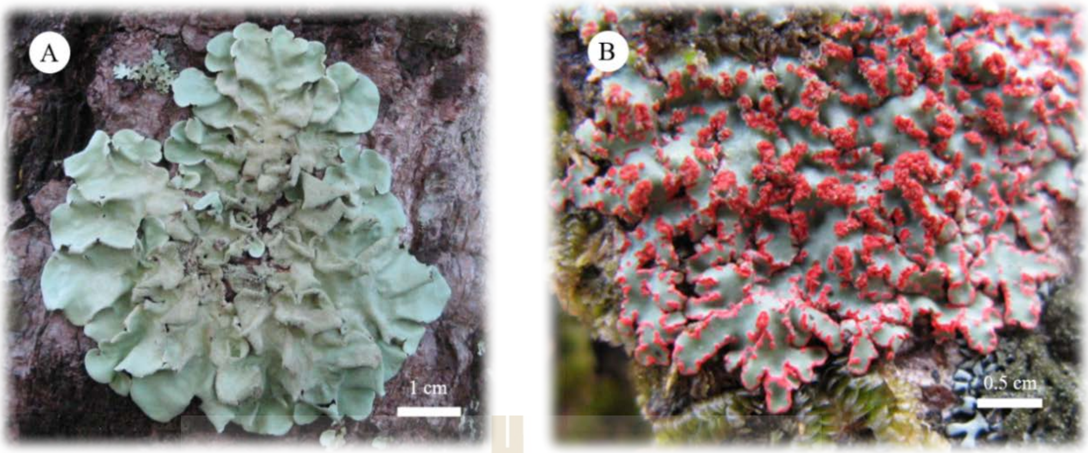

Figure 4.1 The selecting lichen species found in the dry dipterocarp forest at Khao Yai National Park, (A: *Parmotrema tinctorum* and B: *Pyxine coccifera*).

Table 4.1 A comparison of two selected lichens.

Characters	Lichens	
	Parmotrema tinctorum	*Pyxine coccifera*
Taxonomic treat	Class Lecanoromycetes Order Lecanorales Family Parmeliaceae	Class Lecanoromycetes Order Caliciales Family Caliciaceae
Morphology	broadly lobe,	narrowly lobe,
Lobe character	size 10-25 mm wide	size 0.4-1.2 mm wide
Photobiont	Chlorococcoid, (*Trebouxia*)	Chlorococcoid, (*Trebouxia*)
Vegetative propagules	isidia, simple to coralloid	soredia, red powder
Ascomata	very rare, disc-like apothecia, lecanorine, gray to brown	very rare, disc-like apothecia, lecideine, black
Spore character	simple, hyaline, ellipsoid	1 septate, brown, ellipsoid
Common-rare status (see table 1A)	IV = 2.47	IV = 1.07
Population size	unknown	unknown
Distributions / forest types	dry dipterocarp, mix-deciduous, tropical rainforest, lower montane forest	dry dipterocarp, mix-deciduous, and shrub forests
References	Pooprang, 2001	Monkolsuk et al, 2012

Table 4.2 Life stage characteristics of two lichen species.

Life stages	Lichen species	
	Parmotrema tinctorum	*Pyxine coccifera*
Juvenile	No reproductive organ	No reproductive organ
Small-adult	Thallus diameter < 2 cm with apothecia or isidia	Thallus diameter < 1 cm with apothecia or soredia
Medium-adult	Thallus diameter 2-10 cm with apothecia or isidia	Thallus diameter 1-5 cm apothecia or soredia
Large-adult	Thallus diameter > 10 cm with apothecia or isidia	Thallus diameter > 5 cm apothecia or soredia

Data analysis

The lichen occurrences were compared within different habitats on trees and elevation ranges. The detection probabilities were calculated to predict the chance of distribution at different elevations. All statistical analyses were performed using program R version 3.4.1 (R Core Team, 2013).

4.5 Results and Discussions

The population size of two lichens in the DDF of KYNP

The individual thalli of two foliose lichens in the DDF of KYNP were found in a similar number, that *Parmotrema tinctorum* having a little bit more thalli compared to *Pyxine coccifera*, which accounted for 484 and 475 thalli, and estimated for 3,227 and 3,167 individuals per hectare, respectively (Table 4.3). However, the number of host trees was not equal; there were 49 and 32 trees hosted for *Parmotrema tinctorum* and *Pyxine coccifera* respectively. The number of lichen thalli was recorded in different values influenced by elevation ranges. Lichen *Parmotrema tinctorum* showed the highest detection probability (*pr = 0.6757*) at high elevations (501-600 m.a.s.l.), however, no detection probability was recorded at the lowest elevation. These results may indicate that the populations of this lichen are likely distributed at a high elevation of this forest type.

While *Pyxine coccifera* is presented in all elevation ranges, which were commonly present at 201-300 m.a.s.l. (*pr = 0.67*20) (Table 4.3). This indicated that they could have a wide range of distribution in the DDF.

The population size of two foliose lichens found in this work is estimated to be small for the study sites. They perhaps need to be concerned about the conservation priority. According to Scheidegger and Goward (2002) suggested that the thallus individual of red list lichens at about 3,000 per hectare should be used to defend a high conservation priority. However, they mention that the measurement of population size should be carried out only at the mature stage.

Population characteristics and dispersal strategies of two lichens in the DDF of KYNP

This work measured the individual thalli of two lichens that were found on the sampling trees. Therefore, all thallus sizes were presented, and population structures were evaluated.

Population of *Parmotrema tinctorum*: Most of the thalli found were medium thallus size, fewer thalli were large adult (16 %) (Figure 4.2A and Figure 4.3A). While the small-adult and juvenile are in the middle, which were found 26.7 and 22.1 percent respectively. This lichen species has a clear complete life cycle in this forest type, as shown that the juvenile stage (without any reproductive parts) appeared on the trees in many study sites. They may establish many new colonies that can be replaced the adult generations. However, this was not observed for the sexual reproductive part (apothecia), therefore, the juvenile stage could be developed from the vegetative propagules (isidia). This type of vegetative propagule may play an important role on the dispersion and provided its population characteristics.

Population of *Pyxine coccifera*: This lichen species has the majority of population characteristics with the medium-adults (70.3 %) (Figure 4.2B and Figure 4.3B). The small-adult and large-adult showed only 16.4 and 13.2 percent respectively. However, the juvenile stage of the population was not observed for this lichen. It was observed that the thalli of this lichen produce the soredia as a vegetative propagule, that were found even when the thallus size is very small. The smallest thalli was 0.25 cm in diam. As similar to *Parmotrema tinctorum* the sexual reproductive part was not observed from *Pyxine coccifera*. Therefore, soredia would be the important diaspore that this lichen uses to disperse in the forest.

Lichen species that use the vegetative propagules as a dispersal strategy are successfully for establishing a new colony. According to Bowler and Rundel (1975) pointed out that vegetative propagules (perhaps, isidia or soredia) could be beneficial for foliose lichen that can have a greater world distribution than their sexual reproduction. While Hilmo, Rocha, Holien, and Gauslaa (2011) found that the isidia can be developed to new thallus faster than soredia, these recorded from two different species of *Lobaria*. However, Schideger and Werth (2009) pointed out that the critical stage for the successful development of lichen thallus was the establishment of the thallus from a propagule.

Table 4.3 Number of thallus individuals and the prediction of density and occurrence of two foliose lichens in the DDF of KYNP.

Population character	Elevation range (m.a.s.l)					total
	101-200	201-300	301-400	401-500	501-600	
Parmotrema tinctorum						
no of tree (observed)	29	31	44	48	46	198
no of tree (hosted)	0	11	5	12	21	49
no of thalli	0	207	28	39	210	484
Estimate thallus density (individual / ha)	0	6,900	933	1,300	7,000	3,227
Detection probability	0	0.5957	0.3371	0.5	0.6757	
Pyxine coccifera						
no of tree (observed)	29	31	44	48	46	198
no of tree (hosted)	2	14	4	7	5	32
no of thalli	3	239	25	125	83	475
Estimate thallus density (individual / ha)	100	7,967	833	4,167	2,767	3,167
Detection probability	0.2626	0.6720	0.3015	0.3819	0.3297	

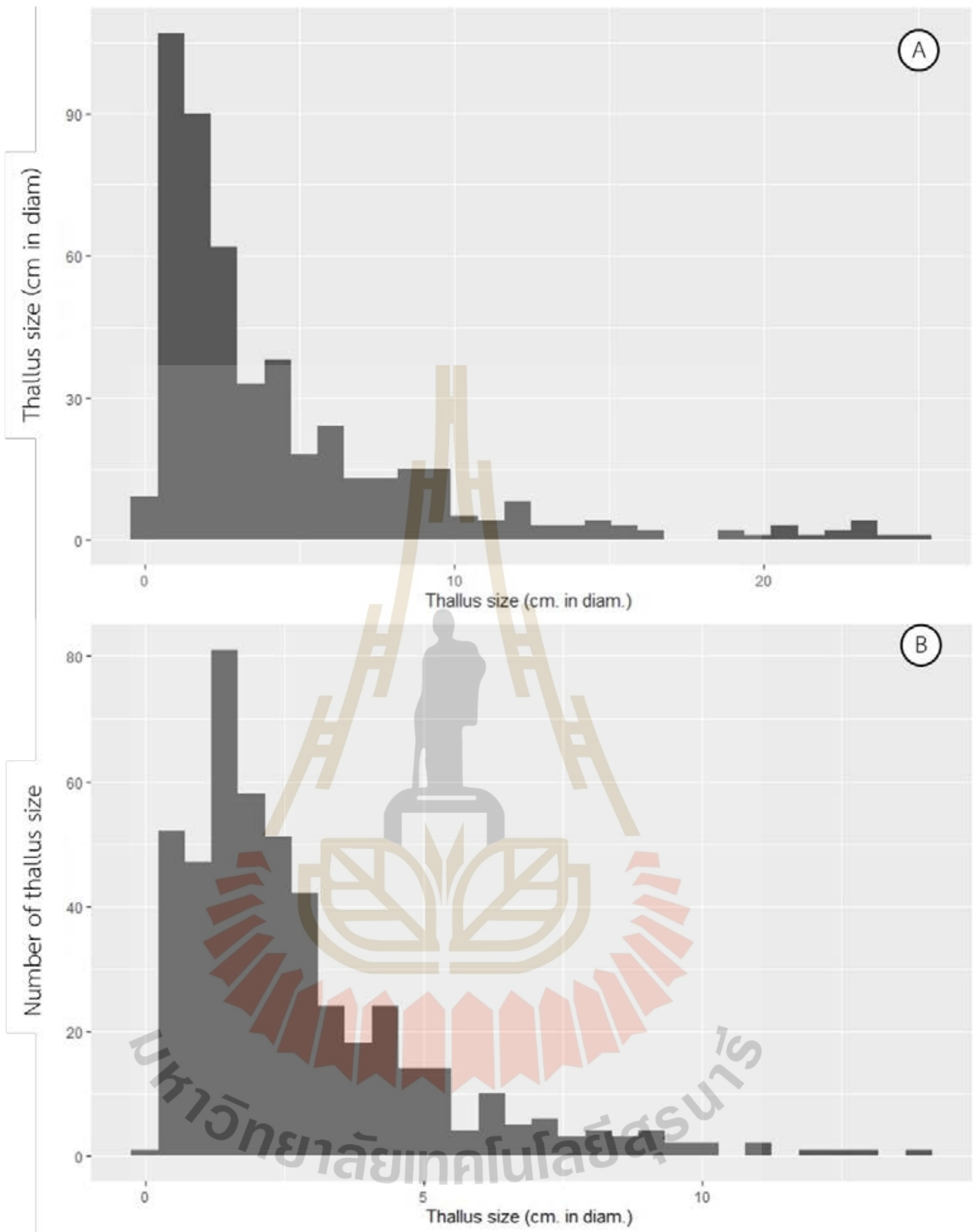

Figure 4.2 Frequency of thallus size of the two lichen species in the DDF of KYNP, (A: *Parmotrema tinctorum* and B: *Pyxine coccifera*).

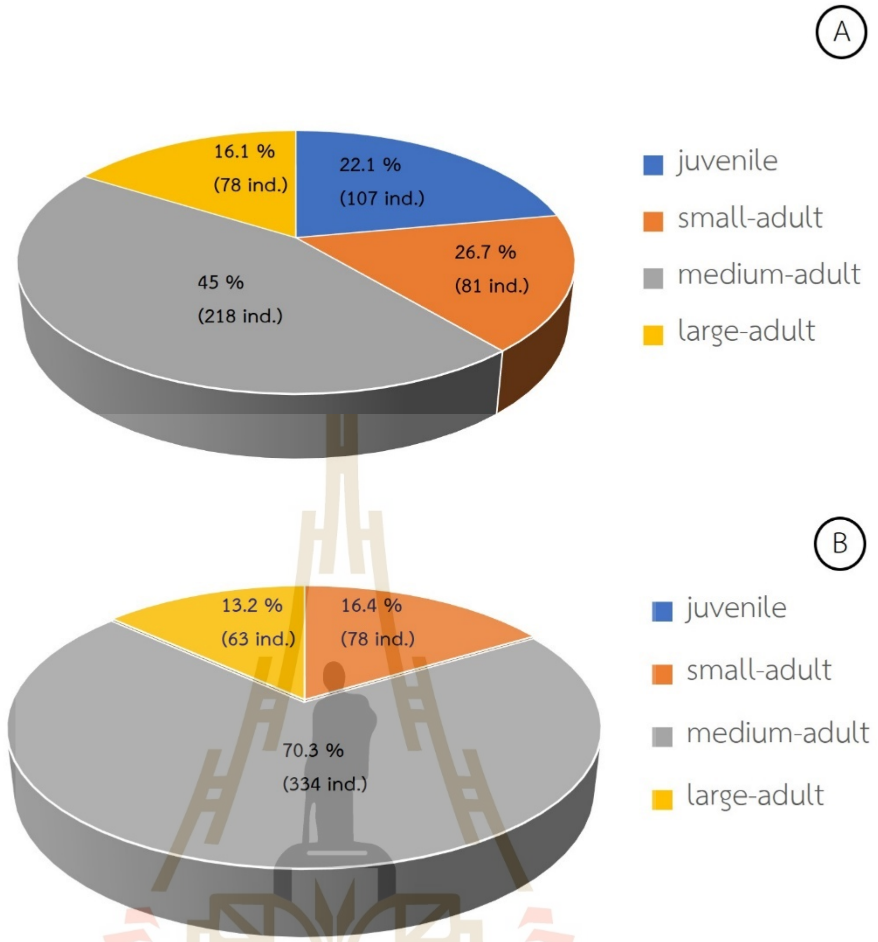

Figure 4.3 Proportion of the life stage of two foliose lichens in the DDF of KYNP, (A: *Parmotrema tinctorum* and B: *Pyxine coccifera*).

Distribution of two foliose populations in the DDF of KYNP

The distribution of both *Parmotrema tinctorum* and *Pyxine coccifera* populations were considered related to the elevation ranges in the DDF of KYNP. They have a similar pattern of the high density of thalli in the elevation ranges between 201 and 300 m.a.s.l. Where *Parmotrema tinctorum* has the largest population size (210 thalli) recorded between 501 and 600 m.a.s.l., whereas, at 301-400 m.a.s.l. and 401-500 m.a.s.l. a few thalli (28-29 individuals) were recorded. However, the population of this lichen was not distributed to the lowest elevation (101-200 m.a.s.l.) (Figure 4.4A and Figure 4.5A).

The population of *Pyxine coccifera* is found in all elevation ranges. Although the population of this lichens can be occurred at all elevations, however, at the lowest elevation, only three individuals were found (Figure 4.4A and Figure 4.5A). It may reveal that the forest habitat at lowest elevation may not be suitable for supporting those two foliose lichen populations.

Host trees for two foliose lichen populations

Host tree species: In this study, 198 trees (belonging to 20 species) have been investigated for two lichen populations. Only 49 trees (24.7%) and 32 trees (16.1%) were found as the host of *Parmotrema tinctorum* and *Pyxine coccifera* respectively. The most common tree species that has been hosted for *Parmotrema tinctorum* population is *Vatica odorata* (164 thalli), and lower at a half number recorded from *Corallia brachiata* and *Dipterocarpus obtusifolius* (78 thalli for each tree species).

The most common host tree for *Pyxine coccifera* is *Gluta usitata* (119 thalli), with a lower number of thalli recorded from *Vatica odorata*, *Shorea roxbergii*, and *Corallia brachiata* (accounted for 95, 71, and 69 thalli, respectively). There were ten tree species where the thalli of each lichen species were not found (see Table 4.5). The tree may play an important role in establishment, colonization, and distribution for the population of these two lichen species. That may relate to tree species and bark properties. (see Chapter II and Chapter III in this dissertation). For the tree species, finding the key stone trees for lichens is important. These was suggested by Bnesperi et al. (2018) that the conservation strategies of the rare lichen populations need to be found out for the correct tree habitat of lichens and retention of tree is the priority.

The positions on trees: When comparing the distribution of the population on the different positions of trees. *Parmotrema tinctorum* has a distribution pattern preferred on tree branches. This may suggest that on the branch habitat, lichen could uptake the suitable conditions, for instant light intensity or other microclimates. The branches may refer to the best condition for this lichen to survive, showing that all life stages were found on the branch habitats. While *Pyxine coccifera* dominated on the trunk (Figure 4.6). The trunk base seems to be the most favorite habitat for this lichen. As according to Wolseley and Aguirre-Hudson (1997) they found that *Pyxine coccifera* was common in the DDF, this lichen species could adapt to survive the forest with frequently forest fire.

The directions on trees: the direction on tree may be another influencing factor on lichen population distribution. Many of the *Parmotrema tinctorum* individuals preferred north-to-east directions, but most of the population was found on the branch habitat that leaned horizontally to the sun. Establishment of lichen thalli on the directions which facing to the sun during the active periods are to be benefit to photosynthesis process of poikilohydric lichen. That lichen required a suitable condition of microclimates for their photosynthesis (Mongkol Phaengphech, Pitakchai Fangkaew, Wetchasart Polyiam, Chaiwat Boonpeng, Santhi Watthana, and Kansri Boonpragob, 2019).

The population of *Pyxine coccifera* is found mostly in east-to-west directions, with a majority found on the southern face of the trees (Table 4.4 and Figure 4.7). That may be explained by the south facing on the tree perhaps provided the dry conditions of microhabitat that this lichen species preferred. This dry condition was commonly found on the south facing of the trunk especially in cool season (Boonpragob and Polyiam, 2007).

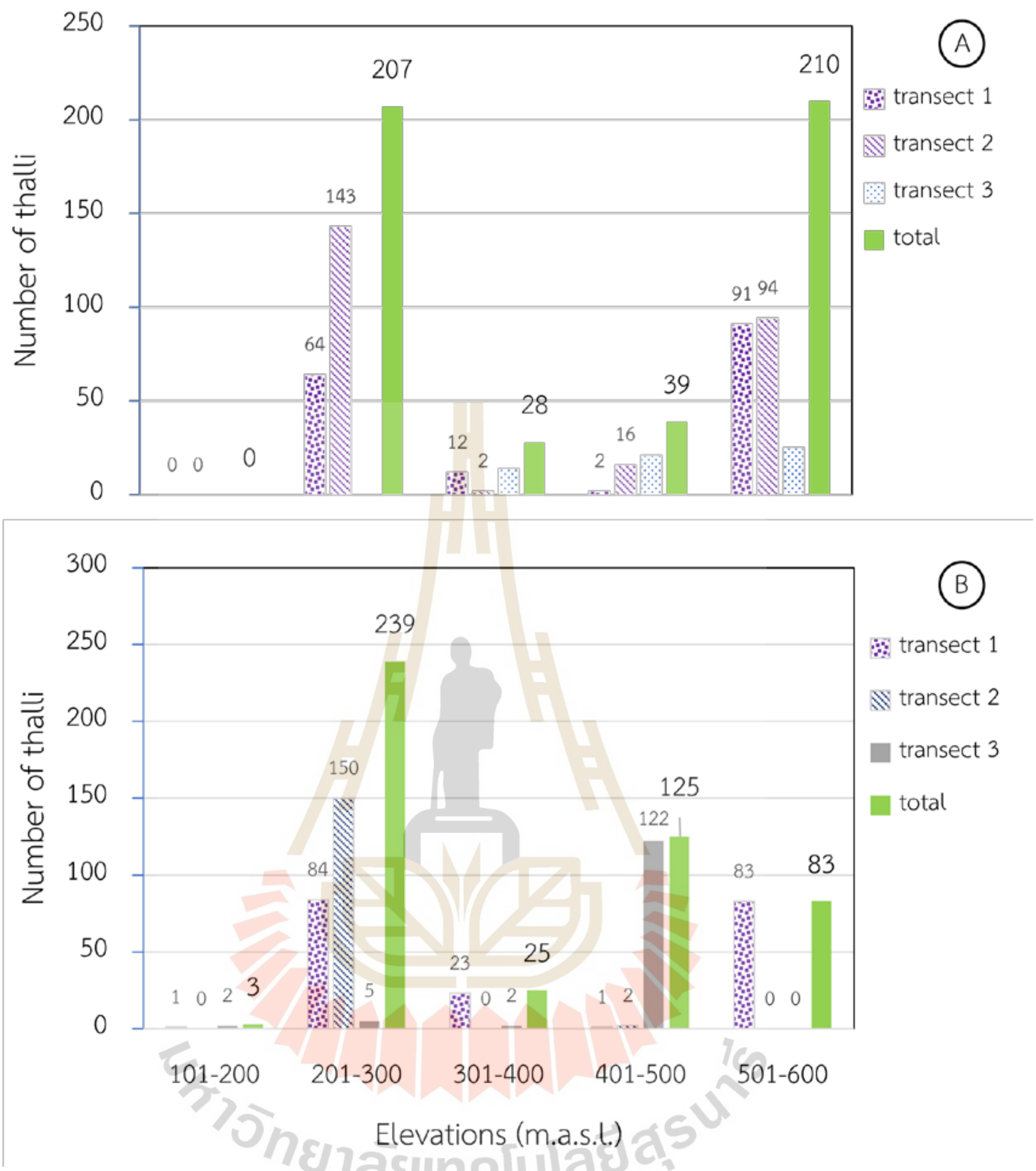

Figure 4.4 Number of lichen thalli occurring in different elevations of the DDF of KYNP, (A: *Parmotrema tinctorum* and B: *Pyxine coccifera*).

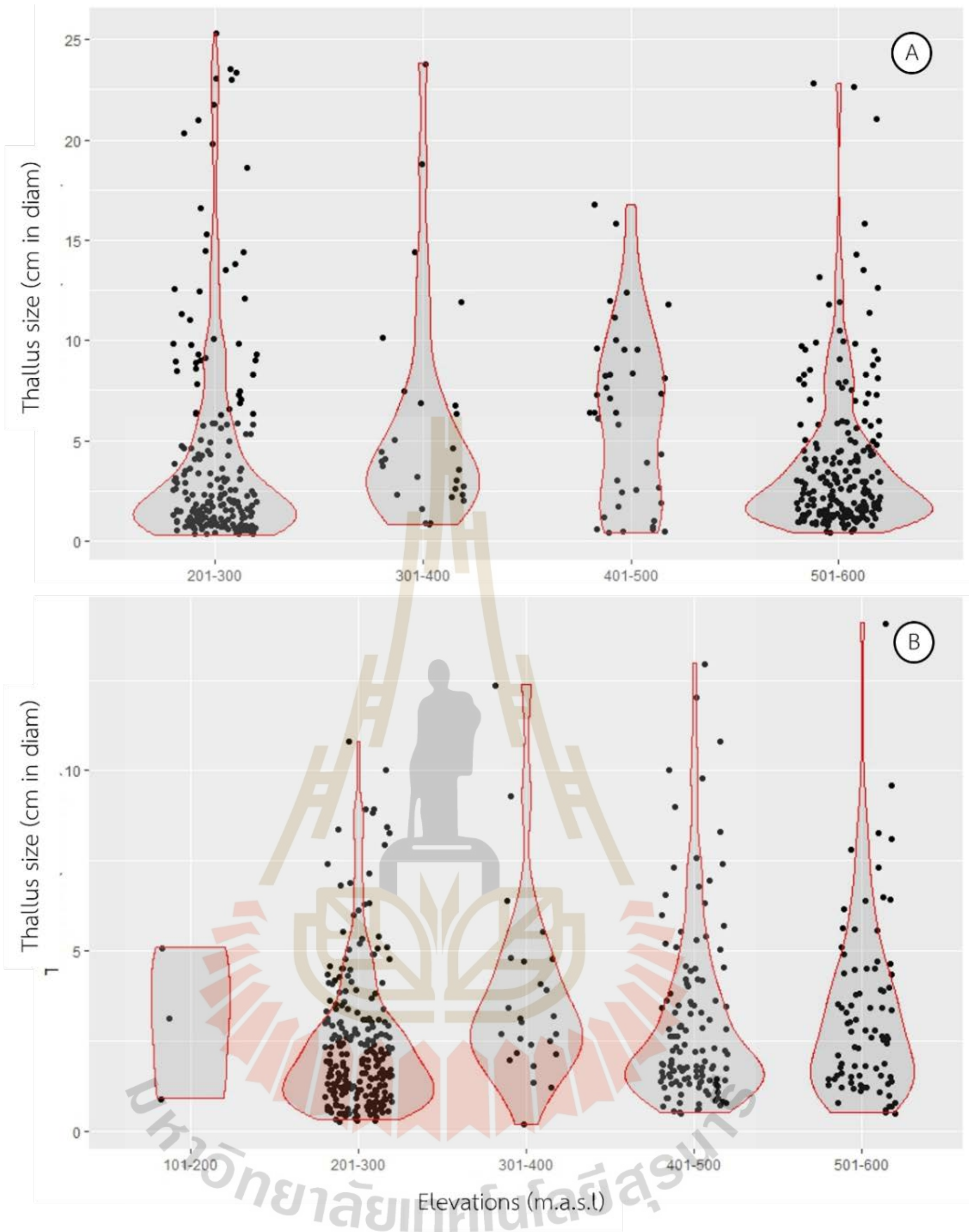

Figure 4.5 Occurrence of two lichen populations on different elevations in the DDF of KYNP, (A: *Parmotrema tinctorum* and B: *Pyxine coccifera*).

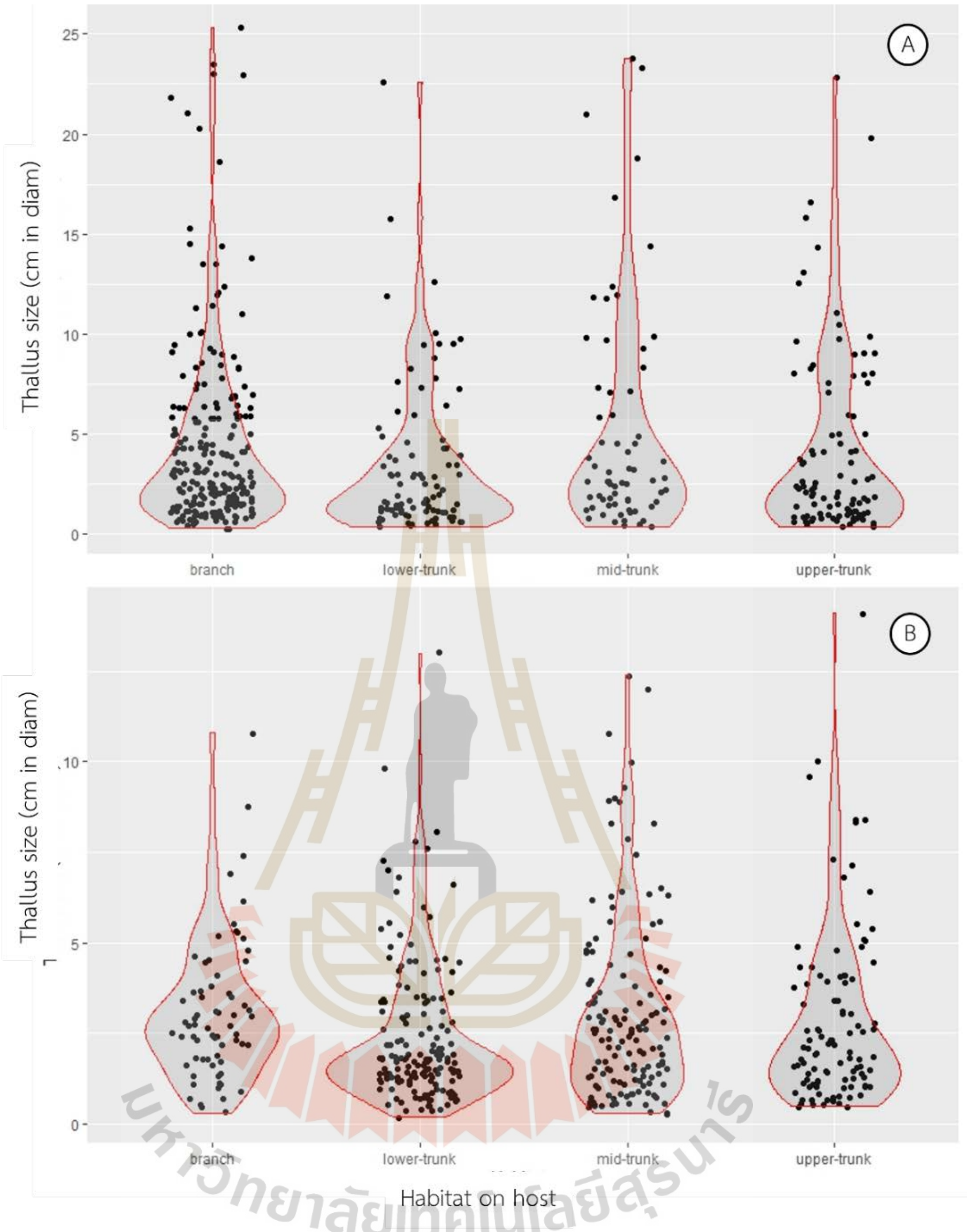

Figure 4.6 Occurrence of two lichen populations in a different positions on host trees in the DDF of KYNP, (A: *Parmotrema tinctorum* and B: *Pyxine coccifera*).

Table 4.4 Distribution of two lichen populations in different directions of the tree trunks in the DDF of KYNP.

Angle on tree	*Parmotrema tinctorum*		*Pyxine coccifera*	
	no. of thalli	% occurrence	no. of thalli	% occurrence
0-45	62	12.8	42	8.8
46-90	36	7.5	68	14.3
91-135	30	6.2	66	13.9
136-180	20	4.1	69	14.5
181-225	13	2.7	60	12.6
226-270	26	5.4	50	10.5
270-315	32	6.6	29	6.1
316-360	36	7.5	23	4.8
Horizontal	228	47.2	68	14.3
Total	483	100	475	100

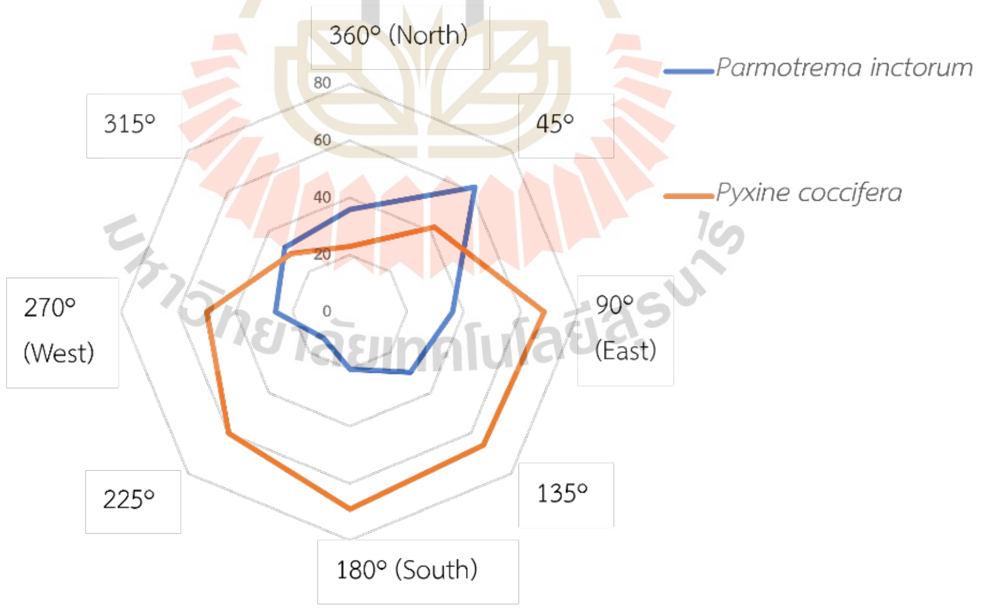

Figure 4.7 Distribution pattern of two lichen populations in the different directions on tree trunks in the DDF of KYNP, (A: *Parmotrema tinctorum* and B: *Pyxine coccifera*).

Table 4.5 List of tree species and the number of recorded thalli.

no.	Tree species	no. of tree	Number of thalli	
			Parmotrema tinctorum (%)	*Pyxine coccifera* (%)
1	*Acronychia pedunculata*	2	0	0
2	*Catunaregram tomentosa*	1	0	0
3	*Corallia brachiata*	6	78 (16.1)	69 (14.5)
4	*Cratoxylum formosum*	1	0	0
5	*Croton* sp.	1	0	0
6	*Dalbergia chochinchinensis*	1	0	0
7	*Dipterocarpus intricatus*	6	13 (2.7)	3 (0.6)
8	*Dipterocarpus obtusifolius*	120	78 (16.1)	54 (11.4)
9	*Gluta usitata*	13	18 (3.7)	119 (25)
10	*Hynocarpus ilicifolia*	1	0	0
11	*Irvingia malayana*	4	9 (1.9)	14 (2.9)
12	*Melodorum fruticosum*	1	0	0
13	*Memecylon scutellatum*	1	0	0
14	*Ochna intergerima*	3	32 (6.6)	3 (0.6)
15	*Parinari anamensis*	4	43 (8.9)	47 (9.9)
16	*Schima wallichii*	1	8 (1.7)	0
17	*Shorea roxbergii*	6	41 (8.5)	71 (14.9)
18	*Sindora siamensis*	2	0	0
19	*Syzygium* sp.A	4	0	0
20	*Vatica odorata*	20	164 (33.9)	95 (20)
	Total	198	484	475

4.6 Conclusions

The result of this study is the first reported on investigation of the lichen population found in the DDF.

1) The results showed that the most population structure of these two lichen species was found in the medium-adult life-stage class. The total number of individual records indicated that two lichen species could be considered to have a small size population (*Parmotrema tinctorum* was recorded for 484 individuals, estimated at

3,227 individuals/ ha, and *Pyxine coccifera* was found for 475 individuals, about 3,167 individuals/ ha).

2) Tree species are important to maintaining the large size of the lichen population, that *Vatica odorata* is the most important host for *Parmotrema tinctorum*, while *Gluta usitata* is the most important for *Pyxine coccifera*. The finding of information on the population size and population structures of two foliose lichens in this forest habitat can be extended to the plan for conservation strategies for the forest lichens.

3) The habitats known for their high density of lichen populations should be selected for lichen transplantations, which can be applied for *in situ* conservation. However, creating a habitat similar to the lichen habitat in nature and transplanting lichens to new habitats is the choice for *ex-situ* conservation. The transplanting technique may be useful for many foliose and fruticose lichens that can increase their population size and biomass. However, this technique may not be suitable for crustose lichens.

4) In this work, it was suggested that settlement of the permanent plots may be needed for the long-term monitoring of the population dynamics, this work can be promoted that the DDF of KYNP should be selected for a permanent plot for lichen population monitoring in DDF habitat. Finally, the study of other lichen populations is important, the method from this work should be applied to study the rare and vulnerable lichens.

4.7 References

Anjali, D. B., Mohabe, S., Reddy, A. M., and Nyauaka, S. (2015). Antimicrobial activities of 2-Propanol crude extract from lichen *Parmotrema tinctorum* (Despr.ex. Nyl.) Hale, collected from Eastern Ghats, India. *Current Research in Environmental & Applied Mycology, 5*(3), 160-168.

Benesperi, R., Nascimbene, J., Lazzaro, L., Bianchi, E., Tepsich, A., Longinotti, S., and Giordani, P. (2018). Successful conservation of the endangered forest lichen *Lobaria pulmonaria* requires knowledge of fine-scale population structure. *Fungal Ecology, 33*, 65-71. doi:https://doi.org/10.1016/j.funeco.2018.01.006.

Boonpeng, C., Polyiam, W., Sriviboon, C., Sangiamdee, D., Watthana, S., Nimis, P.L., and Boonpragob, K. (2017). Airborne trace elements near a petrochemical industry complex in Thailand assessed by the lichen *Parmotrema tinctorum* (Despr. Ex Nyl.) Hale. *Environmental Science Pollution Research 24*, 12393-12404.

Boonpeng, C., Sriviboon, Polyiam, W., C., Sangiamdee, D., Watthana, S., and Boonpragob, K. (2018). Assessing atmospheric pollution in a petrochemical industrial distric using lichens air quality index (LiAQI). *Ecological Indicator, 9*(1), 589-594.

Boonpragob, K., and Polyiam, W. (2007). Ecological groups of lichens along environmental gradients on two different host tree species in the tropical rain forest at Khao Yai National Park. *Bibliotheca Lichenologica, 96*, 25-48.

Bower, P. A., and Rundel, P. W. (1975). Reproductive strategies in lichens. *Bot. J. Linn. Soc. 70*, 325-340.

Brodo, I. M., Sharnoff, S. D., and Sharnoff, S. (2001). *Lichens of North America*. New Haven: Yale University Press.

Casselman, K., and Terada, T. (2012). *The Politics of Purple: Dyes from Shellfish and Lichens.* Paper presented at the Textile Society of America Symposium Proceedings.

Devkota, S., Chaudhary, R. P., Werth, S., and Scheidegger, C. (2017). Indigenous knowledge and use of lichens by the lichenophilic communities of the Nepal Himalaya. *Journal of Ethnobiology and Ethnomedicine* 13:15. Doi: htpps://doi 10.1186/s13002-017-0142-2.

Elkhateeb, W. A., El-Ghwas, D. E., and Daba, G. M. (2022). Lichens Uses: Surprising Uses of Lichens that Improve Human Life. *Journal of Biomedical Research & Environmental Sciences, 3*(2), 189-194.

Fahselt, D. (2008). Individuals and populations of lichens. In T.H. Nash III, (Ed.) *Lichen biology* (pp. 252-247). Cambridge: Cambridge University Press.

Hestmark, G., Skogesal, O., and Skullerud, Ø. (2005). Growth, population density and population structure of *Cetraria nivalis* during 240 years of primary colonization. *The Lichenologist, 37*(6), 535-541.

Hilmo, O., Rocha, L., Holien, H., and Gauslaa, Y. (2011). Establishment success of lichen diaspores in young and old boreal rainforest: a comparision between *Lobaria pulmonaria* and *L. scrobiculata*. *The Lichenologist 43*(3), 241-255.

Ignatenko, R. V., and Tarasova, V. N. (2017). The population structure of the lichen *Lobaria pulmonaria* in the middle boreal forests depends on the time-since-disturbance. *Folia Cryptogamica Estonica, 54*, 83-94.

Jüriado, I., and Liira, J. (2010). Threatened forest lichen-its past, present and future in Estonia. *Forestry Studies, 53*, 15-24.

Lõhmus, P., and Lõhmus, A. (2019). The potential of production forests for sustaining lichen diversity: a perspective on sustainable forest management. *Forests, 10*(12), 1063.

Knops, J. M. H., Nash, T. H., Boucher, V. L., and Schlesinger, W. H. (2007). Mineral cycling and epiphytic lichens: Implications at the ecosystem level. *The Lichenologist, 23*(3), 309-321.

Lücking, R., Rivas Plata, E., Chaves, J. L., Umaña, L., and Sipman, H. J. (2009). How many tropical lichens are there… really? *Bibliotheca Lichenologic, 100*, 399-418.

Mongkol Phaengphech, Pitakchai Fangkaew, Wetchasart Polyiam, Chaiwat Boonpeng, Santhi Watthana, and Kansri Boonpragob. (2019). Diel pattern of CO_2 gas exchange and chlorophyll fluorescence in the lichen *Parmotrema tinctorum* in Khao Yai National Park. *Thai Journal of Botany 11*(2), 169-181.

Mongkolsuk, P., Meesim, S., Poengsungnoen, V., and Kalb, K. (2012). The lichen family Physciaceae in Thailand--I. The genus *Pyxine*. *Phytotaxa, 59*, 32-54.

Nadyeina, O., Dymytrova, L., Naumovych, A., Postoyalkin, S., and Scheidegger, C. (2014). Distribution and dispersal ecology of *Lobaria pulmonaria* in the largest primeval beech forest of Europe. *Biodiversity and Conservation, 23*, 3241-3262.

Nash III, T. H. (2008). Nutrients, elemental accumulation, and mineral cycling. In T.H. Nash III, (Ed.) *Lichen biology* (pp. 234-251). Cambridge: Cambridge University Press.

Ohmura, Y., Kawachi, M., Kasai, F., Sugiura, H., Ohtara, K., Kon, Y., and Hamada, N. (2009). Morphology and chemistry of *Parmotrema tinctorum* (Parmeliaceae, lichenized

Ascomycota) transplanted into sites with different air pollution levels. *Bulletin of the National Museum of Nature and Science, Series B, 35*, 91-98.

Purvis, O. W. (2000). *Lichens*. London: Natural History Museum and Washington: Smithsonian Institution.

R Core Team, R. (2013). *R: A language and environment for statistical computing*. Retrieved from http://R-project.org.

Scheidegger, C., and Goward, T. (2002). Monitoring lichens for conservation: red lists and conservation action plans. *Monitoring with lichens-Monitoring lichens*, 163-181.

Scheidegger, C., and Werth, S. (2009). Conservation strategies for lichens: insights from population biology. *Fungal Biology Reviews, 23*(3), 55-66.

Swinscow, T. D. V., and Krog, H. (1988). *Macrolichens of East Africa*. London: British Museum (Natural History).

Tithiporn Pooprang (2001). *Systematic study of the lichens family Parmeliaceae in Thailand.* (Master's thesis). Ramkhamhaeng University, Bangkok.

Will-Wolf, S., Esseen, P. A., and Neitlich, P. (2002). Monitoring biodiversity and ecosystem function: Forests. In P. L. Nimis, C. Scheidegger, & P. A. Wolseley (Eds.), *Monitoring with lichens-Monitoring lichens* (pp. 203-222). Netherland: Kluwer Academic Publishers.

Wipawan Lekpet (2021). *Developing dye from the lichen Parmotrema tinctorum for sustainable utilization of biological resource*. (Master's thesis). Ramkhamhaeng University, Bangkok.

Wolseley, P. A., and Aguirre-Hudson, B. (1997). Fire in tropical dry forests: corticalous lichens as indicators of recent ecological changes in Thailand. *Journal of Biogeography, 24*, 345-362.

Wolseley, P. A., Aguirre-Hudson, B., and McCarthy, P. M. (2002). Catalogue of the lichens of Thailand. *Bulletin of the Natural History Museum, London (Botany), 32,* 13-59.

Yang, M. X., Devkota, S., Wang, L. S., and Scheidegger, C. (2021). Ethnolichenology-The use of lichens in the Himalayas and southwestern parts of China. *Diversity, 13,* 330. https://doi.org/10.3390/d13070330.

CHAPTER V
CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Species diversity of lichens in the DDF of KYNP

One hundred and seventy-five lichen species found in this study indicated a high diversity of lichen, at least three to four times higher than the other study from DDF that have been reported in Thailand. Although the studied areas were small forest patches, they had a unique property that could not be found in other forests in KYNP. As evidenced by several specific species of lichen and about 29 species newly recorded for the country, an undescribed species in the genus *Aptrootia* was found. This genus is also new to Thailand. The family with the highest species diversity was the family Graphidaceae, followed by the family Trypetheliaceae; these two families were the major group of lichens in tropical forests.

The bark's properties and textures played an important role in determining lichen diversity. *Vativa odorata* was the host species that housed the most lichen, with 86 species, followed by *Dipterocarpus obtusifolius* with 70 species. *Corallia brachiata* and *Gluta usitata* were two other important hosts that supported over 40 lichen species. These host plants were essential for promoting lichen diversity in the DDF.

Ecological aspect of lichens in the DDF of KYNP

The studies of ecological characteristics of lichens in DDF in KYNP focused on the lichen community. There were a variety of lichen groups; crustose lichens were the major community with 89 percent (155 species); other growth forms (foliose, squamulose, and byssoid) made up about 10 percent. The dominant lichen species was *Bacidia* sp. 1 (IV = 32.9), followed by *Maronina corallifera* (IV = 21.7). These lichens have well adapted to the DDF conditions and are likely to maintain the dominant pattern in their community. Many lichens were extremely rare (IV < 0.1) in the studied sites with fewer than 2-3 individuals, and they have not been reported elsewhere; they would be a great risk to threat and loss. Therefore, they were at very high risk of disappearing from areas such as those with the lichens *Celothelium aciculiferum* and *Pseudopyrenula endoxanthoides*. However, extremely rare lichen species in DDF that could be found in other forests probably had a wide habitat, such as *Myriotrema subconforme* and *Sarcographa labyrinthica* (IV < 0.1), these species were well adapted to different environments and posed no risk.

Lichen habitats and environmental indicators

This study reveals that lichen species could only have DDF as a habitat. On the contrary, what species could also grow in different forest types? The presence of lichens on various plant species may indicate the need for habitat acquisition. Based on the relationship analysis between lichens and their host plant characteristics, several lichen species could be statistically significant indicators of different bark habitats. Trees with rough barks could be found in many species, such as *Dipterocarpus obtusifolius*, and there were indicator lichens measured in *Bacidia* sp.1, where the smooth barks *Gluta usitata* and *Vatica odorata* are indicated by the lichens *Dyplolabia afzelii* and *Phaeographis brasiliensis*, respectively. Even if the characteristics of hosted bark could be used as an indicator for observing specific lichen species, it might not mean that lichen species would always be found on these plants. However, the proverbiality found on those lichens' preferred barks was more likely than other lichens, plant species, or environmental features.

Comparison of the lichen habitats of two dominant species of host

The two dominant species of lichen hosts (*Dipterocarpus obtusifolius* and *Gluta usitata*) were found to be important habitats that encourages lichen diversity, accounting for roughly half of the total diversity in this forest. Thirty-one lichen species could be found growing on both plant species. There were 23 species of lichen found only on *Dipterocarpus obtusifolius* and 32 species occurred only on *Gluta usitata*.

Environmental characteristics and important habitats

Plant size (age) has statistically significantly affected lichen diversity. The highest diversity of lichens was found on trees in the large size class (diameters > 10 cm in diameter) and declined in the smaller size classes. These trends were found in both tree species.

The location and height at which lichens grow had a statistically significant impact on lichen diversity. Most of which were observed at the tree base, while tree branches are recorded as another favorite habitat for lichen richness.

Bark pH and bark water-holding capacity influenced the lichen diversity. The CCA results show that bark pH has a strong correlation with lichen diversity, and the bark pH of *Gluta usitat*a was higher than that of *Dipterocarpus obtusifolius*, as was its water holding capacity.

Population structure of two foliose lichens

The population structure of lichen *Parmotrema tinctorum* and *Pyxine coccifera* were similar and had the medium-adult life stage as it's a major structure. The total number of individuals recorded is 484 individuals, estimated at 3,227 individuals per hectare for the earliest species, and 475 individuals, about 3,167 individuals per hectare for later species. It was concluded that the two foliose lichen species may be considered to have a small population size in the DDF of KYNP.

Two lichen populations depend on host species; the host that is suitable for maintaining a large population size of *Parmotrema tinctorum* is *Vatica odorata*, but *Gluta usitata* is suitable for *Pyxine coccifera*. Most *Parmotrema tinctorum* prefer tree branches, while *Pyxine coccifera* prefers tree trunks. It has been suggested that transplantation of lichen thalli to appropriate substrate and habitats could increase the population size of the two lichens.

Recommendations

Going up lichens for that area is truly specific to the DDF in order to understand the habitats that are the origins of each lichen species. This is the appropriate management to conserve diversity and the lichen community. Lichens in the DDF have a diverse range of habitats that have yet to be thoroughly explored. For example, lichens on the surface of rocks are mostly specific to this substrate. So, studying the diversity and community of lichens on rocks will be another interesting issue that should be carried out in order to fully fill the knowledge gap about the diversity of lichens in the DDF of Thailand.

A comparison of the diversity and distribution of lichens on dominant plants in DDF in KYNP provides clear information on the major habitats of lichens, although it is known that there are areas that have not been surveyed. Then, further study should be done with different plant species. Many species of lichen were discovered on the base twigs of *Vatica odorata*. As a result, if the study covers the entire stem, more lichen species, newly recorded or even undescribed species, should be discovered, adding to the data on lichen biodiversity (both species and habitats) in Thailand.

This is the first report on the lichen population in Thailand and Southeast Asia, and while it may be a good model, there are still flaws in data collection methods, data analysis, and a lichen species model.

This study has some weaknesses that should be addressed in order to obtain accurate information, such as identifying lichen species at the genus and species levels for comparison with another study area. So, the study of the taxonomy of lichens should be considered first. Then, the data collected by the lichen community can be used to sustain long-term environmental changes and plan for long-term experiments. So, this should be clearly set up at the beginning of data collection in order to obtain data that can be compared over a long period of time. This will benefit the assessment of the biological impact on lichen communities.

APPENDICES

APPENDIX A

LIST OF LICHEN SPECIES, IMPORTANT VALUES, AND PROBABILITY OF OCCURRENCE IN THE DDF OF KYNP

Table 1A List of epiphytic lichens detected from the dry dipterocarp forest of Khao Yai National Park.

	Lichen species	Abbreviation (STAT-code)	Growth form	Detection probability (at each elevation; m.a.s.l.) 101-200	201-300	301-400	401-500	501-600	IV
1	*Amandinea efflorescens*	Ama_eff	Crd	0.2857	0.4552	0.547	0.2085	0.2085	17.76
2	*Amandinea* sp.1	Ama_sp1	Crd				0.1043		0.14
3	*Amandinea* sp.2	Ama_sp2	Crd					0.1078	0.04
4	*Anisomeridium ambiguum**	Anis_am	Crp		0.0949	0.0887	0.1043	0.1078	0.55
5	*Ani. leucochlorum**	Anis_leu	Crp			0.0887			0.21
6	*Ani. polycarpum**	Anis_pol	Crp		0.0949				0.07
7	*Aptrootia* sp.1*	Aptr_sp1	Crp		0.1644			0.1078	0.49
8	*Arthonia collectiva**	Arth_col	Cri	0.1010			0.2554	0.1078	1.01
9	*Art. inconspicua**	Arth_inc	Cri			0.0887			0.10
10	*Art. radiata**	Arth_rad	Cri		0.0949				0.04
11	*Art. ravida**	Arth_rav	Cri	0.1010					0.08
12	*Art. subvelata**	Arth_sub	Cri	0.2259	0.2847	0.2348	0.2554	0.1525	2.08
13	*Arthonia* sp.1	Arth_sp1	Cri					0.1078	0.07
14	*Arthonia* sp.2	Arth_sp2	Cri					0.1078	0.12
15	*Arthothelium dispersum**	Arto_dis	Cri					0.1078	0.23
16	*Arl. ruanum*	Arto_rau	Cri			0.0887			0.15
17	*Astrothelium ambiguum*	Asth_amb	Crp					0.1525	0.14
18	*Ast. deforme*	Asth_def	Crp			0.0887			0.08
19	*Ast. meristosporum*	Asth_mer	Crp			0.0887	0.1043		0.23
20	*Ast. neogalbineum**	Asth_neo	Crp			0.0887	0.1474	0.1525	0.36
21	*Ast. nigratum*	Astr_nig	Crp			0.0887			0.04
22	*Ast. porosum*	Asth_por	Crp		0.0949	0.0887		0.1078	0.17
23	*Ast. rufescens*	Asth_ruf	Crp			0.1537	0.1806		0.38
24	*Ast. subdiscretum*	Asth_sub	Crp	0.1010	0.1342	0.1537	0.1043		0.83
25	*Astrothelium* sp.1	Asth_sp1	Crp					0.1078	0.10
26	*Astrothelium* sp.2	Asth_sp2	Crp			0.0887	0.1043		0.11
27	*Astrothelium* sp.3	Asth_sp3	Crp				0.1043		0.08
28	*Astrothelium* sp.4	Asth_sp4	Crp				0.1043		0.08
29	*Astrothelium* sp.5	Asth_sp5	Crp			0.0887			0.08
30	*Astrothelium* sp.6	Asth_sp6	Crp		0.1644	0.0887	0.1043		0.46
31	*Bacidia* sp.1	Baci_sp1	Crd	0.3642	0.5695	0.7209	0.5417	0.4313	32.92
32	*Bathelium albidoporum*	Bath_alb	Crp	0.1010					0.15
33	*Bat. madreporiforme*	Bath_mad	Crp	0.1750	0.1898	0.1255			0.90
34	*Bathelium* sp.1	Bath_sp1	Crp					0.1078	0.08
35	*Bulbothrix queenslandica*	Bulb_que	Fog	0.1010	0.3422	0.1255	0.2085	0.1868	3.19
36	*Candellariella sorediosa**	Cand_sor	Squ		0.0949	0.1255	0.1806	0.1525	0.75
37	*Celothelium aciculiferum*	Celo_aci	Crp		0.0949				0.06
38	*Chapsa indica*	Chap_ind	Crt	0.1010	0.1898	0.2348	0.1043	0.1868	1.56

Table 1A List of epiphytic lichens detected from the dry dipterocarp forest of Khao Yai National Park (Continued).

	Lichen species	Abbreviation (STAT-code)	Growth form	Detection probability (at each elevation; m.a.s.l.)					
				101-200	201-300	301-400	401-500	501-600	IV
39	*Chapsa* cf. *velata*	Chap_vel	Crt	0.1429	0.1342	0.1537		0.1078	0.79
40	*Chapsa* sp.1	Chap_sp1	Crt			0.1255	0.1043	0.1078	0.21
41	*Chapsa* sp.2	Chap_sp2	Crt					0.1078	0.04
42	*Chrysothrix xanthina*	Chry_xan	Cst	0.2020	0.2122	0.3549	0.4038	0.4575	7.22
43	*Coccocarpia adnata*	Cocc_adn	Fob			0.0887			0.20
44	*Coc. dissecta*	Cocc_dis	Fob	0.1010	0.1342	0.0887	0.1043		1.16
45	*Coc. erythroxyli*	Cocc_ery	Fob				0.1043		0.36
46	*Coc. palmicola*	Cocc_pal	Fob					0.1078	0.27
47	*Coenogonium geralense*	Coen_ger	Crd			0.0887			0.17
48	*Cratiria obscurior*	Crat_obs	Crd	0.3194	0.2325	0.4066	0.3759	0.305	8.69
49	*Cra. rutilans*	Crat_rut	Crd		0.0949				0.12
50	*Cratiria* sp.1	Crat_sp1	Crd			0.1255			0.11
51	*Crocynia* sp.1	Croc_sp1	Bys			0.0887			0.06
52	*Cruentotrema kurandense*	Crue_kur	Crt	0.1010					0.07
53	*Cryptothecia polymorpha**	Cryp_pol	Cri					0.1078	0.08
54	*Dictyomeridium amylosporum*	Dict_amy	Crp	0.1010	0.0949				0.15
55	*Dic. proponens*	Dict_pro	Crp		0.0949				0.10
56	*Diorygma junhuhnii*	Dior_jun	Crl	0.1010					0.06
57	*Dirinaria aegialita*	Diri_aeg	Fog	0.1429	0.2511	0.1537	0.1043		1.12
58	*Dir. picta*	Diri_pic	Fog	0.1750	0.2122	0.1775	0.1806	0.1868	2.04
59	*Dyplolabia afzelii*	Dypl_afz	Crl	0.1750	0.2122	0.2348	0.2331		1.51
60	*Fissurina* sp.1	Fiss_sp1	Crl	0.1010					0.22
61	*Gassicurtia* cf. *caririensis**	Gass_car	Crd				0.1043	0.1525	0.42
62	*Gassicurtia* sp.1	Gass_sp1	Cst	0.1010	0.3676	0.3968	0.5108	0.3235	9.85
63	*Glyphis scyphulifera*	Glyp_scy	Crl			0.1255	0.1043		0.48
64	*Graphis caesiella*	Grap_cae	Crl			0.0887			0.04
65	*Gra. copelandii**	Grap_cop	Crl		0.0949				0.14
66	*Gra. descissa**	Grap_des	Crl			0.0887		0.1078	0.21
67	*Gra. furcata*	Grap_fur	Crl	0.1010	0.1342	0.0887			0.30
68	*Graphis gloriosensis**	Grap_glo	Crl				0.1043	0.1525	0.18
69	*Gra. handelii*	Grap_han	Crl			0.0887			0.08
70	*Gra. immersella**	Grap_ime	Crl			0.0887			0.19
71	*Gra. immersicans**	Grap_ims	Crl	0.1429					0.28
72	*Gra. inspersoradians**	Grap_ins	Crl					0.1078	0.27
73	*Gra. intricata**	Grap_int	Crl			0.0887		0.1078	0.12
74	*Gra. lineola*	Grap_lin	Crl		0.0949				0.10
75	*Gra. nanodes*	Grap_nan	Crl	0.1010	0.0949	0.0887			0.65
76	*Gra. nuda*	Grap_nud	Crl			0.1537			0.21

Table 1A List of epiphytic lichens detected from the dry dipterocarp forest of Khao Yai National Park (Continued).

	Lichen species	Abbreviation (STAT-code)	Growth form	Detection probability (at each elevation; m.a.s.l.) 101-200	201-300	301-400	401-500	501-600	IV
77	*Gra. streblocarpa*	Grap_str	Crl	0.2259	0.3422	0.2174	0.1474	0.2853	3.59
78	*Graphis* sp.1	Grap_sp1	Crl				0.1043		0.04
79	*Graphis* sp.2	Grap_sp2	Crl				0.1043		0.08
80	*Graphis* sp.3	Grap_sp3	Crl			0.0887			0.04
81	*Graphis* sp.4	Grap_sp4	Crl					0.1078	0.04
82	*Graphis* sp.5	Grap_sp5	Crl				0.1043		0.04
83	*Graphis* sp.6	Grap_sp6	Crl				0.1043		0.18
84	*Graphis* sp.7	Grap_sp7	Crl	0.1010	0.1342	0.2348	0.1043	0.1868	1.65
85	*Hafellia bahiana**	Hafe_bah	Crd				0.1043	0.1078	0.08
86	*Haf. subnexa**	Hafe_sub	Crd		0.0949				0.04
87	*Lecanora achroa*	Leca_ach	Crd	0.1429	0.0949	0.0887			0.44
88	*Lec. phaeocardia*	Leca_pha	Crd				0.1043		0.14
89	*Lecanora* sp.1	Leca_sp1	Crd		0.0949	0.0887			0.15
90	*Lepraria* sp.1	Lepr_sp1	Cst		0.0949	0.2662	0.3901	0.305	14.98
91	*Marcelaria benguelensis*	Marc_ben	Crp	0.3350	0.3001	0.2806	0.2758	0.2157	3.63
92	*Maronea* sp.1	Maro_sp1	Crd				0.1043	0.1078	0.19
93	*Maronina corallifera*	Marro_col	Crd	0.3350	0.4245	0.5324	0.6676	0.6559	21.69
94	*Mycomicrothelia subfallens*	Myco_sub	Crp	0.1010				0.1078	0.04
95	*Mycoporum lacteum**	Myco_lac	Crp				0.1043		0.04
96	*Myriotrema subconforme*	Myri_sub	Crt		0.0949				0.08
97	*Nigrovothelium bullatum*	Nigr_bul	Crp	0.1010		0.0887	0.1043		0.28
98	*Nig. tropicum*	Nigr_tro	Crp	0.1010		0.251	0.1806	0.1078	0.80
99	*Ocellularia arecae*	Ocel_are	Crt		0.1898		0.1043	0.1868	1.11
100	*Oce. exuta*	Ocel_exu	Crt		0.0949	0.1537	0.1806	0.1525	0.91
101	*Oce. massalongoi*	Ocel_mas	Crt			0.0887			0.15
102	*Oce. meiosperma*	Ocel_mei	Crt		0.0949				0.42
103	*Oce. punctulata*	Ocel_pun	Crt			0.1255		0.1078	0.42
104	*Ocellularia* sp.1	Ocel_sp1	Crt			0.1537			0.57
105	*Ocellularia* sp.2	Ocel_sp2	Crt	0.1010					0.12
106	*Ocellularia* sp.3	Ocel_sp3	Crt		0.0949				0.14
107	*Ocellularia* sp.4	Ocel_sp4	Crt		0.0949				0.18
108	*Ocellularia* sp.5	Ocel_sp5	Crt		0.0949			0.1078	0.23
109	*Ocellularia* sp.6	Ocel_sp6	Crt				0.1043		0.19
110	*Pallidogramme chrysenteron*	Pall_chy	Crl			0.1255	0.2554	0.2411	1.03
111	*Parmelinella wallichiana*	Par_wal	Fog		0.0949			0.1525	0.36
112	*Parmotrema merrillii*	Parm_mer	Fog			0.1255			0.19
113	*Par. overeemii*	Parm_ove	Fog		0.1342		0.1243	0.1078	0.44
114	*Par. praesorediosum*	Parm_pra	Fog		0.0949	0.2887	0.1043		0.12

Table 1A List of epiphytic lichens detected from the dry dipterocarp forest of Khao Yai National Park (Continued).

	Lichen species	Abbreviation (STAT-code)	Growth form	Detection probability (at each elevation; m.a.s.l.)					
				101-200	201-300	301-400	401-500	501-600	IV
115	*Par. tinctorum*	Parm_tin	Fog	0.1429	0.2685	0.1775	0.1806	0.2641	2.47
116	*Pertusaria amara*	Pert_ama	Cst		0.1342	0.1775		0.1868	0.68
117	*Per. tetrathalamia* var. *plicatula*	Pert_tet	Csp					0.1078	0.06
118	*Pertusaria* sp.1	Pert_sp1	Csp					0.1078	0.04
119	*Pertusaria* sp.2	Pert_sp2	Csp				0.1043	0.1078	0.07
120	*Phaeographis brasiliensis*	Phae_bra	Crl	0.2673	0.2847	0.3437	0.2949	0.1078	4.69
121	*Pha. caesioradians*	Phae_cae	Crl	0.1010	0.1342	0.1537	0.1043	0.1078	1.08
122	*Pha. intricans*	Phae_int	Crl			0.1984		0.1525	1.12
123	*Phaeographis* sp.1	Phae_sp1	Crl		0.0949		0.1043		0.17
124	*Phaeographis* sp.2	Phae_sp2	Crl		0.0949				0.04
125	*Phyllopsora corallina*	Phyl_cor	Sqa	0.1010					0.07
126	*Platygramme discurrens**	Plat_dis	Crl			0.0887			0.10
127	*Pla. pudica*	Plat_pud	Crl		0.0949	0.0887	0.1806	0.1525	0.41
128	*Platygramme* sp.1	Plat_sp1	Crl					0.1078	0.13
129	*Polymeridium quinqueseptatum*	Poly_qui	Crp		0.0949	0.251	0.1806	0.1868	2.17
130	*Pol. subcinereum**	Poly_sub	Crp			0.1255	0.1806	0.1257	0.55
131	*Porina eminentior*	Pori_emi	Crp	0.1010	0.1342				0.42
132	*Pseudopyrenula endoxanthoides*	Pseu_end	Crp			0.0887			0.04
133	*Pyrenula anomala*	Pyre_ann	Crp	0.1010			0.1043		0.51
134	*Pyxine coccifera*	Pyxi_coc	Fog		0.2685		0.1043	0.1525	1.07
135	*Ramboldia russula*	Ramb_rus	Crd				0.1043		0.04
136	*Relicina intertexta*	Reli_int	Fog		0.1644	0.0887	0.1474	0.1078	1.21
137	*Rel. malaccensis*	Reli_mal	Fog	0.1429	0.2122	0.1537	0.1474	0.1868	3.09
138	*Rel. palmata*	Reli_pal	Fog				0.1043	0.1525	0.14
139	*Rel. rahengensis*	Reli_rah	Fog	0.2673	0.2685	0.1775	0.2331	0.2853	3.81
140	*Sarcographa glyphisa*	Sarc_gly	Crl					0.1078	0.14
141	*Sar. labyrinthica*	Sarc_lab	Crl			0.0887			0.04
142	*Stigmatochroma glaucothecum*	Stig_gla	Crd	0.1010		0.0887			0.15
143	*Stirtonia macrocarpa**	Stir_mac	Cri					0.1078	0.39
144	*Stirtonia* sp.1	Stir_sp1	Cri			0.0887			0.07
145	*Thelenella* sp.1	Thel_sp1	Crp		0.0949				0.08
146	*Thelotrema albo-olivaceum**	Thel_alb	Crt	0.1010	0.0949			0.1078	0.15
147	*The. lepadermersum*	Thel_lep	Crt		0.0949				0.41
148	*The. monosporum*	Thel_mon	Crt		0.3797	0.2348		0.3235	4.98

Table 1A List of epiphytic lichens detected from the dry dipterocarp forest of Khao Yai National Park (Continued).

	Lichen species	Abbreviation (STAT-code)	Growth form	Detection probability (at each elevation; m.a.s.l.)					
				101-200	201-300	301-400	401-500	501-600	IV
149	*The. platysporum*	Thel_pla	Crt		0.1342				0.12
150	*Thelotrema* sp.1	Thel_sp1	Crt		0.0949				0.28
151	*Thelotrema* sp.2	Thel_sp2	Crt		0.0949				0.21
152	*Thelotrema* sp.3	Thel_sp3	Crt		0.0949	0.0887			0.21
153	*Thelotrema* sp.4	Thel_sp4	Crt			0.0887			0.04
154	*Trypethelium eluteriae*	Tryp_elu	Crp		0.0949	0.1255			0.34
155	*Trypethelium* sp.1	Tryp_sp1	Crp		0.1342	0.0887	0.1043	0.1078	0.66
156	*Trypethelium* sp.2	Tryp_sp2	Crp		0.0949		0.1043		0.08
157	*Trypethelium* sp.3	Tryp_sp3	Crp			0.0887			0.12
158	*Vainionora flavidorufa*	Vain_fla	Crd	0.1750	0.1898	0.1255	0.1806	0.1525	1.06
159	*Viridothelium virens*	Viri_vir	Crp			0.0887			0.12
160	*Vir. leptoseptatum**	Viri_lep	Crp		0.0949				0.08
161	Unidentified crustose sp.1	Unc_sp1	Cst	0.1010	0.1342				0.14
162	Unidentified crustose sp.2	Unc_sp2	Cst				0.1043		0.04
163	Unidentified crustose sp.3	Unc_sp3	Cst	0.1429					0.15
164	Unidentified crustose sp.4	Unc_sp4	Cst					0.1078	0.14
165	Unidentified crustose sp.5	Unc_sp5	Cst	0.1010					0.12
166	Unidentified crustose sp.6	Unc_sp6	Cst	0.1010					0.49
167	Unidentified crustose sp.7	Unc_sp7	Cst		0.1644				0.68
168	Unidentified crustose sp.8	Unc_sp8	Cst		0.1644	0.0887		0.1078	0.58
169	Unidentified crustose sp.9	Unc_sp9	Cst		0.0949	0.2510	0.1043	0.3050	2.65
170	Unidentified crustose sp.10	Unc_sp10	Cst			0.0887		0.1525	0.33
171	Unidentified crustose sp.11	Unc_sp11	Cst		0.1342				0.08
172	Unidentified crustose sp.12	Unc_sp12	Cst					0.1078	0.20
173	Unidentified crustose sp.13	Unc_sp13	Cst	0.1010	0.0949				0.33
174	Unidentified crustose sp.14	Unc_sp14	Cst			0.0887			0.15
175	Unidentified crustose sp.15	Unc_sp15	Cst					0.1078	0.04
	Total number of species			50	80	87	70	78	

Note. * lichen species recorded as a first time to Thailand (according to Buaruang et al., 2017), and Fog = foliose with green algae, Fob = foliose with blue-green algae, Bys = byssoid, Squ = squamulose, Crd = crustose with disc-like apothecia, Crl = crustose with lirellate apothecia, Cri = crustose with irregular apothecia, Crp = crustose with perithecia, Crt = crustose thelotremoid graphidaceae, and Cst = sterile crustose.

APPENDIX B

LIST OF EPIPHYTIC LICHEN SPECIES, ABUNDANCE, AND OCCURANCE ON THEIR HOST SPECIES IN THE DDF OF KYNP

Table 1B Host trees species and number of the sampling trees in the DDF of KYNP.

	Host species	Abbreviation	No of sampling tree in each plot at different elevations															no. of trees	bark pH	bark WC
			101 - 200			201 - 300			301 - 400			401 - 500			501 - 600				(average)	
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15			
1	*Acronychia pedunculata*	Acp							1						2			3	3.8	97.7
2	*Corallia brachiata*	Cob	1		1	2	2		3	5			1	4				19	3.4	81.4
3	*Cratoxylum formosum*	Crf								1								1	5.0	88.8
4	*Dalbergia chochinchinensis*	Dac		3					1									4	3.6	90.9
5	*Dellinia obovata*	Del	1															1	3.3	112
6	*Diospyros* sp. A	Dis			2													2	4.3	71.1
7	*Dipterocarpus intricatus*	Dii													21			21	3.3	58.9
8	*Dipterocarpus obtusifolius*	Dio	23	13	13	29	20	19	32	32	30	27	19	23		19	23	322	3.3	65.4
9	*Garcinia cowa*	Gac									1							1	3.5	175
10	*Gluta usitata*	Glu	4	2	3	7	1	8				1	1	3				30	3.4	101
11	*Irvingia malayana*	Irm	4	3	2	1		2		1	3							16	3.6	92.6
12	*Lagerstroemia* sp. A	Las		1														1	4.8	138
13	*Melodorum fruticosum*	Mef		1	2					1			1					5	3.8	79.2
14	*Memecylon scutellatum*	Mes															1	1	3.5	84.6
15	*Neonauclea purpurea*	Nep									1							1	4.0	50
16	*Ochna intergerima*	Oci	1		1	2			1							2		7	3.9	90.6
17	*Parinari anamensis*	Paa		2				3	2				1					8	3.5	68.7
18	*Schima wallichii*	Scw														1		1	4.2	88.4
19	*Shorea roxbergii*	Shr				1	3											4	2.8	82.2
20	*Sindora siamensis*	Sis	1	4	3													8	3.3	47.9
21	*Syzygium antisepticum*	Sya				2	1							2			3	8	4.1	87.9
22	*Syzygium* sp. A	Sys				2	1		2			1				1	1	8	3.9	92.4
23	*Vatica odorata*	Vao	2	1	4		2	3	4	2	3	3	2	2		4	1	33	4.1	71.9
24	unknown A	una									1							1	3.6	93.1
25	unknown B	unb															1	1	3.7	63.2
26	unknown C	unc										1						1	4.4	67.4
27	unknown D (Ebenaceae)	Ebe															6	6	3.9	74.1
	No of tree in each plot		37	30	31	46	30	35	46	42	39	33	25	34	23	27	36	514		
	No of trees in each elevation			98			111			127			92			86				

Table 2B Host trees species and number of the lichen species collected from each tree species in the DDF of KYNP.

	Host species	Abbreviation	No of lichen species in each plot at different elevations															No. of lichen species
			101 - 200			201 - 300			301 - 400			401 - 500			501 - 600			
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1	*Acronychia pedunculata*	Acp							6						no			6
2	*Corallia brachiata*	Cob	no		1	5	10		10	19			5	12				39
3	*Cratoxylum formosum*	Crf								2								2
4	*Dalbergia chochinchinensis*	Dac		6					11									14
5	*Dellinia obovata*	Del	2															2
6	*Diospyros* sp. A	Dis			5													4
7	*Dipterocarpus intricatus*	Dii													23			23
8	*Dipterocarpus obtusifolius*	Dio	15	10	5	19	11	19	21	23	22	17	21	18		29	27	70
9	*Garcinia cowa*	Gac									2							2
10	*Gluta usitata*	Glu	9	2	3	23	6	23				2	6	12				46
11	*Irvingia malayana*	Irm	4	1	no	1		4		3	10							20
12	*Lagerstroemia* sp. A	Las		no														0
13	*Melodorum fruticosum*	Mef		no	4					2			4					9
14	*Memecylon scutellatum*	Mes															no	0
15	*Neonauclea purpurea*	Nep									5							5
16	*Ochna intergerima*	Oci	1		1	4			3							5		12
17	*Parinari anamensis*	Paa		2				15	4				3					18
18	*Schima wallichii*	Scw														5		5
19	*Shorea roxbergii*	Shr				2	11											13
20	*Sindora siamensis*	Sis	no	7	6													11
21	*Syzygium antisepticum*	Sya				1	no							no			no	1
22	*Syzygium* sp. A	Sys				4	5		5			no				no	4	14
23	*Vatica odorata*	Vao	1	5	10		13	18	20	10	18	24	9	15		22	6	86
24	unknown A	una									2							2
25	unknown B	unb															2	2
26	unknown C	unc										1						1
27	unknown D (Ebenaceae)	Ebe															17	17
Total no of lichen species in each plot			28	22	27	44	36	47	54	39	44	40	44	38	23	44	48	175
Total no of lichen species in each plot				50			80			87			70			78		

Table 3B Species list and number of thalli of epiphytic lichens on different host species occurring in the DDF of KYNP (Section 1).

	Lichens	Abbrevia-tions	Hosts												
			Acp	Cob	Crf	Dac	Del	Dis	Dii	Dio	Gac	Glu	Irm	Las	Mef
1	*Amandinea efflorescens*	Ama_eff		29		1			26	598		26	10		
2	*Amandinea* sp.1	Ama_sp1								4					
3	*Amandinea* sp.2	Ama_sp2							1						
4	*Anisomeridium ambiguum*	Anis_am								17					
5	*Ani. leucochlorum*	Anis_leu								7					
6	*Ani. polycarpum*	Anis_pol													
7	*Aptrootia* sp.1	Aptr_sp1								9					
8	*Arthonia collectiva*	Arth_col							3	18		8			
9	*Art. inconspicua*	Arth_inc													
10	*Art. radiata*	Arth_rad													
11	*Art. ravida*	Arth_rav										2			
12	*Art. subvelata*	Arth_sub		1		7			2	11		14			1
13	*Arthonia* sp.1	Arth_sp1								1					
14	*Arthonia* sp.2	Arth_sp2							3						
15	*Arthothelium dispersum*	Arto_dis													
16	*Arl. ruanum*	Arto_rua													
17	*Astrothelium ambiguum*	Asth_amb													
18	*Ast. deforme*	Asth_def													
19	*Ast. meristosporum*	Asth_mer													
20	*Ast. neogalbineum*	Asth_neo								6					
21	*Ast. nigratum*	Asth_nig													
22	*Ast. porosum*	Asth_por													
23	*Ast. rufescens*	Asth_ruf		1						1		1			2
24	*Ast. subdiscretum*	Asth_sub				1				15		2			
25	*Astrothelium* sp.1	Asth_sp1													
26	*Astrothelium* sp.2	Asth_sp2													
27	*Astrothelium* sp.3	Asth_sp3													
28	*Astrothelium* sp.4	Asth_sp4													
29	*Astrothelium* sp.5	Asth_sp5													
30	*Astrothelium* sp.6	Asth_sp6		3									3		
31	*Bacidia* sp.1	Baci_sp1							32	1225		1	1		
32	*Bathelium albidoporum*	Bathe_alb											5		
33	*Bat. madreporiforme*	Bath_mad		1								14			
34	*Bathelium* sp.1	Bath_sp1													
35	*Bulbothrix queenslandica*	Bulb_que		3						72		11			
36	*Candelariella sorediosa*	Cand_sor								30					
37	*Celothelium aciculiferum*	Celo_aci													
38	*Chapsa indica*	Chap_ind	1	9	7				5			1			
39	*Chapsa* cf. *velata*	Chap_sp1	1	1								7	8		
40	*Chapsa* sp.1	Chap_sp2		3											
41	*Chapsa* sp.2	Chap_sp3													
42	*Chrysothrix xanthina*	Chry_xan		32					27	169	1	19			5
43	*Coccocarpia adnata*	Cocc_adn													

Table 3B Species list and number of thalli of epiphytic lichens on different host species occurring in DDF of KYNP (Section 1) (Continued).

	Lichens	Abbrevia-tions	Hosts												
			Acp	Cob	Crf	Dac	Del	Dis	Dii	Dio	Gac	Glu	Irm	Las	Mef
44	*Coc. dissecta*	Cocc_dis										25	19		
45	*Coc. erythroxyli*	Cocc_ery													
46	*Coc. palmicola*	Cocc_pal							13						
47	*Coenogonium geralense*	Coen_ger		4											
48	*Cratiria obscurior*	Crat_obs		65					22	184			1		
49	*Cra. rutilans*	Crat_rut								3					
50	*Cratiria* sp.1	Crat_sp1		1											
51	*Crocynia* sp.1	Croc_sp1								2					
52	*Cruentotrema kurandense*	Crue_kur													
53	*Cryptothecia polymorpha*	Cryp_pol													
54	*Dictyomeridium amylosporum*	Dict_amy										3			
55	*Dic. proponens*	Dict_pro													
56	*Diorygma junhuhnii*	Dior_jun						1							
57	*Dirinaria aegialita*	Diri_aeg										4			
58	*Dir. picta*	Diri_pic										6	1		1
59	*Dyplolabia afzelii*	Dipl_afz	1	3		6						15			4
60	*Fissurina* sp.1	Fiss_sp1					6			5					
61	*Gassicurtia* cf. *caririensis*	Gass_car		3						11					
62	*Gassicurtia* sp.1	Gass_sp1		11					9	303		20			
63	*Glyphis scyphulifera*	Glyp_scy		8											
64	*Graphis caesiella*	Grap_cae													
65	*Gra. copelandii*	Grap_cop		4											
66	*Gra. descissa*	Grap_des								5					
67	*Gra. furcata*	Grap_fur	3										1		
68	*Graphis gloriosensis*	Grap_glo													
69	*Gra. handelii*	Grap_han								2					
70	*Gra. immersella*	Grap_ime													
71	*Gra. immersicans*	Grap_ims									8				
72	*Gra. inspersoradians*	Grap_ins													
73	*Gra. intricata*	Grap_int				1				2					
74	*Gra. lineola*	Grap_lin										3			
75	*Gra. nanodes*	Grap_nan								5		2			
76	*Gra.. nuda*	Grap_nud								5					
77	*Gra. streblocarpa*	Grap_str		1					3	50		16			
78	*Graphis* sp.1	Grap_sp1													
79	*Graphis* sp.2	Grap_sp2								2					
80	*Graphis* sp.3	Grap_sp3													
81	*Graphis* sp.4	Grap_sp4							1						
82	*Graphis* sp.5	Grap_sp5										1			
83	*Graphis* sp.6	Grap_sp6													
84	*Graphis* sp.7	Grap_sp7								55			1		
85	*Hafellia bahiana*	Hafe_bah										1			
86	*Haf. subnexa*	Hafe_sub													
87	*Lecanora achroa*	Leca_ach		5						5					
88	*Lec. phaeocardia*	Leca_pha													
89	*Lecanora* sp.1	Leca_sp1								3					

Table 3B Species list and number of thalli of epiphytic lichens on different host species occurring in DDF of KYNP (Section 1) (Continued).

	Lichens	Abbrevia-tions	Hosts												
			Acp	Cob	Crf	Dac	Del	Dis	Dii	Dio	Gac	Glu	Irm	Las	Mef
90	*Lepraria* sp.1	Lepr_sp1							15	596		5			
91	*Marcelaria benguelensis*	Marc_ben		8		8						19	5		3
92	*Maronea* sp.1	Maro_sp1													
93	*Maronina corallifera*	Marro_col		77	2	18			85	355		51	25		
94	*Mycomicrothelia subfallens*	Myco_sub													
95	*Mycoporum lacteum*	Myco_lac										1			
96	*Myriotrema subconforme*	Myri_sub													
97	*Nigrovothelium bullatum*	Nigr_bul													
98	*Nig. tropicum*	Nigr_tro		3		1							1		
99	*Ocellularia arecae*	Ocel_are								4		2	5		
100	*Oce. exuta*	Ocel_exu								20					
101	*Oce. massalongoi*	Ocel_mas								3					
102	*Oce. meiosperma*	Ocel_mei													
103	*Oce. punctulata*	Ocel_pun								16					
104	*Ocellularia* sp.1	Ocel_sp1								19					
105	*Ocellularia* sp.2	Ocel_sp2													
106	*Ocellularia* sp.3	Ocel_sp3													
107	*Ocellularia* sp.4	Ocel_sp4								5					
108	*Ocellularia* sp.5	Ocel_sp5							2						
109	*Ocellularia* sp.6	Ocel_sp6													6
110	*Pallidogramme chrysenteron*	Pall_chy		1						1		3			
111	*Parmelinella wallichiana*	Par_wal								14					
112	*Parmotrema merrillii*	Parm_mer													
113	*Par. overeemii*	Parm_ove								2		2			
114	*Par. praesorediosum*	Parm_pra		1						2					
115	*Par. tinctorum*	Parm_tin							2	22		14	3		
116	*Pertusaria amara*	Pert_ama								19					
117	*Per. tetrathalamia* var. *plicatula*	Pert_tet													
118	*Pertusaria* sp.1	Pert_sp1													
119	*Pertusaria* sp.2	Pert_sp2								2					
120	*Phaeographis brasiliensis*	Phae_bra	4	38		2				8		16			2
121	*Pha. caesioradians*	Phae_cae	3			6						13			
122	*Pha. intricans*	Phae_int		3											
123	*Phaeographis* sp.1	Phae_sp1										1			
124	*Phaeographis* sp.2	Phae_sp2										1			
125	*Phyllopsora corallina*	Phyl_cor					1								
126	*Platygramme discurrens*	Plat_dis		3											
127	*Pla. pudica*	Plat_pud		2											
128	*Platygramme* sp.1	Plat_sp1													
129	*Polymeridium quinqueseptatum*	Poly_qui		18		1			1			13			
130	*Pol. subcinereum*	Poly_sub		1						3					
131	*Porina eminentior*	Pori_emi						5				4			

Table 3B Species list and number of thalli of epiphytic lichens on different host species occurring in DDF of KYNP (Section 1) (Continued).

	Lichens	Abbrevia-tions	Hosts												
			Acp	Cob	Crf	Dac	Del	Dis	Dii	Dio	Gac	Glu	Irm	Las	Mef
132	*Pseudopyrenula endoxanthoides*	Pseu_end													
133	*Pyrenula anomala*	Pyre_ann						5							
134	*Pyxine coccifera*	Pyxi_coc								13		4			
135	*Ramboldia russula*	Ramb_rus								1					
136	*Relicina intertexta*	Reli_int		1						13					
137	*Rel. malaccensis*	Reli_mal							2	97			24		3
138	*Rel. palmata*	Reli_pal								4					
139	*Rel. rahengensis*	Reli_rah		6					2	94		16	8		
140	*Sarcographa glyphisa*	Sarc_gly													
141	*Sar. labyrinthica*	Sarc_lab													
142	*Stigmatochroma glaucothecum*	Stig_gla													
143	*Stirtonia macrocarpa*	Stir_mac													
144	*Stirtonia* sp.1	Stir_sp1													
145	*Thelenella* sp.1	Thel_sp1								2					
146	*Thelotrema albo-olivaceum*	Thel_alb		1											
147	*The. lepademersum*	Thel_lep		6					2			2			
148	*The. monosporum*	Thel_mon							3	132		1			
149	*The. platysporum*	Thel_pla								3					
150	*Thelotrema* sp.1	Thel_sp1								10					
151	*Thelotrema* sp.2	Thel_sp2								7					
152	*Thelotrema* sp.3	Thel_sp3								5					
153	*Thelotrema* sp.4	Thel_sp4								1					
154	*Try. eluteriae*	Tryp_elu											25		
155	*Trypethelium* sp.1	Tryp_sp1				2				1		2			
156	*Trypethelium* sp.2	Tryp_sp2				1									
157	*Trypethelium* sp.3	Tryp_sp3		3						25		1			
158	*Vainionora flavidorufa*	Vain_fla								1					
159	*Viridothelium virens*	Viri_vir													
160	*Vir. leptoseptatum*	Viri_lep								4					
161	Unidentified crustose sp.1	Unc_sp1								1					
162	Unidentified crustose sp.2	Unc_sp2								1					
163	Unidentified crustose sp.3	Unc_sp3								1					
164	Unidentified crustose sp.4	Unc_sp4								4					
165	Unidentified crustose sp.5	Unc_sp5								3					
166	Unidentified crustose sp.6	Unc_sp6		25											
167	Unidentified crustose sp.7	Unc_sp7								8			6		
168	Unidentified crustose sp.8	Unc_sp8		2								2			

Table 3B Species list and number of thalli of epiphytic lichens on different host species occurring in DDF of KYNP (Section 1) (Continued).

	Lichens	Abbrevia-tions	Hosts												
			Acp	Cob	Crf	Dac	Del	Dis	Dii	Dio	Gac	Glu	Irm	Las	Mef
169	Unidentified crustose sp.9	Unc_sp9								82		7	2		
170	Unidentified crustose sp.10	Unc_sp10						6							
171	Unidentified crustose sp.11	Unc_sp11		1											
172	Unidentified crustose sp.12	Unc_sp12						12							
173	Unidentified crustose sp.13	Unc_sp13													
174	Unidentified crustose sp.14	Unc_sp14													
175	Unidentified crustose sp.15	Unc_sp15								1					
	Total		6	39	2	14	2	4	23	70	2	46	20	0	9

Note. Acp = *Acronychia pedunculata*, Cob = *Corallia brachiata*, Crf = *Cratoxylum formosum*, Dac = *Dalbergia chochinchinensis*, Del = *Dellinia obovata*, Dis = *Diospyros* sp.A, Dii = *Dipterocarpus intricatus*, Dio = *Dipterocarpus obtusifolius*, Ebe = Ebenaceae, Gac = *Garcinia cowa*, Glu = *Gluta usitata*, Irm = *Irvingia malayana*, Las = *Lagerstroemia* sp.A, Mef = *Melodorum fruticosum*.

Table 4B Species list and number of thalli of epiphytic lichens on different host species occurring in the DDF of KYNP (Section 2).

	Lichens	Abbrevia-tions	Hosts													
			Mes	Nep	Oci	Paa	Scw	Shr	Sis	Sya	Sys	Vao	una	unb	unc	und
1	*Amandinea efflorescens*	Ama_eff				13			1							
2	*Amandinea* sp.1	Ama_sp1														
3	*Amandinea* sp.2	Ama_sp2														
4	*Anisomeridium ambiguum*	Anis_am												1		
5	*Ani. leucochlorum*	Anis_leu														
6	*Ani. polycarpum*	Anis_pol										1				
7	*Aptrootia* sp.1	Aptr_sp1						1								
8	*Arthonia collectiva*	Arth_col														
9	*Art. inconspicua*	Arth_inc										3				
10	*Art. radiata*	Arth_rad														
11	*Art. ravida*	Arth_rav									1					
12	*Art. subvelata*	Arth_sub			2	8					2	5				
13	*Arthonia* sp.1	Arth_sp1														
14	*Arthonia* sp.2	Arth_sp2														
15	*Arthothelium dispersum*	Arto_dis														7
16	*Arl. ruanum*	Arto_rua									5					
17	*Astrothelium ambiguum*	Asth_amb														2
18	*Ast. deforme*	Asth_def										2				
19	*Ast. meristosporum*	Asth_mer										5				
20	*Ast. neogalbineum*	Asth_neo										1				1
21	*Ast. nigratum*	Asth_nig										1				
22	*Ast. porosum*	Asth_por										4				
23	*Ast. rufescens*	Asth_ruf										3				
24	*Ast. subdiscretum*	Asth_sub										12				
25	*Astrothelium* sp.1	Asth_sp1										1				
26	*Astrothelium* sp.2	Asth_sp2										2				
27	*Astrothelium* sp.3	Asth_sp3										2				
28	*Astrothelium* sp.4	Asth_sp4										4				
29	*Astrothelium* sp.5	Asth_sp5										2				
30	*Astrothelium* sp.6	Asth_sp6										7				
31	*Bacidia* sp.1	Baci_sp1			1											
32	*Bathelium albidoporum*	Bathe_alb														
33	*Bat. madreporiforme*	Bath_mad										1				
34	*Bathelium* sp.1	Bath_sp1										2				
35	*Bulbothrix queenslandica*	Bulb_que				25		13			1	10				
36	*Candelariella sorediosa*	Cand_sor														
37	*Celothelium aciculiferum*	Celo_aci										2				
38	*Chapsa indica*	Chap_ind		2	12	1					2	5				
39	*Chapsa* cf. *velata*	Chap_sp1									1	4				3
40	*Chapsa* sp.1	Chap_sp2										2				
41	*Chapsa* sp.2	Chap_sp3										1				
42	*Chrysothrix xanthina*	Chry_xan			3	2		8	1			7				15
43	*Coccocarpia adnata*	Cocc_adn										10				

Table 4B Species list and number of thalli of epiphytic lichens on different host species occurring in the DDF of KYNP (section 2) (Continued).

	Lichens	Abbrevia-tions	Hosts													
			Mes	Nep	Oci	Paa	Scw	Shr	Sis	Sya	Sys	Vao	una	unb	unc	und
44	*Coc. dissecta*	Cocc_dis										5				
45	*Coc. erythroxyli*	Cocc_ery													16	
46	*Coc. palmicola*	Cocc_pal														
47	*Coenogonium geralense*	Coen_ger														
48	*Cratiria obscurior*	Crat_obs				23						3				16
49	*Cra. rutilans*	Crat_rut														
50	*Cratiria* sp.1	Crat_sp1										1				
51	*Crocynia* sp.1	Croc_sp1														
52	*Cruentotrema kurandense*	Crue_kur										1				
53	*Cryptothecia polymorpha*	Cryp_pol										2				
54	*Dictyomeridium amylosporum*	Dict_amy														
55	*Dic. proponens*	Dict_pro										3				
56	*Diorygma junhuhnii*	Dior_jun														
57	*Dirinaria aegialita*	Diri_aeg			4			5			1	15				
58	*Dir. picta*	Diri_pic			4	10	20					34				
59	*Dyplolabia afzelii*	Dipl_afz										7				
60	*Fissurina* sp.1	Fiss_sp1														
61	*Gassicurtia* cf. *caririensis*	Gass_car														
62	*Gassicurtia* sp.1	Gass_sp1				11										
63	*Glyphis scyphulifera*	Glyp_scy										7				
64	*Graphis caesiella*	Grap_cae											1			
65	*Gra. copelandii*	Grap_cop														
66	*Gra. descissa*	Grap_des														
67	*Gra. furcata*	Grap_fur										4				
68	*Graphis gloriosensis*	Grap_glo										3				
69	*Gra. handelii*	Grap_han														
70	*Gra. immersella*	Grap_ime									6					
71	*Gra. immersicans*	Grap_ims														
72	*Gra. inspersoradians*	Grap_ins										13				
73	*Gra. intricata*	Grap_int														
74	*Gra. lineola*	Grap_lin														
75	*Gra. nanodes*	Grap_nan				20										
76	*Gra.. nuda*	Grap_nud														
77	*Gra. streblocarpa*	Grap_str			7				6		15	4				
78	*Graphis* sp.1	Grap_sp1										1				
79	*Graphis* sp.2	Grap_sp2														
80	*Graphis* sp.3	Grap_sp3										1				
81	*Graphis* sp.4	Grap_sp4														
82	*Graphis* sp.5	Grap_sp5														
83	*Graphis* sp.6	Grap_sp6										5				
84	*Graphis* sp.7	Grap_sp7				1										
85	*Hafellia bahiana*	Hafe_bah									1					
86	*Haf. subnexa*	Hafe_sub				1										
87	*Lecanora achroa*	Leca_ach							2							
88	*Lec. phaeocardia*	Leca_pha										4				
89	*Lecanora* sp.1	Leca_sp1														
90	*Lepraria* sp.1	Lepr_sp1						25								

Table 4B Species list and number of thalli of epiphytic lichens on different host species occurring in the DDF of KYNP (section 2) (Continued).

	Lichens	Abbrevia-tions	Hosts													
			Mes	Nep	Oci	Paa	Scw	Shr	Sis	Sya	Sys	Vao	una	unb	unc	und
91	*Marcelaria benguelensis*	Marc_ben				4		1	13		2	18				9
92	*Maronea* sp.1	Maro_sp1										2				4
93	*Maronina corallifera*	Marro_col		2	15	51	23	1	16		4	46				12
94	*Mycomicrothelia subfallens*	Myco_sub										1				
95	*Mycoporum lacteum*	Myco_lac														
96	*Myriotrema subconforme*	Myri_sub						1				1				
97	*Nigrovothelium bullatum*	Nigr_bul										8				
98	*Nig. tropicum*	Nigr_tro										12				1
99	*Ocellularia arecae*	Ocel_are				5	2	1				4				
100	*Oce. exuta*	Ocel_exu														
101	*Oce. massalongoi*	Ocel_mas														
102	*Oce. meiosperma*	Ocel_mei						20								
103	*Oce. punctulata*	Ocel_pun														
104	*Ocellularia* sp.1	Ocel_sp1														
105	*Ocellularia* sp.2	Ocel_sp2							3							
106	*Ocellularia* sp.3	Ocel_sp3										4				
107	*Ocellularia* sp.4	Ocel_sp4														
108	*Ocellularia* sp.5	Ocel_sp5										3				
109	*Ocellularia* sp.6	Ocel_sp6														
110	*Pallidogramme chrysenteron*	Pall_chy										16				6
111	*Parmelinella wallichiana*	Par_wal														
112	*Parmotrema merrillii*	Parm_mer			2							2				
113	*Par. overeemii*	Parm_ove				6						2				
114	*Par. praesorediosum*	Parm_pra														
115	*Par. tinctorum*	Parm_tin			2	3	10	1				33				
116	*Pertusaria amara*	Pert_ama														
117	*Per. tetrathalamia* var. *plicatula*	Pert_tet										1				
118	*Pertusaria* sp.1	Pert_sp1										1				
119	*Pertusaria* sp.2	Pert_sp2														
120	*Phaeographis brasiliensis*	Phae_bra		1		3						37	8			3
121	*Pha. caesioradians*	Phae_cae										7				1
122	*Pha. intricans*	Phae_int										33				1
123	*Phaeographis* sp.1	Phae_sp1														
124	*Phaeographis* sp.2	Phae_sp2														
125	*Phyllopsora corallina*	Phyl_cor														
126	*Platygramme discurrens*	Plat_dis														
127	*Pla. pudica*	Plat_pud										8				
128	*Platygramme* sp.1	Plat_sp1										3				2
129	*Polymeridium quinqueseptatum*	Poly_qui		6							5	4		8		3
130	*Pol. subcinereum*	Poly_sub					2					6				
131	*Porina eminentior*	Pori_emi														
132	*Pseudopyrenula endoxanthoides*	Pseu_end										1				
133	*Pyrenula anomala*	Pyre_ann										9				
134	*Pyxine coccifera*	Pyxi_coc						11				9				
135	*Ramboldia russula*	Ramb_rus														

Table 4B Species list and number of thalli of epiphytic lichens on different host species occurring in the DDF of KYNP (section 2) (Continued).

	Lichens	Abbrevia-tions	Hosts													
			Mes	Nep	Oci	Paa	Scw	Shr	Sis	Sya	Sys	Vao	una	unb	unc	und
136	*Relicina intertexta*	Reli_int										37				
137	*Rel. malaccensis*	Reli_mal							3			3				
138	*Rel. palmata*	Reli_pal														
139	*Rel. rahengensis*	Reli_rah							18			10				
140	*Sarcographa glyphisa*	Sarc_gly										4				
141	*Sar. labyrinthica*	Sarc_lab										1				
142	*Stigmatochroma glaucothecum*	Stig_gla							4			1				
143	*Stirtonia macrocarpa*	Stir_mac			18											
144	*Stirtonia* sp.1	Stir_sp1										1				
145	*Thelenella* sp.1	Thel_sp1														
146	*Thelotrema albo-olivaceum*	Thel_alb														
147	*The. lepademersum*	Thel_lep														
148	*The. monosporum*	Thel_mon										1				
149	*The. platysporum*	Thel_pla														
150	*Thelotrema* sp.1	Thel_sp1														
151	*Thelotrema* sp.2	Thel_sp2														
152	*Thelotrema* sp.3	Thel_sp3														
153	*Thelotrema* sp.4	Thel_sp4														
154	*Try. eluteriae*	Tryp_elu										5				2
155	*Trypethelium* sp.1	Tryp_sp1		6												
156	*Trypethelium* sp.2	Tryp_sp2														
157	*Trypethelium* sp.3	Tryp_sp3				1						1				
158	*Vainionora flavidorufa*	Vain_fla														
159	*Viridothelium virens*	Viri_vir										4				
160	*Vir. leptoseptatum*	Viri_lep														
161	Unidentified crustose sp.1	Unc_sp1														
162	Unidentified crustose sp.2	Unc_sp2										4				
163	Unidentified crustose sp.3	Unc_sp3														
164	Unidentified crustose sp.4	Unc_sp4														
165	Unidentified crustose sp.5	Unc_sp5														
166	Unidentified crustose sp.6	Unc_sp6														
167	Unidentified crustose sp.7	Unc_sp7								5						
168	Unidentified crustose sp.8	Unc_sp8						3				9				
169	Unidentified crustose sp.9	Unc_sp9			1							5				
170	Unidentified crustose sp.10	Unc_sp10														
171	Unidentified crustose sp.11	Unc_sp11										1				
172	Unidentified crustose sp.12	Unc_sp12														
173	Unidentified crustose sp.13	Unc_sp13									2					5
174	Unidentified crustose sp.14	Unc_sp14										5				
175	Unidentified crustose sp.15	Unc_sp15														
	Total		0	5	12	18	5	13	11	1	14	86	2	2	1	17

Note. Mes = *Memecylon scutellatum*, Nep = *Neonauclea purpurea*, Oci = *Ochna intergerima*, Paa = *Parinari anamensis*, Scw = *Schima wallichii*, Shr = *Shorea roxbergii*, Sis = *Sindora siamensis*, Sya = *Syzygium antisepticum*, Sys = *Syzygium* sp.A, Vao = *Vatica odorata*, una = unknown A, unb = unknown B, unc = unknown C, und = unknown D.

APPENDIX C

STATISTICAL ANALYSIS OF SPECIES COMPOSITION OF EPIPHYTIC LICHENS THAT OCCURRED IN THE DDF OF KYNP

Table 1C The axis summary statistics of three canonical axes.

	Axis 1	Axis 2	Axis 3
Eigenvalue	0.589	0.389	0.346
Variance in species data			
% of variance explained	1.1	0.7	0.7
Cumulative % explained	1.1	1.9	2.5
Pearson Correlation, Spp-Envt	0.837	0.74	0.721
Kendall (Rank) Correlation, Spp-Envt	0.547	0.38	0.424

Note. The total variance ("inertia") in the species data is 52.1914.

Table 2C Multiple regression results.

	Variable	Canonical Coefficients						S.Dev
		Standardized			Original Units			
		Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3	
1	DBH	-0.287	0.368	0.421	-0.056	0.071	0.082	5.15E+00
2	bark_sur	-0.568	-0.095	-0.103	-1.005	-0.168	-0.182	5.65E-01
3	bark_len	0.202	-0.046	0.102	0.342	-0.077	0.172	5.90E-01
4	bark_she	0.031	-0.247	0.583	0.104	-0.837	1.97	2.96E-01
5	bark_resin	0.123	0.407	-0.184	0.249	0.823	-0.373	4.94E-01
6	bark_pH	0.216	0.084	0.118	0.332	0.128	0.181	6.52E-01
7	bark_WC	0.105	-0.334	0.035	0.004	-0.011	0.001	2.92E+01
8	LAI	-0.046	0.063	-0.03	-0.06	0.082	-0.039	7.63E-01
9	Elevation	-0.181	-0.418	0.053	-0.001	-0.003	0	1.32E+02

Note. Regression of trees in lichen species space on nine environmental variables.

Table 3C The final score of host variables.

	Host *	WA Score (species score)			LC Scores (environmental score)			Totals
		Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3	
1	Acp_7_1	1.2734	-0.6605	0.0252	0.7753	-0.3974	-0.4513	13
2	Cob_4_1	-0.1912	0.8487	1.8261	0.8274	0.4626	0.4735	5
3	Cob_4_2	1.5158	-0.6187	0.2778	1.8436	-1.6620	0.3292	12
4	Cob_5_1	-0.7570	0.6105	1.4573	-0.7569	0.4245	0.9029	14
5	Cob_5_2	-0.4287	0.7900	-0.1318	-1.3182	0.3588	0.4010	5
6	Cob_7_1	1.5880	-1.0611	0.3898	1.6948	-0.6790	0.0918	16
7	Cob_7_2	1.6296	-0.5609	0.2592	0.8182	0.2740	0.9162	1
8	Cob_7_3	1.7105	-1.1093	0.0503	1.5015	-0.6630	0.1070	13
9	Cob_8_1	1.0049	-0.2121	-0.2247	1.3690	-0.2241	0.2512	6
10	Cob_8_2	1.2530	-0.2366	0.3077	1.3594	-0.4914	0.1801	9
11	Cob_8_3	1.2720	-1.1405	0.7224	1.2276	-0.3598	0.1426	18
12	Cob_8_4	1.1578	-0.7848	0.4614	1.4157	-0.3559	0.1030	17
13	Cob_8_5	1.5491	-0.4333	-0.3230	1.2829	-0.4496	-0.0792	6
14	Cob_11_1	0.4712	-0.3587	-0.2101	0.8278	-0.8922	0.6798	12
15	Cob_12_1	0.0534	-0.6178	-1.0716	0.6842	-0.9439	0.4172	5
16	Cob_12_2	-0.4541	-0.1229	0.7857	0.4595	-0.7180	0.5745	4
17	Cob_12_3	0.9251	-0.6036	0.4118	1.1246	-1.8210	-0.0916	5
18	Cob_12_4	-0.5569	-0.2497	-0.7267	0.9231	-1.2650	0.3888	5
19	Crf_8_1	0.5198	-1.8535	1.9318	1.1614	-1.5783	1.8231	7
20	Dac_2_1	0.9004	-0.2115	-0.2748	0.0934	0.0797	-0.4492	18
21	Dac_2_2	-0.1024	-0.5518	0.6996	0.0986	0.0700	-0.0301	7
22	Dac_7_1	0.9925	-0.3646	0.2454	1.1684	-0.6978	-0.2227	19
23	Del_1_1	-0.5463	-1.5254	-0.8203	-0.2175	-0.1261	-0.2598	6
24	Dii_13_5	-1.4511	2.6481	0.6115	-1.9854	-0.7888	-0.4899	2
25	Dii_13_6	-2.2596	-1.7091	-1.2069	-1.6869	-1.2351	-0.5872	5
26	Dii_13_8	-0.9901	-0.1614	-0.0710	-2.4498	-0.8679	2.6537	7
27	Dii_13_9	-0.7720	-0.2569	-0.3514	-1.7957	-0.7936	-0.4219	4
28	Dii_13_1	-2.7590	-2.2073	-0.8221	-1.9069	-1.0819	-0.3203	15
29	Dii_13_1	-0.5308	-0.3648	2.2064	-2.7296	0.0854	0.6218	2
30	Dii_13_1	-0.8468	-0.3825	-0.3659	-1.8059	-1.0157	-0.3821	5
31	Dii_13_1	1.1115	-1.1844	0.3081	-2.9078	0.5278	1.1294	1
32	Dii_13_1	-1.3551	0.4860	-0.4685	-2.4259	-0.0891	0.2208	1
33	Dio_1_2	-0.2977	0.0280	-0.4815	0.3917	0.1239	0.9430	2
34	Dio_1_4	-0.6205	-0.7038	-1.5919	0.4459	-0.0099	1.0018	1
35	Dio_1_12	-0.9593	-0.1778	3.7132	0.2959	0.1013	1.2113	2
36	Dio_1_17	-0.2737	-0.1110	1.2816	-0.2916	0.4021	1.6115	2
37	Dio_1_20	1.3124	-0.4859	0.4296	0.2712	-0.4044	1.0336	6
38	Dio_1_22	-0.2737	-0.1110	1.2816	-0.3254	0.4216	1.7120	4
39	Dio_1_23	-0.9953	-0.1586	-0.7018	-0.2785	0.6866	1.4220	1
40	Dio_2_1	-0.8786	0.1695	0.3212	-0.4577	0.5545	1.3955	9
41	Dio_2_9	-0.9593	-0.1778	3.7132	-1.3907	1.7857	2.5330	2
42	Dio_2_10	0.7192	0.1439	1.0427	-0.6853	0.9263	1.8320	2
43	Dio_3_4	-1.1335	2.9273	4.4727	-0.6680	1.1397	1.5457	3
44	Dio_3_5	-1.0633	0.5951	1.5775	-0.1492	0.0547	1.0897	2
45	Dio_4_1	-0.9951	-0.236	-0.5706	-0.6296	0.4475	0.2164	4
46	Dio_4_2	-1.4123	0.3620	-0.4088	-0.3151	0.3470	-0.1428	4
47	Dio_4_3	-1.1486	-0.0916	-0.9574	-0.8285	0.3117	-0.0405	8
48	Dio_4_4	-1.0634	0.5952	1.5775	-1.3796	0.5055	0.0416	1

Table 3C The final score of host variables (Continued).

	Host *	WA Score (species score)			LC Scores (environmental score)			Totals
		Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3	
49	Dio_4_6	-1.2232	0.2647	0.9254	-0.7688	-0.1477	-0.3955	9
50	Dio_4_8	-1.3551	0.4860	-0.4685	-0.9387	0.0271	-0.0826	7
51	Dio_4_11	-1.3551	0.4860	-0.4685	-0.8597	-0.0862	-0.4364	1
52	Dio_4_15	-1.0203	-0.0450	-0.5558	-0.6801	0.2184	0.0769	19
53	Dio_4_17	-1.3551	0.4860	-0.4685	-0.9504	1.1965	0.0335	10
54	Dio_4_18	-0.9744	-0.0191	-0.0967	-0.5742	-0.0074	-0.0334	7
55	Dio_4_20	-1.4932	0.6969	0.4604	-0.6298	0.4339	-0.0987	10
56	Dio_4_22	-1.4986	3.3042	0.7861	-0.7076	1.5093	0.0921	7
57	Dio_4_27	-0.9953	-0.1586	-0.7018	-1.3583	0.7437	0.5066	3
58	Dio_5_1	-0.7105	0.8755	0.0296	-0.6620	0.6708	0.1869	2
59	Dio_5_3	-1.3551	0.4860	-0.4685	-1.1013	0.5769	-0.2143	3
60	Dio_5_6	-0.7953	-0.7345	-1.1789	-0.3361	-0.5382	-0.5929	17
61	Dio_5_13	-1.3551	0.4860	-0.4685	-0.8864	0.1575	-0.2620	3
62	Dio_5_14	-1.1718	0.7527	-0.4811	-0.6435	1.1490	-0.5957	8
63	Dio_5_20	-1.3551	0.4860	-0.4685	-0.4867	-0.6654	-0.4996	8
64	Dio_6_2	-0.9773	-0.1682	1.5057	-0.0784	0.6417	0.4514	2
65	Dio_6_3	-1.0515	-0.2667	-0.7643	-0.8257	1.9296	0.1915	4
66	Dio_6_4	-1.3551	0.4860	-0.4685	-0.2319	-0.1560	-0.4045	6
67	Dio_6_5	-0.3502	0.3273	0.4631	-0.3627	0.0812	-0.2356	11
68	Dio_6_8	-0.9102	-0.0008	-0.6783	-0.3976	0.2354	-0.1974	8
69	Dio_6_10	-0.9593	-0.1778	3.7132	-0.1816	0.1366	0.0361	1
70	Dio_6_12	-0.9953	-0.1586	-0.7018	-0.7605	0.7642	0.2032	5
71	Dio_6_13	-0.9693	0.2517	-0.5136	-0.5330	0.4973	-0.0150	7
72	Dio_6_14	-0.8510	-0.1491	-0.3051	-0.1439	-0.0315	-0.3335	5
73	Dio_7_1	-0.9953	-0.1586	-0.7018	-0.5247	0.9113	-0.4970	3
74	Dio_7_2	-0.4624	0.2146	0.0957	-0.2794	-0.2106	-0.1622	7
75	Dio_7_3	-0.9792	-0.1373	-0.4121	-0.5665	0.3580	0.1604	15
76	Dio_7_4	-0.8150	3.4611	-0.1270	-0.4803	1.3475	-0.0439	7
77	Dio_7_5	-0.6672	1.8588	0.0634	-0.2714	1.0465	-0.0979	3
78	Dio_7_7	-0.9484	0.1296	-0.5924	-0.6711	0.5087	0.4610	7
79	Dio_7_13	-0.9953	-0.1586	-0.7018	-0.3501	0.8331	-0.7926	1
80	Dio_7_15	-0.3940	-0.0608	0.6515	-0.4807	-0.0299	-0.0577	11
81	Dio_7_18	-1.2804	0.3617	-0.3879	-1.0776	0.5232	0.3091	14
82	Dio_7_22	-1.2204	-0.5910	-0.9521	-0.7831	0.2663	0.1855	3
83	Dio_7_24	-0.7764	0.2820	0.3986	-1.0422	0.2322	0.0579	12
84	Dio_7_28	-0.9953	-0.1586	-0.7018	-0.2065	0.5682	-0.4309	5
85	Dio_8_1	-1.3551	0.4860	-0.4685	-0.5421	-0.1160	-0.3307	6
86	Dio_8_5	-1.0159	0.6905	-0.4031	-0.2774	0.0922	-0.7609	5
87	Dio_8_6	-1.1921	0.2608	0.3290	-0.5289	-0.1455	-0.4371	1
88	Dio_8_8	-0.9593	-0.1778	3.7132	-0.8502	0.0212	0.3171	10
89	Dio_8_9	-0.8430	-0.0868	-0.2347	-1.0336	0.1365	0.0165	7
90	Dio_8_10	-1.3111	0.4122	-0.0038	-1.1987	0.4556	0.3163	9
91	Dio_8_11	-0.3951	0.1207	-1.0235	-0.0563	0.3331	-0.6799	8
92	Dio_8_12	-0.9953	-0.1586	-0.7018	-0.7022	0.1331	-0.1602	5
93	Dio_8_18	0.0851	0.8580	-0.2868	-0.5682	-0.3225	-0.4070	11
94	Dio_8_20	-1.2204	-0.5910	-0.9521	-0.3840	0.5029	-0.5132	1
95	Dio_8_21	-1.3551	0.4860	-0.4685	-0.3197	-0.5246	-0.2900	1
96	Dio_8_22	-0.4468	0.0668	-0.3464	-0.3997	-0.6466	-0.5015	6
97	Dio_8_23	-1.0606	-0.2265	-0.0087	-0.5645	-0.4983	-0.2002	3
98	Dio_8_24	-0.4485	0.1055	0.3183	-0.8766	0.1708	0.1202	3

Table 3C The final score of host variables (Continued).

	Host *	WA Score (species score)			LC Scores (environmental score)			Totals
		Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3	
99	Dio_8_25	-0.9953	-0.1586	-0.7018	-0.6396	-0.2888	0.0690	2
100	Dio_8_26	-0.9953	-0.1586	-0.7018	-0.3166	-0.6161	-0.3737	4
101	Dio_8_27	-0.5675	0.0328	-0.8133	-0.5180	-0.3612	-0.2990	4
102	Dio_8_29	-0.9953	-0.1586	-0.7018	-0.2745	-0.5951	-0.2153	1
103	Dio_8_32	-0.4544	1.7325	-1.7327	-0.2678	0.6745	-0.5988	2
104	Dio_9_1	-0.1274	-0.0345	-0.3834	-0.1112	0.4505	-0.9103	3
105	Dio_9_3	-0.1398	0.2242	-0.9249	-0.6356	0.3911	-0.6452	4
106	Dio_9_5	0.1194	0.4784	0.2790	-0.0376	-0.2065	-0.9411	2
107	Dio_9_6	-0.9953	-0.1586	-0.7018	-0.4270	0.6503	-0.7099	2
108	Dio_9_7	-1.2896	-0.0844	-0.4657	-0.4727	-0.2955	-0.3851	4
109	Dio_9_10	0.1053	0.0250	-1.3058	-0.6227	-0.3485	-0.5557	16
110	Dio_9_11	-0.1398	0.2242	-0.9249	-0.5913	-0.3910	-0.5472	1
111	Dio_9_12	-0.1398	0.2242	-0.9249	-0.5721	-0.3927	-0.5897	1
112	Dio_9_14	-1.3551	0.4860	-0.4685	-1.3678	0.7023	0.7905	1
113	Dio_9_15	-0.1398	0.2242	-0.9249	-0.2724	-0.6881	-0.4421	1
114	Dio_9_17	-0.9621	-1.3890	-2.1810	-0.5581	-0.4340	-0.5845	3
115	Dio_9_20	-1.5839	-0.0101	-0.2297	-0.9982	0.2062	-0.0331	8
116	Dio_9_21	-0.9953	-0.1586	-0.7018	-0.6908	-0.1295	-0.5423	1
117	Dio_9_22	-1.1783	-0.3482	-1.3806	-0.6837	-0.2197	-0.6329	6
118	Dio_9_24	-1.2422	-0.2595	-0.4984	-0.5277	-0.7709	-0.8330	9
119	Dio_9_25	-0.9621	-1.3890	-2.1810	-0.5573	-0.5782	-0.7816	14
120	Dio_9_26	-0.9621	-1.3890	-2.1810	-0.6478	-0.4387	-0.8120	2
121	Dio_9_28	-1.1816	-0.6698	-0.2625	-0.5358	-0.7290	-0.7635	8
122	Dio_10_1	-1.1727	-0.2700	-1.2461	-0.6455	-0.3092	-0.7619	10
123	Dio_10_3	-0.9953	-0.1586	-0.7018	-0.7249	-1.3691	-0.6330	4
124	Dio_10_4	-0.2977	0.0280	-0.4815	-0.5095	-1.8380	-0.5786	2
125	Dio_10_1	-0.9953	-0.1586	-0.7018	-0.6348	0.0545	-0.9317	1
126	Dio_10_1	0.3412	1.5086	-0.1415	-0.5433	-0.2202	-0.8870	1
127	Dio_10_2	-0.2964	-1.3957	-2.0911	-0.5001	-0.7037	-1.0499	4
128	Dio_10_2	-0.0789	2.1609	-0.6245	-0.5822	-0.0050	-0.8515	7
129	Dio_10_2	-1.1608	-0.1897	-1.3196	-0.8438	0.5808	-0.5300	1
130	Dio_11_3	0.1622	-0.8759	-1.3463	-0.6372	-0.0532	-0.6668	2
131	Dio_11_4	-1.1708	-0.3623	-0.5261	-0.5108	-0.3746	-0.6899	6
132	Dio_11_6	-0.9802	-0.1386	-0.4302	-0.5555	-0.0336	-0.5068	4
133	Dio_11_7	-1.0780	-0.1742	-1.0107	-0.5441	0.0864	-0.5104	2
134	Dio_11_8	-0.3402	-0.4092	-0.4580	-0.4495	-0.2100	-0.6844	3
135	Dio_11_9	-0.0456	0.5230	-0.7768	-0.8817	0.5932	-0.0956	1
136	Dio_11_1	-0.9953	-0.1586	-0.7018	-0.5532	0.2120	-0.7199	2
137	Dio_11_1	-0.9593	-0.1778	3.7132	-0.4635	-0.1241	-0.2239	5
138	Dio_12_2	-0.9953	-0.1586	-0.7018	-0.3767	-0.7483	-0.9813	6
139	Dio_12_3	-0.9361	-0.2447	-0.8423	-0.5333	-0.1127	-0.8692	19
140	Dio_12_4	-0.9973	-0.1227	0.4426	-0.6108	-0.0193	-0.7796	5
141	Dio_12_5	-0.7909	-0.4560	-1.1873	-0.3509	-0.5506	-0.9013	11
142	Dio_12_7	-0.9328	-0.2495	-0.8501	-0.7004	-0.0434	-0.5653	18
143	Dio_12_8	-0.9953	-0.1586	-0.7018	-0.6419	-0.1563	-0.8588	8
144	Dio_12_9	-1.0065	0.1361	-1.3696	-0.7044	0.1344	-0.8177	7
145	Dio_12_1	-1.4568	0.4436	-1.8246	-0.8334	0.2189	-0.9449	1
146	Dio_12_1	-0.9953	-0.1586	-0.7018	-0.8094	-0.1087	-0.7084	11
147	Dio_12_1	-0.9953	-0.1586	-0.7018	-0.4828	0.0728	-0.8064	4
148	Dio_12_1	-0.2580	-0.8945	0.2035	-0.4715	-0.4469	-0.8342	3

Table 3C The final score of host variables (Continued).

	Host *	WA Score (species score)			LC Scores (environmental score)			Totals
		Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3	
149	Dio_12_1	-1.1921	0.2608	0.3290	-0.5044	-0.1491	-0.5837	1
150	Dio_14_2	-0.2104	-1.0513	-1.3886	-0.4342	-0.2942	-0.8438	9
151	Dio_14_3	-0.9773	-0.1682	1.5057	-0.8105	0.2749	-0.4231	2
152	Dio_14_6	-1.2927	0.3443	-0.4014	-1.0790	0.0878	-0.3237	12
153	Dio_14_7	-1.9497	-0.7558	0.9436	-1.3347	-0.2619	0.5240	15
154	Dio_14_9	-1.4965	0.5653	2.7879	-1.9125	0.6076	1.3922	13
155	Dio_14_1	-0.9493	0.1641	-0.5653	-0.8350	0.3281	-0.1021	11
156	Dio_14_1	-1.0860	0.3650	-0.0288	-1.2262	-0.6435	0.3467	4
157	Dio_14_1	-1.3061	0.0943	-0.6443	-0.9716	-0.7397	0.3664	11
158	Dio_14_1	-0.5463	-1.5254	-0.8203	-0.4473	-1.1552	-0.3118	5
159	Dio_14_1	0.1263	0.9611	-0.4945	-0.5981	0.2519	-0.4895	9
160	Dio_14_1	-1.1608	-0.1897	-1.3196	-1.4979	1.1429	0.9208	2
161	Dio_15_4	-0.1398	0.2242	-0.9249	-0.3507	-0.9741	-0.8099	3
162	Dio_15_6	-1.2087	0.2722	0.1944	-0.8836	0.1265	-0.3162	16
163	Dio_15_1	0.3412	1.5086	-0.1415	-0.5271	-1.4323	-0.5227	1
164	Dio_15_1	-0.9953	-0.1586	-0.7018	-0.5942	0.2435	-0.6390	3
165	Dio_15_1	-0.3876	-0.0026	-0.3662	-0.3040	-0.4987	-0.7628	21
166	Dio_15_1	-0.0797	-1.1853	-2.0492	-0.6547	-0.3433	-0.9509	2
167	Dio_15_1	-1.3012	0.0552	-0.6619	-0.9574	-0.0797	-0.6269	5
168	Dio_15_1	-1.1189	0.0391	-0.9130	-0.6526	0.0275	-0.3648	6
169	Dio_15_1	-1.1296	-1.8223	-0.4629	-0.6534	-1.0569	-0.2542	18
170	Dio_15_2	-1.2376	0.2597	-0.7389	-0.2201	-0.0940	-0.2935	3
171	Dio_15_2	-0.1398	0.2242	-0.9249	0.0085	-0.4418	-0.7345	6
172	Dio_15_2	-1.1675	-0.1219	2.3989	-1.1820	-0.2336	0.6598	3
173	Dis_3_1	1.5652	-0.6094	-0.8913	1.0609	0.0185	-0.1099	10
174	Ebe_15_2	0.9714	-0.9216	0.0511	0.8283	-1.1527	-0.1756	8
175	Ebe_15_3	1.0308	-1.0441	0.1158	0.8701	-0.9899	0.0278	5
176	Ebe_15_5	1.1287	-0.6112	-0.5169	0.9424	-1.3213	-0.0982	4
177	Ebe_15_6	1.3614	-0.9472	-0.3042	1.0591	-1.0120	0.0370	15
178	Gac_9_1	3.5994	-3.5454	-1.6581	2.1211	-1.3803	-0.5730	8
179	Glu_1_1	1.2924	2.3736	0.6859	0.7644	0.2346	0.2060	3
180	Glu_1_2	0.9650	-0.6630	0.1449	0.8890	-0.5961	0.0402	6
181	Glu_1_3	0.2417	-0.2233	0.8396	0.5812	-0.0645	0.2190	6
182	Glu_3_1	0.8892	-0.3746	-0.0777	-0.5568	0.2990	0.2789	2
183	Glu_3_2	0.2970	-0.4617	1.5123	-0.6488	0.6965	-0.1222	6
184	Glu_4_2	1.0581	-1.5243	-0.4033	1.0771	-1.2682	-0.0946	15
185	Glu_4_3	1.2331	-0.1977	-0.0624	1.0665	0.2650	0.2289	15
186	Glu_4_4	-0.9593	-0.1778	3.7132	-1.4919	2.3998	2.6947	3
187	Glu_4_5	-0.3099	-0.2537	-0.3178	0.1514	1.8552	-0.0869	4
188	Glu_4_6	-0.3018	0.0197	0.4857	-0.2455	1.2306	0.7944	6
189	Glu_4_7	0.6755	0.2231	0.0182	0.3600	-0.4804	-0.3754	5
190	Glu_5_1	0.9522	-0.2479	0.1261	0.9037	-1.2443	-0.3954	6
191	Glu_6_1	0.8243	0.7042	0.1442	0.3125	0.8413	0.6692	5
192	Glu_6_3	0.9702	0.2618	-0.1036	0.6707	1.0034	0.3894	10
193	Glu_6_4	1.3240	-0.7275	0.3096	0.5414	-0.0029	0.5848	4
194	Glu_6_5	0.4158	0.6627	-0.4158	0.4429	0.3706	0.8001	17
195	Glu_6_6	-0.4300	-0.0132	0.3574	0.4153	0.0692	0.7887	5
196	Glu_6_7	0.5963	-0.7906	-0.6883	-1.7527	0.0946	0.5430	4
197	Glu_6_8	0.1702	1.4158	-0.2145	0.4439	1.6018	0.0029	15
198	Glu_11_1	0.8672	-1.0965	0.3165	0.1372	-0.8770	0.5539	10

Table 3C The final score of host variables (Continued).

	Host *	WA Score (species score)			LC Scores (environmental score)			Totals
		Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3	
199	Glu_12_1	0.9154	-0.8286	0.2332	0.2889	-0.3291	-0.3940	10
200	Glu_12_2	0.8725	-0.7618	0.0781	0.6629	-0.5974	-0.6548	12
201	Glu_12_3	-0.3211	-0.5484	-1.1444	0.2608	0.0237	-0.4017	11
202	Irm_1_4	0.5920	2.1930	1.5093	0.0814	-0.4226	2.2255	5
203	Irm_6_2	-0.4312	0.8723	0.1133	0.5708	0.2407	-0.3451	8
204	Irm_8_1	1.6104	-0.2376	-0.9706	0.7643	-1.2781	1.8133	1
205	Irm_9_1	0.4307	1.9810	1.3745	0.1879	1.3163	0.3818	20
206	Mef_3_2	1.2467	-0.1208	0.1489	-0.1120	-0.7369	1.7629	4
207	Mef_8_1	0.7370	-1.0721	0.6374	0.1488	-1.3606	1.6788	4
208	Mef_11_1	-0.2352	-2.2791	-0.8792	-0.5792	-1.5531	-0.4666	11
209	Nep_9_1	1.1877	-0.8446	1.8456	0.7206	0.1206	1.7417	15
210	Oci_3_1	0.5198	-1.8535	1.9318	-1.1854	-0.1689	-0.3646	6
211	Oci_4_1	-0.7450	-0.2713	2.9598	-1.2062	-1.1868	2.0547	8
212	Oci_4_2	0.6990	1.7620	0.8820	-1.4251	0.0103	-0.0745	7
213	Oci_7_1	0.3518	-1.9950	1.8970	-1.0235	-1.7245	1.3885	8
214	Paa_6_1	0.7607	0.5293	0.0479	0.1759	0.3001	-0.4830	19
215	Paa_6_2	-0.5416	0.7814	0.1497	-0.4082	0.0495	-0.1768	7
216	Paa_7_2	-0.1024	-0.5518	0.6996	-0.1747	-1.3079	1.5085	4
217	Paa_11_1	-0.9953	-0.1586	-0.7018	-0.7086	-1.0536	-0.2923	11
218	Shr_4_1	-1.4157	1.3063	1.1286	-0.9834	0.3658	0.2581	2
219	Sis_2_1	-0.9593	-0.1778	3.7132	-0.7343	0.1655	2.7529	6
220	Sis_2_4	0.9793	0.7501	0.0312	0.5930	0.5555	-0.0550	3
221	Sis_3_1	0.7380	0.9390	0.4264	-0.1747	0.7886	-0.0271	8
222	Sis_3_2	0.9251	-0.6036	0.4118	-0.1653	-0.1980	1.5522	7
223	Sis_3_3	-0.3996	0.1830	3.4580	-0.3173	-0.1015	1.5710	5
224	Sys_4_1	-0.1704	-0.8935	4.5283	0.8611	-1.5025	4.6349	12
225	Sys_5_1	-0.7452	-0.3248	3.1156	0.9996	-1.1675	1.8737	10
226	Sys_7_1	1.4791	-1.0360	-0.5022	0.9971	-0.4233	-0.2943	7
227	Sys_7_2	1.1417	-0.5914	0.3711	0.4198	-0.0328	0.1486	6
228	Sys_15_1	-0.4410	-5.3829	3.8076	-0.3775	-2.4008	1.4742	8
229	una_9_1	1.6296	-0.5609	0.2592	0.5943	-0.6698	-0.2388	8
230	unb_15_1	0.8808	-1.0660	0.2562	-0.4441	-1.2837	-0.4742	9
231	Vao_2_1	1.0549	1.4871	0.1462	1.4555	1.3822	0.1185	23
232	Vao_3_1	1.9961	-1.2638	0.0424	1.5336	0.4604	2.4195	1
233	Vao_3_2	1.8571	4.7110	-0.4205	1.1144	2.0642	-0.1322	13
234	Vao_3_3	1.3218	0.6870	-0.1415	1.4945	1.1216	-0.2480	6
235	Vao_5_1	0.1768	0.6825	-0.1164	0.4463	0.1802	-0.1605	20
236	Vao_5_2	-0.2414	1.4846	0.1099	-0.1016	2.2442	0.6788	14
237	Vao_6_1	0.6207	2.3787	0.1992	0.6376	1.7417	0.2622	30
238	Vao_6_2	1.0249	0.4466	-0.9760	1.2983	0.6155	-0.7164	15
239	Vao_6_3	1.3337	-0.0915	0.1175	0.8520	0.3712	-0.0038	19
240	Vao_7_1	1.2745	1.5120	0.8221	2.3218	1.6766	0.8704	10
241	Vao_7_3	1.3165	0.1973	0.0827	0.8438	-0.1594	-0.1497	16
242	Vao_8_1	0.4629	1.3770	-0.7499	0.2321	0.9339	-0.3228	11
243	Vao_8_2	1.1774	-0.3083	-0.4330	1.0247	0.0962	-0.7730	13
244	Vao_9_1	1.3169	-0.4653	-0.3161	0.8241	0.6072	-0.6951	16
245	Vao_9_2	1.4209	-0.5475	-0.6106	1.1453	0.0459	-0.6559	20
246	Vao_9_3	1.2730	0.1536	-0.5141	0.9656	0.3250	-0.7154	9
247	Vao_10_1	0.9827	0.1994	0.1676	0.7215	0.2864	-0.1572	10
248	Vao_10_2	0.6209	0.8181	-0.2993	0.3114	0.2831	-0.4980	22

Table 3C The final score of host variables (Continued).

	Host *	WA Score (species score)			LC Scores (environmental score)			Totals
		Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3	
249	Vao_10_3	0.6999	0.1193	-0.5166	0.4099	0.2543	-0.4429	32
250	Vao_11_1	0.9239	-0.0960	-0.1037	0.6473	-0.1315	-0.6810	9
251	Vao_11_2	0.4210	0.6496	-0.3498	0.4100	0.4735	-0.1459	14
252	Vao_12_1	0.3959	0.7220	-0.3665	0.0753	0.5071	-0.1374	22
253	Vao_12_2	1.5001	-0.8564	-0.8989	0.6824	-0.4260	-0.7447	17
254	Vao_14_1	0.8194	0.2231	-0.6428	0.7167	0.2619	-0.1884	23
255	Vao_14_2	-1.2005	1.0479	2.1484	-1.4622	1.3036	0.9557	8
256	Vao_14_3	0.3626	0.9141	0.3283	0.0999	0.5792	0.5616	17
257	Vao_14_4	0.7121	1.8339	0.4042	0.0332	0.5595	-0.1115	6
258	Vao_15_1	1.5186	0.3811	-0.1920	0.9177	-0.1969	-0.4437	7

Note. * Host names are presented in Table 1B, showing the final scores of 258 tree individuals.

Table 4C The final scores of lichen species variables.

	Lichens *	Axis 1	Axis 2	Axis 3	Raw data Totals
1	Ama_sp1	-0.9175	0.2154	-1.3910	4
2	Anis_am	-0.7409	-0.0740	-0.0933	13
3	Anis_pol	-0.6257	2.1596	-0.0746	7
4	Aptr_sp1	-1.7222	1.1684	1.2257	10
5	Arth_col	-0.4764	-0.4391	-0.9358	25
6	Arth_inc	1.2579	0.5209	-1.2170	3
7	Arth_rav	0.7572	-0.1033	0.3725	2
8	Arth_sub	-0.0786	-0.3443	0.4112	43
9	Arth_sp2	-2.1975	-1.9794	-0.9988	3
10	Arto_rau	1.2989	-0.6784	-0.5006	5
11	Asth_amb	1.0790	-1.8475	-0.2988	2
12	Asth_def	0.3023	1.4967	-0.5492	2
13	Asth_mer	0.9861	-0.1228	-0.3544	5
14	Asth_neo	-0.2276	-0.8709	-1.2293	8
15	Asth_por	0.8649	2.0009	0.1905	3
16	Asth_ruf	0.4213	-0.9613	0.5073	6
17	Asth_sub	0.1403	0.0538	-0.7558	30
18	Asth_sp2	0.4056	0.4537	-0.8471	1
19	Asth_sp3	0.9399	0.4590	-0.2674	2
20	Asth_sp4	0.5339	0.4075	-0.7535	4
21	Asth_sp5	1.4919	0.0736	-1.1157	2
22	Asth_sp6	0.2078	0.6906	0.3427	10
23	Bath_mad	0.7053	0.3759	0.0398	25
24	Bath_sp1	0.9336	0.4198	-0.3205	2
25	Bulb_que	-0.2285	0.0175	-0.2831	50
26	Cand_sor	-0.8911	-0.1184	-0.7757	28
27	Celo_aci	1.6912	0.9864	-1.2187	2
28	Chap_ind	0.3991	-1.1565	1.1356	40
29	Chap_sp1	1.5323	-0.7886	0.0249	10
30	Chap_sp2	1.3710	-0.3416	-0.2701	5
31	Cocc_dis	0.3132	1.7047	1.1015	24
32	Cocc_pal	-2.4841	-1.7340	-0.5448	13
33	Coen_ger	1.5992	-0.5767	0.2426	4
34	Crat_rut	-0.8859	0.3500	0.1309	3
35	Crat_sp1	1.0428	0.5688	-0.0610	2
36	Croc_sp1	-0.3488	1.0810	-1.0186	2
37	Cryp_pol	-1.9048	2.0893	1.6257	2
38	Dict_amy	0.9284	-0.8936	-0.1672	3
39	Dict_pro	1.6912	0.9864	-1.2187	3
40	Diri_aeg	0.9922	1.4810	0.4032	23
41	Diri_pic	0.6160	0.7750	-0.1966	51
42	Dypl_afz	0.6550	-0.0908	-0.3334	33
43	Fiss_sp1	-0.4194	-0.9518	-0.4822	11
44	Gass_car	-0.1683	-0.7555	-0.8504	11
45	Gass_sp1	-0.7640	-0.0990	-0.4125	239
46	Glyp_scy	1.6003	-0.9359	-0.3010	12
47	Grap_cop	-0.9860	0.6804	1.5360	4
48	Grap_des	-0.8112	-0.5585	-0.9452	1
49	Grap_fur	1.0196	0.0229	0.0306	8
50	Grap_glo	0.7424	0.3056	-0.4363	3

Table 4C The final scores of lichen species variables (Continued).

	Lichens *	Axis 1	Axis 2	Axis 3	Raw data Totals
51	Grap_han	-1.1419	0.2737	0.2045	2
52	Grap_ins	-0.4918	-3.8477	2.5077	6
53	Grap_ime	2.7631	-2.2122	-0.9747	8
54	Grap_ims	1.4898	3.1920	-0.2400	13
55	Grap_int	-0.0612	-0.7396	-1.2047	3
56	Grap_lin	1.4032	-2.0326	-0.1610	3
57	Grap_nan	-0.3513	0.3224	0.1891	7
58	Grap_nud	-0.5122	1.1598	0.0373	5
59	Grap_str	-0.7364	-0.1110	2.1829	84
60	Grap_sp2	-0.7956	-0.0310	-1.3261	2
61	Grap_sp6	0.0980	0.8127	-0.2337	5
62	Grap_sp7	-0.9151	0.1627	0.1934	37
63	Hafe_bah	-0.1566	-2.6266	1.7250	2
64	Leca_ach	-0.1468	0.5295	1.0735	12
65	Leca_pha	0.5339	0.4075	-0.7535	4
66	Leca_sp1	-0.7637	-0.2933	-0.1044	3
67	Leca_sp2	0.7725	0.8903	-0.0935	2
68	Marc_ben	0.7102	-0.3766	0.2421	85
69	Maro_sp1	1.0977	-0.9454	-0.2093	6
70	Myri_sub	0.1302	0.9282	0.9553	1
71	Nigr_bul	1.5265	1.3716	-0.0318	8
72	Nigr_tro	1.2362	-0.1482	-0.5706	18
73	Ocel_are	-0.4514	0.4617	0.1012	19
74	Ocel_exu	-0.9369	-0.3688	-0.5597	20
75	Ocel_mas	-0.8906	-0.3522	-1.0766	3
76	Ocel_pun	-1.6080	-0.5175	0.6103	16
77	Ocel_sp1	-0.7386	-0.8667	-1.2821	19
78	Ocel_sp2	-0.4134	-0.1627	2.6723	3
79	Ocel_sp3	0.8306	2.7914	0.4460	4
80	Ocel_sp4	-0.9217	2.4190	0.1566	5
81	Ocel_sp5	-1.1140	1.6523	0.3595	5
82	Ocel_sp6	-0.7545	-2.4892	-0.7938	6
83	Pall_chy	0.9185	-0.3830	-0.4858	26
84	Par_wal	-0.8623	1.0751	0.3179	1
85	Parm_mer	-0.1171	-1.5096	1.0537	4
86	Parm_ove	0.4913	0.5238	0.2570	4
87	Parm_pra	0.4766	-0.2222	-0.3535	2
88	Parm_tin	0.2619	0.9413	-0.0832	70
89	Pert_ama	-1.2159	-0.0063	-0.1350	18
90	Pert_sp2	-1.1183	0.2768	-1.0726	2
91	Phae_bra	1.2510	-0.3500	0.1523	116
92	Phae_cae	0.6865	-0.6636	-0.4451	30
93	Phae_int	1.7121	0.1972	0.1248	14
94	Plat_dis	2.2077	-1.0883	0.1562	3
95	Plat_pud	0.6486	0.1677	-0.3751	10
96	Plat_sp1	0.0980	0.8127	-0.2337	3
97	Poly_qui	0.8533	-0.7390	0.1811	59
98	Poly_sub	0.0613	0.1714	-0.2233	10
99	Pori_emi	1.3381	-0.3323	-0.1668	9
100	Pyre_ann	1.0650	-0.4283	-0.8811	14
101	Pyxi_coc	0.0855	1.6345	-0.3350	17

Table 4C The final scores of lichen species variables (Continued).

	Lichens *	Axis 1	Axis 2	Axis 3	Raw data Totals
102	Reli_int	-0.0350	0.3263	-0.4567	30
103	Reli_pal	-1.1683	-0.4802	-0.1028	4
104	Sarc_gly	0.9336	0.4198	-0.3205	4
105	Stig_gla	0.4228	1.5484	0.2593	5
106	Thel_sp1	-0.6943	0.7970	-0.0255	2
107	Thel_lep	-0.9107	0.0620	0.8661	10
108	Thel_mon	-1.0403	0.3032	-0.2754	120
109	Thel_pla	-0.5028	0.2949	-0.3574	3
110	Thel_sp2	-0.7480	-0.0119	-0.0569	7
111	Thel_sp3	-0.3640	-0.3375	-0.2758	2
112	Tryp_elu	1.0846	-0.1346	2.1274	8
113	Tryp_sp1	0.4835	0.3007	-0.0652	7
114	Vain_fla	-0.2101	-0.0693	0.7534	21
115	Viri_vir	0.3023	1.4967	-0.5492	4
116	Unc_sp1	-0.8163	0.3714	0.9274	4
117	Unc_sp4	-1.0877	0.5258	-0.1737	4
118	Unc_sp5	-0.8701	1.8265	2.6293	3
119	Unc_sp7	-0.4378	-0.8626	-1.0085	8
120	Unc_sp8	0.5467	1.1443	0.2376	13
121	Unc_sp9	-0.1074	0.1399	-0.5437	42
122	Unc_sp10	-0.7697	-0.1204	-0.7524	6
123	Unc_sp11	-0.9248	2.0859	0.9184	2
124	Unc_sp12	-0.8511	-1.6939	-0.4324	12
125	Unc_sp13	1.1217	-2.4081	7.8843	2

Note. * Lichen names as presented in Table 1A, showing the final scores of 125 lichen species (LC score).

Table 5C Correlation and biplot score of nine environmental variables with the ordination axes.

	Variables	Correlation*			Biplot Scores		
		Axis 1	Axis 2	Axis 3	Axis 1	Axis 2	Axis 3
1	DBH	-0.387	0.568	0.546	-0.339	0.449	0.418
2	bark_sur	-0.854	-0.183	-0.051	-0.748	-0.145	-0.039
3	bark_len	0.467	-0.17	0.09	0.409	-0.134	0.069
4	bark_she	-0.005	-0.236	0.786	-0.005	-0.187	0.603
5	bark_resin	0.116	0.452	-0.262	0.101	0.357	-0.201
6	bark_pH	0.461	0.147	0.224	0.404	0.116	0.172
7	bark_WC	0.303	-0.438	0.116	0.266	-0.346	0.089
8	LAI	0.023	0.107	-0.075	0.020	0.084	-0.058
9	Elevation	-0.229	-0.354	-0.296	-0.201	-0.280	-0.227

Note. * Correlation are "intaset correlation" of ter Braak (1986)

Table 6C Inter-set correlation for nine environmental variables.

	Variables	Axis 1	Axis 2	Axis 3
1	DBH	-0.324	0.420	0.394
2	bark_sur	-0.715	-0.136	-0.037
3	bark_len	0.391	-0.125	0.065
4	bark_she	-0.004	-0.175	0.567
5	bark_resin	0.097	0.334	-0.189
6	bark_pH	0.386	0.109	0.162
7	bark_WC	0.254	-0.324	0.083
8	LAI	0.019	0.079	-0.054
9	Elevation	-0.192	-0.262	-0.214

Table 7C Monte Carlo Test results. (Results for eigen values and species environmental variables and correlations based on 999 runs with randomized data).

Axis	Real data	Randomized data Monte Carlo Test (999 runs)			p
		Mean	Minimum	Maximum	
	Eigenvalue				
1	0.589	0.376	0.291	0.566	0.001***
2	0.389	0.324	0.254	0.454	
3	0.346	0.289	0.222	0.422	
	Spp-Envt. Corr.				
1	0.837	0.74	0.64	0.845	0.005**
2	0.74	0.707	0.624	0.801	
3	0.721	0.68	0.596	0.778	

APPENDIX D

LIST OF THE LICHEN AS INDICATOR SPECIES FOR THE ENVIRONMENTAL VARIABLES OF HOST IN THE DDF OF KYNP

Table 1D Indicator species analysis for bark surfaces of the phorophytes in the DDF of KYNP.

	Lichens	Abbreviation (Stat codes)	Statistically significant correlation	p-value
	Indicator species of rough bark			
1	*Bacidia* sp.1	Baci_sp1	0.415	0.001***
2	*Lepraria* sp.1	Lepr_sp1	0.260	0.001***
3	*Thelotrema monosporum*	Thel_mon	0.191	0.001***
4	*Gassicurtia* sp.1	Gass_sp1	0.156	0.026*
5	*Ocellularia exuta*	Ocel_exu	0.117	0.113
6	*Graphis* sp.7	Grap_sp7	0.116	0.081.
7	*Candellariella sorediosa*	Cand_sor	0.104	0.12
8	*Pertusaria amara*	Pert_ama	0.095	0.182
9	*Anisomeridium ambiguum*	Anis_am	0.084	0.335
10	*Aptrootia* sp.1	Aptr_sp1	0.079	0.427
11	*Relicina palmata*	Reli_pal	0.075	0.571
12	Unidentified crustose sp.1	Unc_sp1	0.075	0.593
13	Unidentified crustose sp.10	Unc_sp10	0.074	0.613
14	*Graphis nuda*	Grap_nud	0.070	0.607
15	*Pertusaria* sp.2	Pert_sp2	0.065	1
16	*Fissurina* sp.1	Fiss_sp1	0.065	0.892
17	*Thelotrema* sp.3	Thel_sp3	0.064	0.863
18	*Lecanora* sp.1	Leca_sp1	0.062	0.876
19	*Thelotrema platysporum*	Thel_pla	0.062	0.865
20	Unidentified crustose sp.9	Unc_sp9	0.061	0.691
21	*Ocellularia* sp.1	Ocel_sp1	0.061	0.649
22	*Graphis descissa*	Grap_des	0.056	0.747
23	*Parmelinella wallichiana*	Par_wal	0.053	0.649
24	*Ocellularia punctulata*	Ocel_pun	0.052	0.645
25	*Graphis nanodes*	Grap_nan	0.047	0.772
26	*Amandinea* sp.1	Ama_sp1	0.046	1
27	*Arthonia* sp.1	Arth_sp1	0.046	1
28	*Crocynia* sp.1	Croc_sp1	0.046	1
29	*Diorygma junhuhnii*	Dior_jun	0.046	1
30	*Graphis handelii*	Grap_han	0.046	1
31	*Graphis* sp.2	Grap_sp2	0.046	1
32	*Hafellia subnexa*	Hafe_sub	0.046	1
33	*Ocellularia meiosperma*	Ocel_mei	0.046	1
34	*Ocellularia* sp.4	Ocel_sp4	0.046	1
35	*Phyllopsora corallina*	Phyl_cor	0.046	1
36	*Ramboldia russula*	Ramb_rus	0.046	1
37	*Thelotrema* sp.1	Thel_sp1	0.046	1
38	*Thelotrema* sp.4	Thel_sp4	0.046	1

Table 1D Indicator species analysis for bark surfaces of the phorophytes in the DDF of KYNP (Continued).

	Lichens	Abbreviation (Stat codes)	Statistically significant correlation	p-value
39	*Viridothelium leptoseptatum*	Viri_lep	0.046	1
40	Unidentified crustose sp.2	Unc_sp2	0.046	1
41	Unidentified crustose sp.4	Unc_sp4	0.046	1
42	*Cratiria rutilans*	Crat_rut	0.046	1
43	*Ocellularia massalongoi*	Ocel_mas	0.046	1
44	*Ocellularia* sp.6	Ocel_sp6	0.046	1
45	Unidentified crustose sp.5	Unc_sp5	0.046	1
46	Unidentified crustose sp.12	Unc_sp12	0.046	1
47	*Anisomeridium leucochlorum*	Anis_leu	0.046	1
48	*Thelotrema* sp.2	Thel_sp2	0.046	1
	Indicator species of rough-scaly bark			
1	*Maronina corallifera*	Marro_col	0.243	0.002**
2	*Cratiria obscurior*	Crat_obs	0.181	0.004**
3	*Chapsa indica*	Chap_ind	0.167	0.011*
4	Unidentified crustose sp.7	Unc_sp7	0.133	0.044*
5	*Thelotrema lepademersum*	Thel_lep	0.124	0.038*
6	*Bathelium* sp.1	Bathe_alb	0.109	0.127
7	*Arthonia* sp.2	Arth_sp2	0.109	0.133
8	*Platygramme discurrens*	Plat_dis	0.109	0.113
9	*Stirtonia macrocarpa*	Stir_mac	0.109	0.129
10	*Amandinea* sp.2	Ama_sp2	0.109	0.119
11	*Coccocarpia palmicola*	Cocc_pal	0.109	0.114
12	*Coenogonium geralense*	Coen_ger	0.109	0.115
13	*Graphis copelandii*	Grap_cop	0.109	0.124
14	*Graphis* sp.4	Grap_sp4	0.109	0.133
15	*Thelotrema albo-olivaceum*	Thel_alb	0.109	0.109
16	Unidentified crustose sp.6	Unc_sp6	0.109	0.122
17	Unidentified crustose sp.15	Unc_sp15	0.109	0.126
18	*Chapsa* sp.2	Chap_sp2	0.103	0.085.
19	*Trypethelium* sp.1	Tryp_sp1	0.099	0.126
20	*Chrysothrix xanthina*	Chry_xan	0.091	0.279
21	*Lecanora achroa*	Leca_ach	0.078	0.475
22	*Parmotrema praesorediosum*	Parm_pra	0.077	0.649
	Indicator species of smooth bark			
1	*Marcelaria benguelensis*	Marc_ben	0.310	0.001***
2	*Dyplolabia afzelii*	Dypl_afz	0.278	0.001***
3	*Pallidogramme chrysenteron*	Pall_chy	0.225	0.001***
4	*Phaeographis caesioradians*	Phae_cae	0.2	0.001***
5	*Bathelium madreporiforme*	Bath_mad	0.195	0.001***
6	*Arthonia subvelata*	Arth_sub	0.166	0.011*
7	*Graphis gloriosensis*	Grap_glo	0.152	0.014*
8	*Nigrovothelium tropicum*	Nigr_tro	0.148	0.016*
9	*Dirinaria aegialita*	Diri_aeg	0.147	0.016*
10	*Astrothelium porosum*	Asth_por	0.144	0.008**

Table 1D Indicator species analysis for bark surfaces of the phorophytes in the DDF of KYNP (Continued).

	Lichens	Abbreviation (Stat codes)	Statistically significant correlation	p-value
11	*Parmotrema tinctorum*	Parm_tin	0.142	0.033*
12	*Dirinaria picta*	Diri_pic	0.131	0.031*
13	*Platygramme pudica*	Plat_pud	0.131	0.031*
14	*Nigrovothelium bullatum*	Nigr_bul	0.128	0.018*
15	*Astrothelium* sp.2	Asth_sp2	0.124	0.054.
16	*Hafellia bahiana*	Hafe_bah	0.124	0.047*
17	*Relicina intertexta*	Reli_int	0.124	0.037*
18	*Trypethelium eluteriae*	Tryp_elu	0.124	0.023*
19	*Platygramme* sp.1	Plat_sp1	0.122	0.049*
20	*Graphis furcata*	Grap_fur	0.121	0.031*
21	*Phaeographis intricans*	Phae_int	0.121	0.029*
22	*Dictyomeridium amylosporum*	Dict_amy	0.118	0.056.
23	*Maronea* sp.1	Maro_sp1	0.118	0.032*
24	*Graphis streblocarpa*	Grap_str	0.114	0.127
25	*Astrothelium subdiscretum*	Asth_sub	0.113	0.051.
26	*Astrothelium meristosporum*	Asth_mer	0.106	0.047*
27	*Stigmatochroma glaucothecum*	Stig_gla	0.106	0.057.
28	Unidentified crustose sp.8	Unc_sp8	0.105	0.082.
29	*Polymeridium subcinereum*	Poly_sub	0.102	0.153
30	*Graphis intricata*	Grap_ins	0.095	0.172
31	*Arthothelium ruanum*	Arto_rau	0.088	0.278
32	*Astrothelium* sp.4	Asth_sp4	0.088	0.28
33	*Lecanora phaeocardia*	Leca_pha	0.088	0.28
34	*Ocellularia* sp.2	Ocel_sp2	0.088	0.287
35	*Arthothelium dispersum*	Arto_dis	0.088	0.294
36	*Chapsa* sp.2	Chap_sp2	0.088	0.296
37	*Graphis lineola*	Grap_lin	0.088	0.298
38	*Pertusaria tetrathalamia var. plicatula*	Pert_tet	0.088	0.301
39	*Cruentotrema kurandense*	Crue_kur	0.088	0.302
40	*Mycoporum lacteum*	Myco_lac	0.088	0.304
41	*Graphis immersella*	Grap_ime	0.088	0.306
42	*Anisomeridium polycarpum*	Anis_pol	0.088	0.307
43	*Phaeographis* sp.1	Phae_sp1	0.088	0.307
44	*Graphis immersicans*	Grap_ims	0.088	0.308
45	*Trypethelium* sp.3	Tryp_sp3	0.088	0.308
46	*Arthonia ravida*	Arth_rav	0.088	0.309
47	*Coccocarpia adnata*	Cocc_adn	0.088	0.31
48	*Coccocarpia erythroxyli*	Cocc_ery	0.088	0.31
49	*Graphis* sp.3	Grap_sp3	0.088	0.31
50	*Cryptothecia polymorpha*	Cryp_pol	0.088	0.311
51	*Stirtonia* sp.1	Stir_sp1	0.088	0.313
52	*Astrothelium ambiguum*	Asth_amb	0.088	0.314
53	*Mycomicrothelia subfallens*	Myco_sub	0.088	0.314
54	*Arthonia inconspicua*	Arth_inc	0.088	0.317

Table 1D Indicator species analysis for bark surfaces of the phorophytes in the DDF of KYNP (Continued).

	Lichens	Abbreviation (Stat codes)	Statistically significant correlation	p-value
55	*Celothelium aciculiferum*	Celo_aci	0.088	0.317
56	*Dictyomeridium proponens*	Dict_pro	0.088	0.317
57	*Phaeographis* sp.2	Phae_sp2	0.088	0.318
58	*Arthonia radiata*	Arth_rad	0.088	0.319
59	*Astrothelium deforme*	Asth_def	0.088	0.32
60	*Viridothelium virens*	Viri_vir	0.088	0.32
61	Unidentified crustose sp.14	Unc_sp14	0.088	0.32
62	*Astrothelium nigratum*	Astr_nig	0.088	0.323
63	*Pseudopyrenula endoxanthoides*	Pseu_end	0.088	0.323
64	*Astrothelium* sp.5	Asth_sp5	0.088	0.326
65	*Sarcographa labyrinthica*	Sarc_lab	0.088	0.326
66	*Bathelium* sp.1	Bath_sp1	0.088	0.327
67	*Graphis* sp.5	Grap_sp5	0.088	0.327
68	*Sarcographa glyphisa*	Sarc_gly	0.088	0.327
69	*Astrothelium* sp.1	Asth_sp1	0.088	0.329
70	*Ocellularia* sp.3	Ocel_sp3	0.088	0.329
71	*Pertusaria* sp.1	Pert_sp1	0.088	0.329
72	*Graphis* sp.1	Grap_sp1	0.088	0.331
73	*Graphis* sp.6	Grap_sp6	0.088	0.332
74	*Astrothelium* sp.3	Asth_sp3	0.088	0.341
75	*Graphis caesiella*	Grap_cae	0.088	0.344
76	Unidentified crustose sp.3	Unc_sp3	0.084	0.303
77	*Astrothelium rufescens*	Asth_ruf	0.083	0.261
78	*Pyrenula anomala*	Pyre_ann	0.078	0.286
79	*Porina eminentior*	Pori_emi	0.075	0.229
80	*Myriotrema subconforme*	Myri_sub	0.067	0.572
81	*Trypethelium* sp.2	Tryp_sp2	0.067	0.51
82	*Relicina rahengensis*	Reli_rah	0.058	0.649
83	*Arthonia collectiva*	Arth_col	0.028	0.92
84	*Graphis intricata*	Grap_ins	0.095	0.172
	Indicator species of rough+rough-scaly bark			
1	*Amandinea efflorescens*	Ama_eff	0.175	0.009**
2	*Relicina malaccensis*	Reli_mal	0.07	0.524
3	*Gassicurtia* cf. *caririensis*	Gass_car	0.058	0.784
4	*Vainionora flavidorufa*	Vain_fla	0.055	0.688
	Indicator species of rough+smooth bark			
1	*Pyxine coccifera*	Pyxi_coc	0.083	0.299
2	*Bulbothrix queenslandica*	Bulb_que	0.078	0.426
3	*Parmotrema overeemii*	Parm_ove	0.063	0.582
4	*Astrothelium neogalbineum*	Asth_neo	0.061	0.521
5	*Graphis intricata*	Grap_int	0.047	1
6	Unidentified crustose sp.13	Unc_sp13	0.045	1
	Indicator species of rough-scaly+smooth bark			
1	*Phaeographis brasiliensis*	Phae_bra	0.21	0.001***

Table 1D Indicator species analysis for bark surfaces of the phorophytes in the DDF of KYNP (Continued).

	Lichens	Abbreviation (Stat codes)	Statistically significant	
			correlation	p-value
2	*Polymeridium quinqueseptatum*	Poly_qui	0.149	0.02*
3	*Astrothelium* sp.6	Asth_sp6	0.103	0.099.
4	*Chapsa* sp.1	Chap_sp1	0.101	0.103
5	*Coccocarpia dissecta*	Cocc_dis	0.082	0.224
6	*Glyphis scyphulifera*	Glyp_scy	0.077	0.205
7	*Cratiria* sp.1	Crat_sp1	0.07	0.271
8	*Parmotrema merrillii*	Parm_mer	0.07	0.275
9	Unidentified crustose sp.5	Unc_sp11	0.07	0.252
10	*Ocellularia* sp.6	Ocel_sp5	0.069	0.399
11	*Ocellularia arecae*	Ocel_are	0.04	0.868

Note. Significant codes: '***' 0.001, '**' 0.01, '*' 0.05, '.' 0.1, ' ' 1

Table 2D Indicator species analysis for tree diameter (DBH) in the DDF of KYNP.

	Lichens*	Abbreviation (Stat codes)	Statistically significant	
			correlation	p-value
	Indicator species of large size of trees (dbh > 10 cm)			
1	*Lepraria* sp.1	Lepr_sp1	0.193	0.007
2	*Graphis streblocarpa*	Grap_str	0.163	0.016
3	*Thelotrema monosporum*	Thel_mon	0.148	0.034
	Indicator species of medium size of trees (dbh between 5 and 10 cm)			
1	*Arthonia collectiva*	Arth_col	0.138	0.03
	Indicator species of small size of trees (dbh less than 5 cm)			
1	*Marcelaria benguelensis*	Marc_ben	0.183	0.003
2	*Cratiria obscurior*	Crat_obs	0.18	0.013
3	*Nigrovothelium tropicum*	Nigr_tro	0.176	0.008
4	*Pyrenula anomala*	Pyre_ann	0.169	0.015
5	*Chrysothrix xanthina*	Chry_xan	0.143	0.03
6	*Astrothelium neogalbineum*	Asth_neo	0.138	0.028
7	*Ocellularia* sp.1	Ocel_sp1	0.137	0.018
8	*Pallidogramme chrysenteron*	Pall_chy	0.126	0.049
9	*Coccocarpia dissecta*	Cocc_dis	0.107	0.039

Note. * Only species with statistical significantly are presented

Table 3D The lichens that for indicated for host species in the DDF of KYNP.

	Lichens*	Abbreviation (Stat codes)	Statistically significant correlation	p.value
	Indicator species of *Dipterocarpus obtusifolius*			
1	*Bacidia* sp.1	Baci_sp1	0.48	0.005
	Indicator species of unknow D (Ebenaceae)			
1	*Astrothelium ambiguum*	Asth_amb	0.392	0.030
2	*Maronea* sp.1	Maro_sp1	0.380	0.032
	Indicator species of *Gluta usitata*			
	Dyplolabia afzelii	Dypl_afz	0.372	0.045
	Indicator species of *Ochna intergerima*			
1	*Chapsa indica*	Chap_ind	0.452	0.007
2	*Stirtonia macrocarpa*	Stir_mac	0.392	0.041
	Indicator species of *Sysygium* sp.1			
1	*Graphis streblocarpa*	Grap_str	0.442	0.007
2	*Arthothelium ruanum*	Arto_rau	0.43	0.012
3	*Arthonia radiata*	Arth_rad	0.43	0.010
4	*Graphis immersella*	Grap_ime	0.43	0.018
5	Unidentified crustose sp.13	Unc_sp13	0.43	0.011
6	*Hafellia bahiana*	Hafe_bah	0.39	0.028
	Indicator species of *Corallia brachiate* and *Vatica odorata*			
1	*Phaeographis brasiliensis*	Phae_bra	0.41	0.017
	Indicator species of unknow D (Ebenaceae) and *Vatica odorata*			
1	*Pallidogramme chrysenteron*	Pall_chy	0.442	0.010

Note. * Only species with statistical significantly are presented

Table 4D The lichens that indicated for bark with lenticel in the DDF of KYNP.

	Lichens*	Abbreviation (Stat codes)	Statistically significant correlation	p.value
	Indicator species of bark with abundance lenticel			
1	*Phaeographis brasiliensis*	Phae_bra	0.386	0.001
2	*Cratiria obscurior*	Crat_obs	0.266	0.027
3	*Polymeridium quinqueseptatum*	Poly_qui	0.244	0.033
4	*Chapsa* sp.2	Chap_sp2	0.236	0.008
5	*Chapsa indica*	Chap_ind	0.21	0.045
	Indicator species of bark with sparsely lenticel			
1	*Marcelaria benguelemsis*	Marc_ben	0.399	0.002
2	*Pallidogramme chrysenteron*	Pall_chy	0.292	0.003
3	*Bathelium madreporiforme*	Bath_mad	0.252	0.015
4	*Phaeographis caesioradians*	Phae_cae	0.228	0.016
5	*Dyplolabia afzelii*	Dypl_afz	0.221	0.046
6	*Arthothelium dispersum*	Arto_dis	0.221	0.031
7	*Astrothelium ambiguum*	Asth_amb	0.221	0.022
8	*Thelotrema albo-olivaceum*	Thel_alb	0.221	0.033
9	*Trypethelium* sp.3	Tryp_sp3	0.221	0.037
10	*Stigmatochroma glaucothecum*	Stig_gla	0.22	0.034
11	*Maronea* sp.1	Maro_sp1	0.218	0.033
	Indicator species of bark with lenticel absent			
1	*Bacidia* sp.1	Baci_sp1	0.399	0.002
2	*Lepraria* sp.1	Lepr_sp1	0.255	0.036

Note. * Only species with statistical significantly are presented

APPENDIX E

ARTRIFICIAL KEY TO THE GROUPS AND GENERA OF EPIPHYTIC LICHENS THAT OCCURRED IN THE DDF OF KYNP

Synopsis key

1a Thallus lobate, attached to substrate by rhizine or lower surface or thallus minutely lobe with one end attachment or with loosely hyphae compact to form lobate .... **Group I**

(foliose/ squamulose/ byssoid)

1b Thallus powdery or compact but not formed lobe or squamules 2

2a Thallus fertile, ascomata present 3

2b Thallus fertile or sterile, if fertile, unorganized ascomata structure or ascomata irregular, or ascomata absent .... **Group II**

(crustose with unorganized ascomata, ascus usually globose and sterile crustose)

3a Ascomata close structure or perithecia .... **Group III**

(crustose with perithecia)

3b Ascomata open structure or apothecia 4

4a Ascomata disc like or irregular to globose emergence or immersed in thallus or perithecoid with wide opening of pore .... **Group IV**

(crustose with disc-like or perithecoid apothecia)

4b Ascomata lip like or elongate .... **Group V**

(crustose with lirellate apothecia)

Group I (foliose/ squamulose/ byssoid)

1a Thallus lobate, attached to substrate by rhizine or lower surface 2

1b Thallus minutely lobe with one end attachment (squamulose) or thallus forming lobate by loosely hyphae compaction (byssoid) 9

2a Photobiont cyanobacteria, bluish grey, lobe plicate, not gelatinous .. *Coccocarpia*

2b Photobiont green algae 3

3a Thallus with narrowly lobe, elongate, more than 3 time long as wide, usually 1-3 mm wide 4

3b Thallus with broadly lobe, flat, less than 2 time long as wide, usually up to or more than 0.5 mm wide 8

4a Thallus attached to substrate by lower surface, lobe compact, plicate, reticulate pseudocyphylle common at lob tip, whitish pruinose present at lobe apices.... .... *Dirinaria*

4b Thallus attached to substrate by rhizine, lobe not plicate 5

5a Thallus ciliate, bulbate cilia present 6

5b Thallus eciliate 7

6a Thallus yellowish, numerous lobulate present on upper surface, upper cortex K- (usnic acid) .... *Relicina* (*R. palmata*)

6b Thallus bluish-grey, numerous isidia present on upper surface, isidia tip with black dot, upper cortex K+ (atranorin) .... *Bulbothrix* (*B. queenslandica*)

7a Thallus yellowish, isidia present or absent, upper cortex K- (usnic acid) .... *Relicina*

7b Thallus greyish, red soredia present at lobe margin and on pseudocyphylae, shiny pruinose, upper cortex K+ yellow (atranorin) .... *Pyxine* (*P. coccifera*)

8a Thallus grey, rhizine dimorphic distributed to lobe tip, lobe usually less than 0.5 mm wide, cilia present at lobe axial, isidia present ... *Parmelinella* (*P. wallichiana*)

8b Thallus grey, rhizine simple, not present exceeded at 0.5 mm from lobe tip, lobe usually large, more than 0.5 mm wide .... *Parmotrema*

9a Thallus byssoid (interwoven or loosely hyphae of upper surface) .... *Crocynia*

9b Thallus squamulose, minute lobes with partly attached on substrates 10

10a Thallus yellowish (sulfur-yellow), marginal soredia common .... *Candelariella* (*C. sorediosum*)

10b Thallus pale brown, coralloid lobe presented, with brown hypothallus .... *Phyllosora* (*P. corallina*)

Group II (crustose with unorganised ascomata, ascus usually globose and sterile crustose)

1a Thallus with irregular ascomata 2

1b Thallus without ascomata (usually sterile).......... 5

2a Well developed ascomata missing (with ascigerous area) 3

2b Well developed ascomata (without ascigerous area) 4

3a With muriform ascospores, septa wavy .... *Cryptothecia*

3b With transversely septate ascospores, septa straight .... *Stirtonia*

4a With muriform ascospores .... *Arthothelium*

4b With transversely septate ascospores .... *Arthonia*

5a Thallus lacking a cortex, leprose to byssoid 6

5b Thallus with upper cortex, compact crustose 7

6a Thallus yellow (with dibenzofurans), leprose .... *Chrysothrix*

6b Thallus grey or different colours, not yellow, lacking dibenzofurans, leprose to byssoid .... *Lepraria*

7a Medulla red with red soredia .... *Gassicurtia*

7b Medulla white with white soredia .... *Pertusaria*

Group III (crustose with perithecia)

1a Ascospores brown 2

1b Ascospores hyaline 4

2a Paraphyses strongly branched and anastomosing 3

2b Paraphyses simple, spore 3 septa, diamond-shaped lumina, thick wall, ascomata black, aggregated in group .... *Pyrenula* (*P. anomala*)

3a Ascospore one-septate .... *Mycomicrothelia*

3b Ascospore muriform .... *Aptrootia*

4a Asci unitunicate .... *Porina*

4b Asci bitunicate 5

5a Paraphyses simple 6

5b Paraphysis consisting of strongly branched and anastomosing paraphyses 7

6a Ascomata stromatoid, ascospores muriform .... *Mycoporum*

6b Ascomata not in stroma, ascospores simple .... *Pertusaria*

7a Ascospores 1-septate .... *Anisomeridium*

7b Ascospores transversely septate to muriform 8

8a Ascospores filiform, transversely septate, eccentric ostiole .... *Celothelium* (*C. aciculiferum*)

8b Ascospores fusiform to ellipsoid, transversely septate to muriform 9

9a Thallus ecorticate, ascomata exposed, dark-pigmented 10

9b Thallus corticate, ascomata at least in part covered by thallus 11

10a Ascospore lumina angular, endospore thin .... *Polymeridium*

10b Ascospores with diamond-shaped lumina, endospore thick, hamathecium yellow .... *Pseudopyrenula* (*P. endoxanthoides*)

11a Ascospores with rectangular to oval lumina, transversely septate 12

11b Ascospores with diamond-shaped lumina, transversely septate to muriform 14

12a Ascomata in brown-black, sessile stromata, ascospores 3–9-septate, up to 40 µm long .... *Bathelium*

12b Ascomata in variously colored stromata or solitary, ascospores (5–)9–19-septate, over 40 µm long 13

13a Ascomata prominent pseudostromata, pigment often present .... *Trypethelium*

13b Ascomata rarely pseudostromata, pigment usually absent .... *Viridothelium*

14a Ascospores transversely septate 15

14b Ascospores muriform 16

15a Ascomata prominent to sessile, fully exposed and black, solitary, lacking pigments .... *Nigrovothelium*

15b Ascomata immersed to prominent or in immersed to sessile stromata, at least partly covered by thallus, often with yellow-orange pigment .... *Astrothelium*

16a Ascomata in prominent stromata filled with yellow-orange pigments .. *Bathelium*

16b Ascomata immersed to sessile or in immersed to sessile stromata, at least partly covered by thallus, with or without pigments 17

17a Ascomata in large, prominent to sessile stromata, red or yellow-orange warts .... *Marcelaria*

17b Ascomata immersed to prominent or in immersed to sessile stromata 18

18a Eccentric ostiole .... *Dictyomeridium*

18b Apical ostiole 19

19a Photobiont trebouxioid .... *Thelenella*

19b Photobiont trentepholoid .... *Astrothelium*

Group IV (crustose with disc-like or perithecoid apothecia)

1a Ascomata perithecoid apothecia 2

1b Ascomata disc like apothecia 6

2a Excipulum with periphysoids 3

2b Excipulum lacking periphysoids 4

3a Apothecia double margin, ascospores with thick outer wall .... *Thelotrema*

3b Apothecia without double margin, ascospores with thin outer wall .... *Chapsa*

4a Ascospores I– ascomata chroodiscoid, disc red pigmented .... *Cruentotrema*

4b Ascospores I+ violet-blue, ascomata ocellularioid or myriotremoid, disc without red pigmented 5

5a Ascomata pore > 0.2 mm wide, erumpent to emergent, mostly with columella .... *Ocellularia*

5b Apothecia pore < 0.1 mm wide, immersed, without columella .... *Myriotrema*

6a Thallus with trentepohlioid photobiont, spore transversely septate, hyaline ....*Bacidia*

6b Thallus with chlorococcoid photobiont 7

7a Ascomata black, ascospores brown 8

7b Ascomata another colours, ascospores hyaline 11

8a Ascospores with apical wall thickenings .... *Cratiria*

8b Ascospores without apical wall thickenings, thick- or thin-walled 9

9a Apothecial discs grey-pruinose .... *Stigmatochroma* (*S. glaucothecum*)

9b Apothecial discs epruinose or with whitish gray pruina 10

10a Medulla white or yellow, conidia filiform .... *Amandinea*

10b Medulla red (pigment), conidia bacilliform or fusiform .... *Gassicurtia*

11a Ascomata biatorine or lecideine, creamy, pink to orange, ascospores simple to multi-transversely septate 12

11b Ascomata lecanorine or cryptolecanorine, pale to brown, ascospore simple 13

12a Ascomata creamy yellowish to pink, ascospores with 1 to many transversely septate .... *Coenogonium*

12b Ascomata orange, ascospores simple .... *Ramboldia*

13a Ascomata brown, asci multi-spored (> 8 ascospores) .... *Maronea*

13b Ascomata lecanorine, pale to brown, asci with 1–8 ascospores 14

14a Hypothecium hyaline or pale yellowish 15

14b Hypothecium orange-brown to dark brown 16

15a Thallus and apothecia brownish, exciple cupulate, conidia bacilliform, usually containing the alectoronic acid (UV+ greenish white), isidia numerous .... *Maronina* (*M. corallifera*)

15b Thallus and apothecia not brownish, exciple annulate, conidia filiform, alectoronic acid absent .... *Lecanora*

16a Conidia filiform .... *Lecanora*

16b Conidia bacilliform .... *Vainionora* (*V. flavidorufa*)

Group V (crustose with lirellate apothecia)

1a Ascomata aggregate and embedded in stromata 2

1b Ascomata not aggregate and not embedded in stromata 3

2a Disc covered brown pruinose, ascospore hyaline, muriform .... *Glyphis*

2b Disc covered by white pruinose, ascospore brown, transversely septate or muriform .... *Sarcographa*

3a Exciple carbonized 4

3b Exciple uncarbonized, brownish or yellowish 6

4a Ascomata covered by white pruinose, lecanoric acid presence on exciple (C + red) .... *Dyplolabia* (*D. afzelii*)

4b Ascomata without white pruinose, if present, lacking lecanoric acid on exciple (C -) 5

5a. Ascospores hyaline, I + blue-violet .... *Graphis*

5b Ascospores brown, I + reddish brown .... *Platygramme*

6a Ascospores hyaline, I + blue or blue-violet 7

6b Ascospores brownish, I + reddish brown 8

7a Disc open, distinctly white pruinose ascospores > 50 µm long .... *Diorygma*

7b Disc closed or slight open, without white pruinose; ascospores < 50 µm long .... *Fissurina*

8a Labia striate, ascospores > 40 µm long .... *Pallidogramme*

8b Labia entire, ascospores < 40 µm long .... *Phaeographis*

APPENDIX F

PICTURES OF THALLUS AND ASCOMATA OF THE EPIPHYTIC LICHENS OCCURRED IN THE DDF OF KYNP

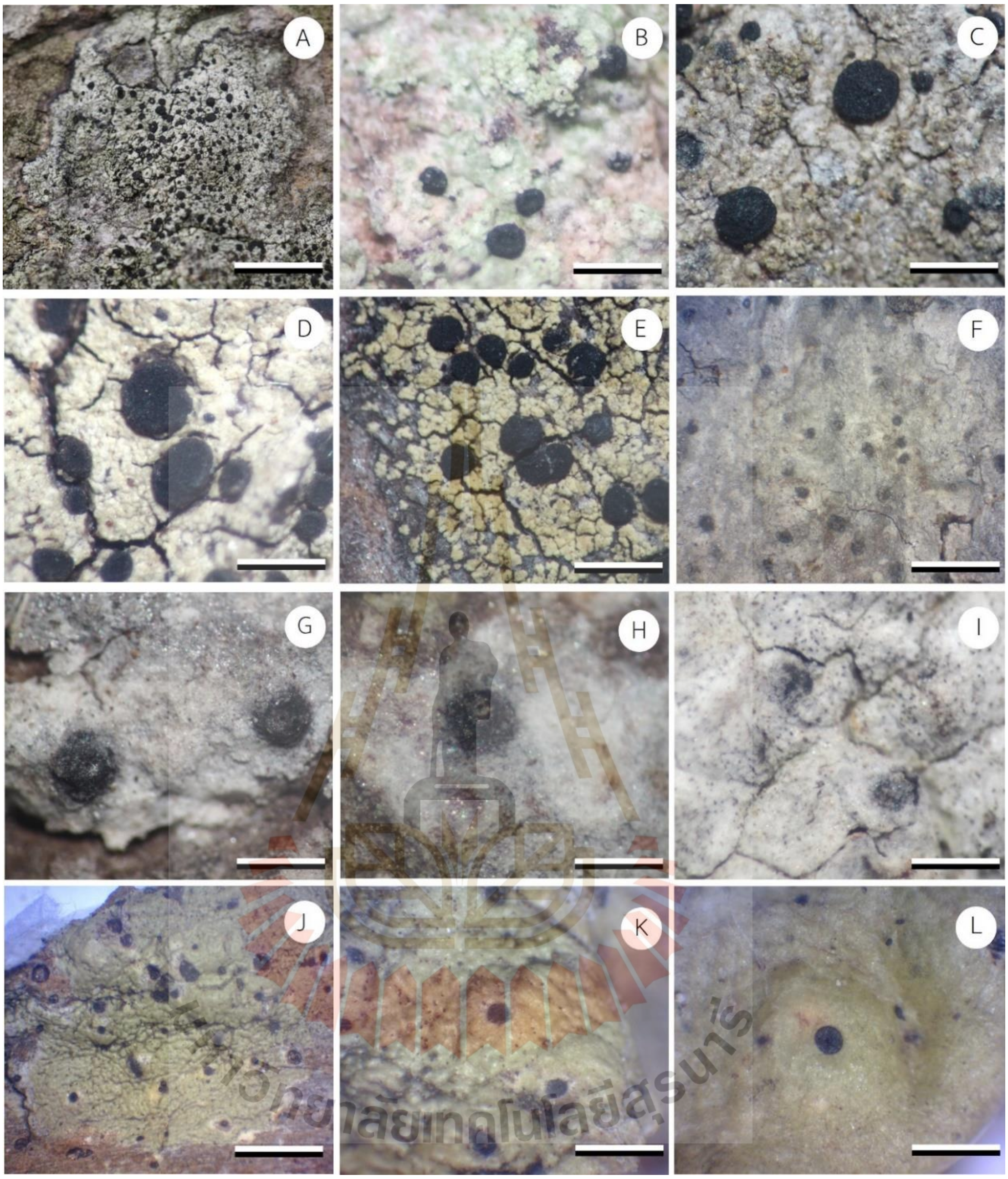

Figure 1F Habitus of *Amandinea, Anisomeridium* and *Aptrootia* (A-C: *Amandinea efflorescens*, D: *Amandinea* sp.1, E: *Amandinea* sp.2, F-G: *Anisomeridium ambiguum*, H: *Anisomeridium leucochlorum*, I: *Anisomeridium polycarpum*, J-L: *Aptrootia* sp.1, [Scale; A = 10 mm, B = 1 mm, C = 0.7 mm, D = 0.5 mm, E = 1 mm, F = 5 mm, G = 1 mm, H = 1.5 mm, I = 1 mm, J = 10 mm, K = 1 mm, L = 0.5 mm]).

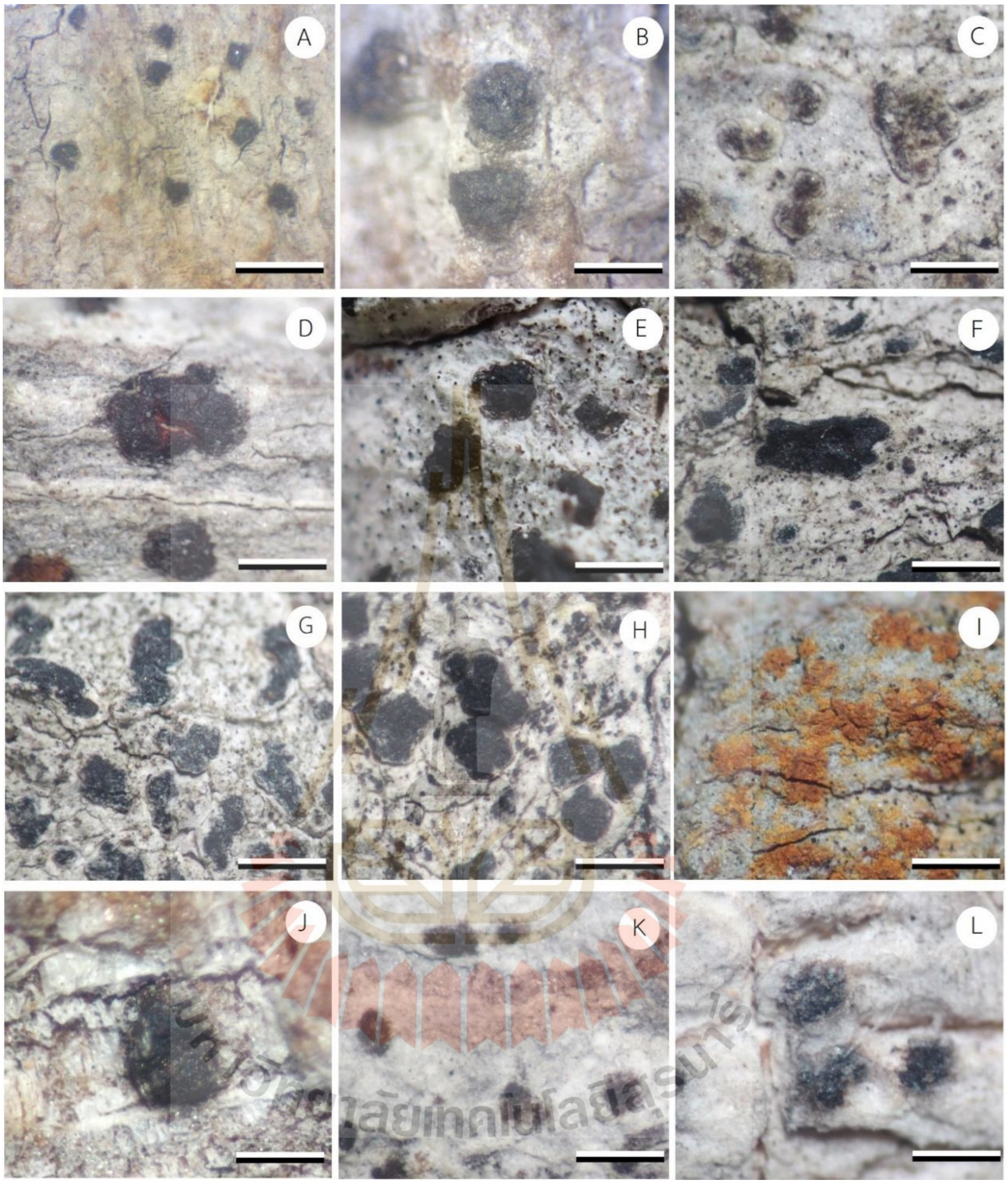

Figure 2F Habitus of *Arthonia* and *Arthothelium* (A-B: *Arthonia collectiva*, C: *Arthonia inconspicua,* D: *Arthonia propingue*, E: *Arthonia radiata,* F: *Arthonia ravida,* G: *Arthonia recedens*, H: *Arthonia subvelata*, I: *Arthonia* sp.1, J: *Arthonia* sp.2, K: *Arthothelium dispersum,* L: *Arthothelium ruanum*, [Scale; A = 2 mm, B = 0.7 mm, C = 0.5 mm, D = 1.5 mm, E = 1 mm, F = 0.5 mm, G = 0.5 mm, H = 0.2 mm, I = 0.3 mm, J = 0.3 mm, K = 0.5 mm, L = 0.5 mm]).

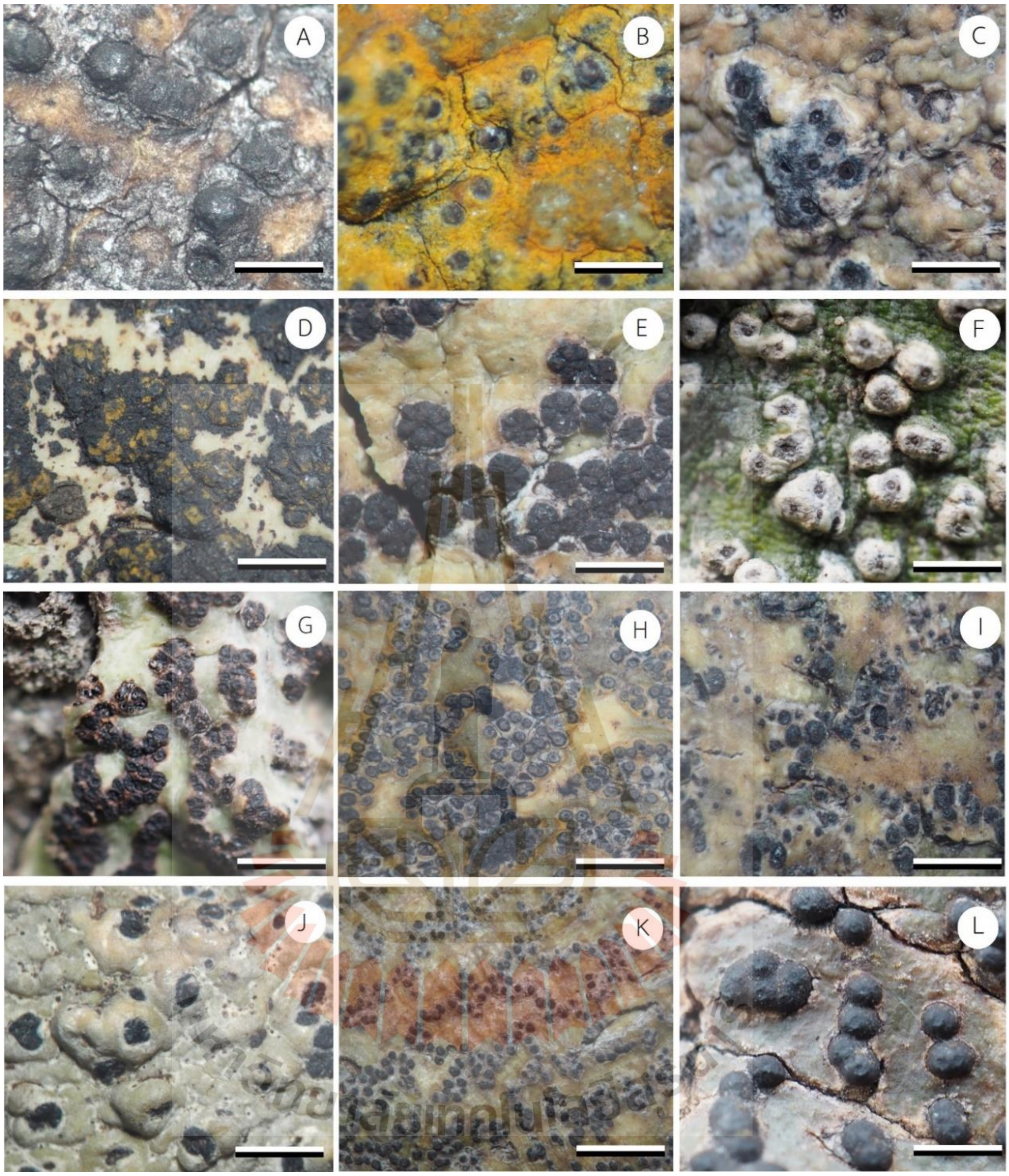

Figure 3F Habitus of *Astrothelium* (A: *Astrothelium ambiguum*, B: *Astrothelium condoricum,* C: *Astrothelium deforme,* D: *Astrothelium duplicate,* E: *Astrothelium keralensis,* F: *Astrothelium meristosporum*, G-H: *Astrothelium neogalbineum,* I: *Astrothelium nigratum*, J: *Astrothelium porosum,* K: *Astrothelium rufescens*, L: *Astrothelium subdiscretum,* [Scale; A = 1 mm, B = 1 mm, C = 0.7 mm, D = 1 mm, E = 1.5 mm, F = 0.5 mm, G = 1 mm, H = 3 mm, I = 1 mm, J = 1 mm, K = 2 mm, L = 1 mm]).

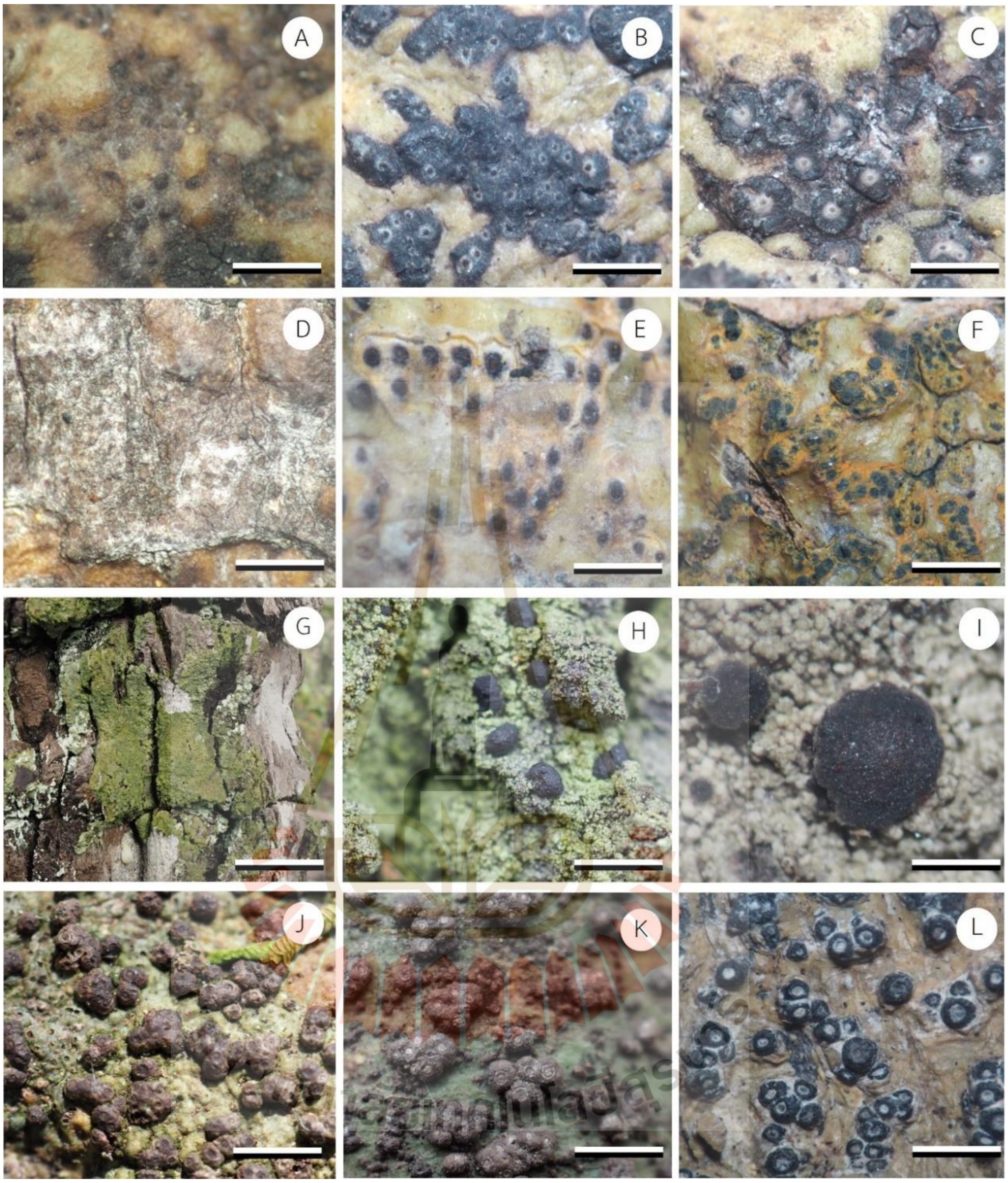

Figure 4F Habitus of *Astrothelium*, *Bacidia* and *Bathelium* (A: *Astrothelium* sp.1, B: *Astrothelium* sp.2, C: *Astrothelium* sp.3, D: *Astrothelium* sp.4, E: *Astrothelium* sp.5, F: *Astrothelium* sp.6, G-I: *Bacidia* sp.1, J: *Bathelium albidoporum,* K: *Bathelium madreporiforme*, L: *Bathelium* sp.1, [Scale; A = 1 mm, B = 2 mm, C = 1 mm, D = 1 mm, E = 1.5 mm, F = 0.8 mm, G = 20 mm, H = 1.5 mm, I = 0.3 mm, J = 2 mm, K = 2 mm, L = 1.5 mm]).

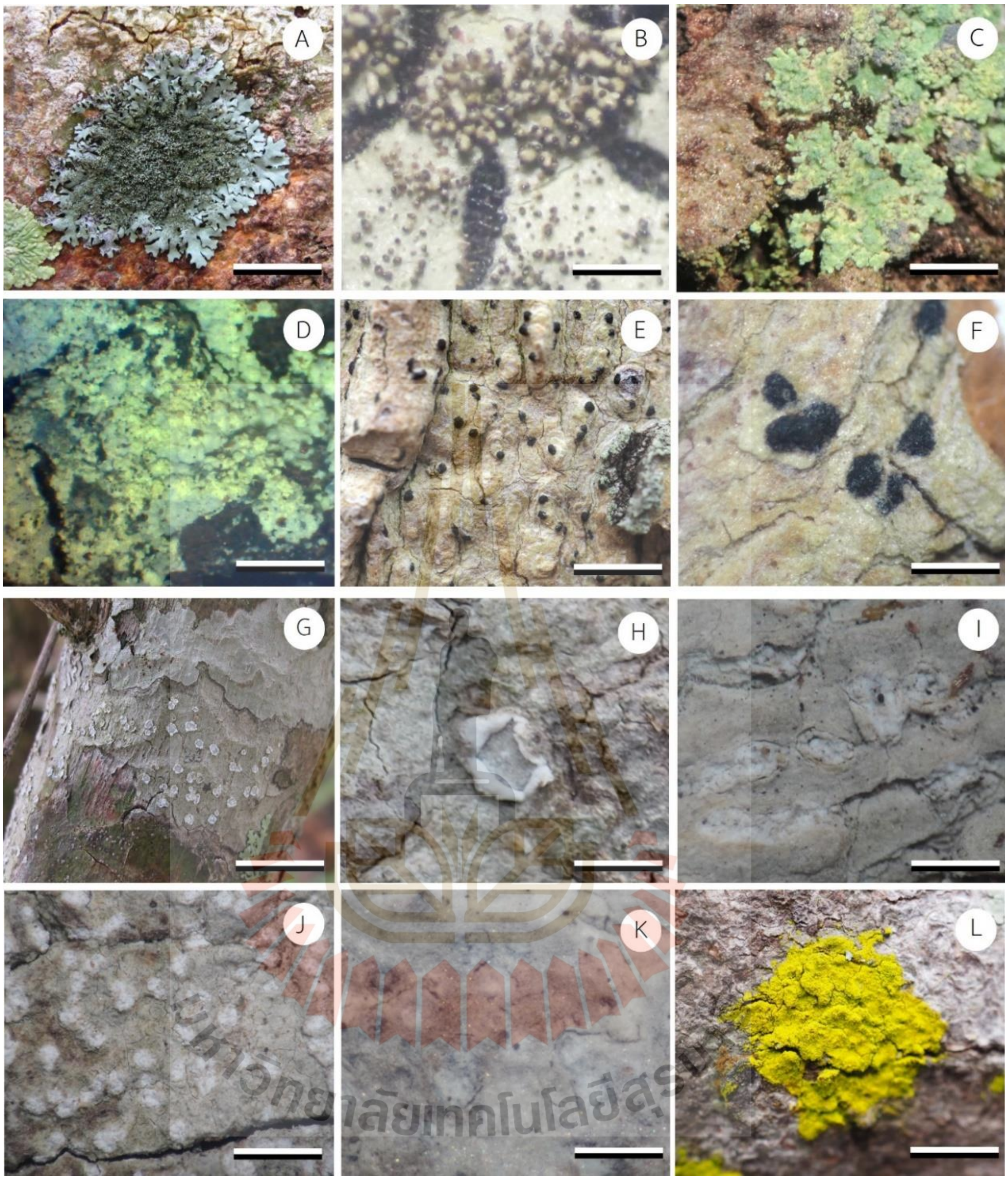

Figure 5F Habitus of *Bulbothrix*, *Candellariella*, *Celothelium, Chapsa* and *Chrysothrix* (A-B: *Bulbothrix queenslandica*, C-D: *Candellariella sorediosa,* E-F: *Celothelium aciculiferum,* G-H: *Chapsa indica,* I: *Chapsa* cf. *velata,* J: *Chapsa* sp.1, K: *Chapsa* sp.2*,* L: *Chrysothrix xanthina,* [Scale; A = 10 mm, B = 1 mm, C = 1 mm, D = 2 mm, E = 3 mm, F = 0.5 mm, G = 10 mm, H = 1 mm, I = 0.2 mm, J = 1 mm, K = 0.5 mm, L = 0.3 mm]).

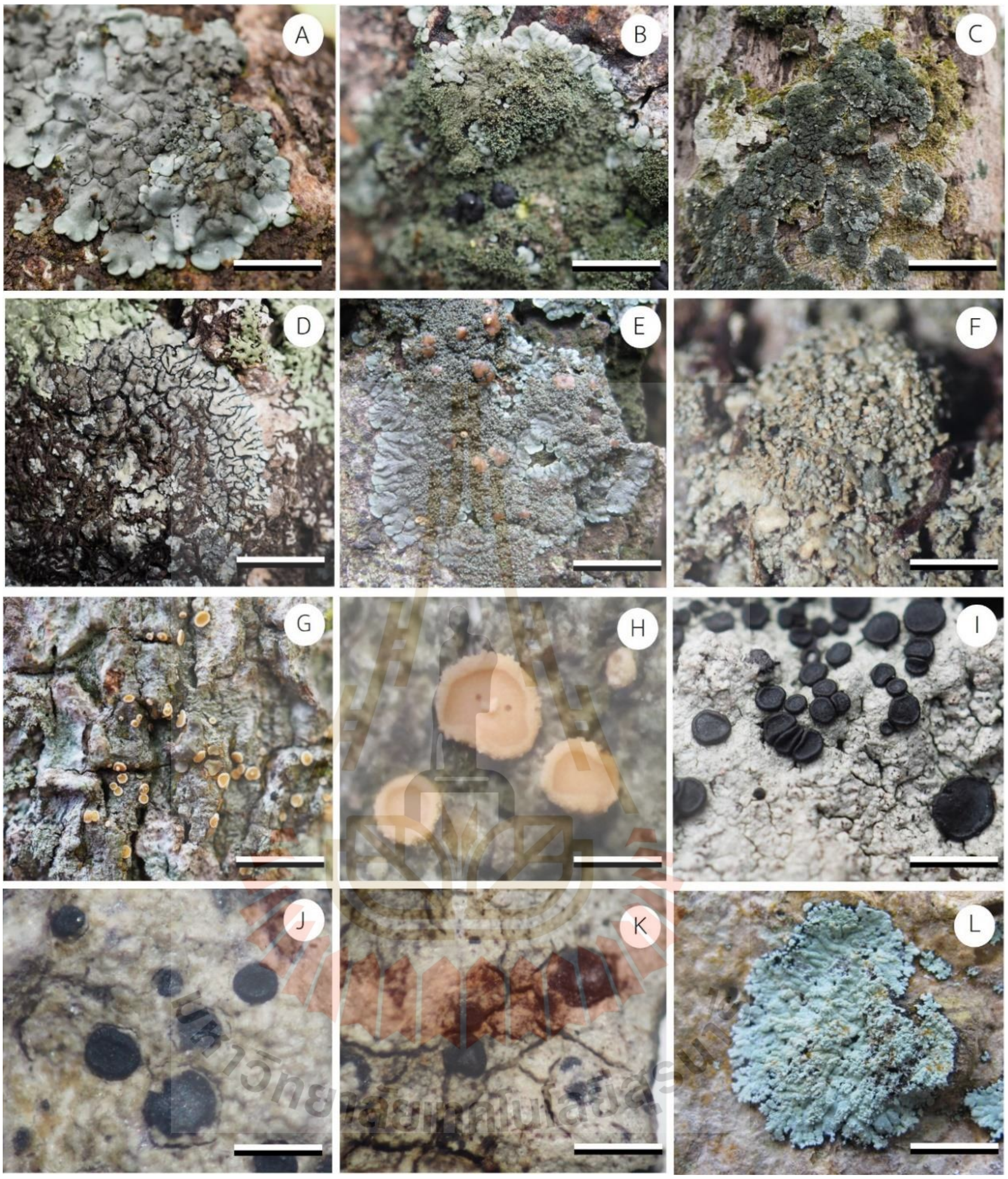

Figure 6F Habitus of *Coccocarpia, Coenogonium Cratiria* and *Crocynia* (A: *Coccocarpia adnate*, B-C: *Coccocarpia dissecta,* D: *Coccocarpia erythroxyli*, E: *Coccocarpia palmicola,* F: *Coccocarpia pellita*, G-H: *Coenogonium geralense,* I: *Cratiria obscurio,r* J: *Cratiria rutilans,* K: Cratiria sp.1, L: *Crocynia* sp.1 [Scale; A = 1.2 mm, B = 2 mm, C = 1 mm, D = 1 mm, E = 1 mm, F = 10 mm, G = 7 mm, H = 0.7 mm, I = 0.5 mm, J = 0.3 mm, K = 0.6 mm, L = 5 mm]).

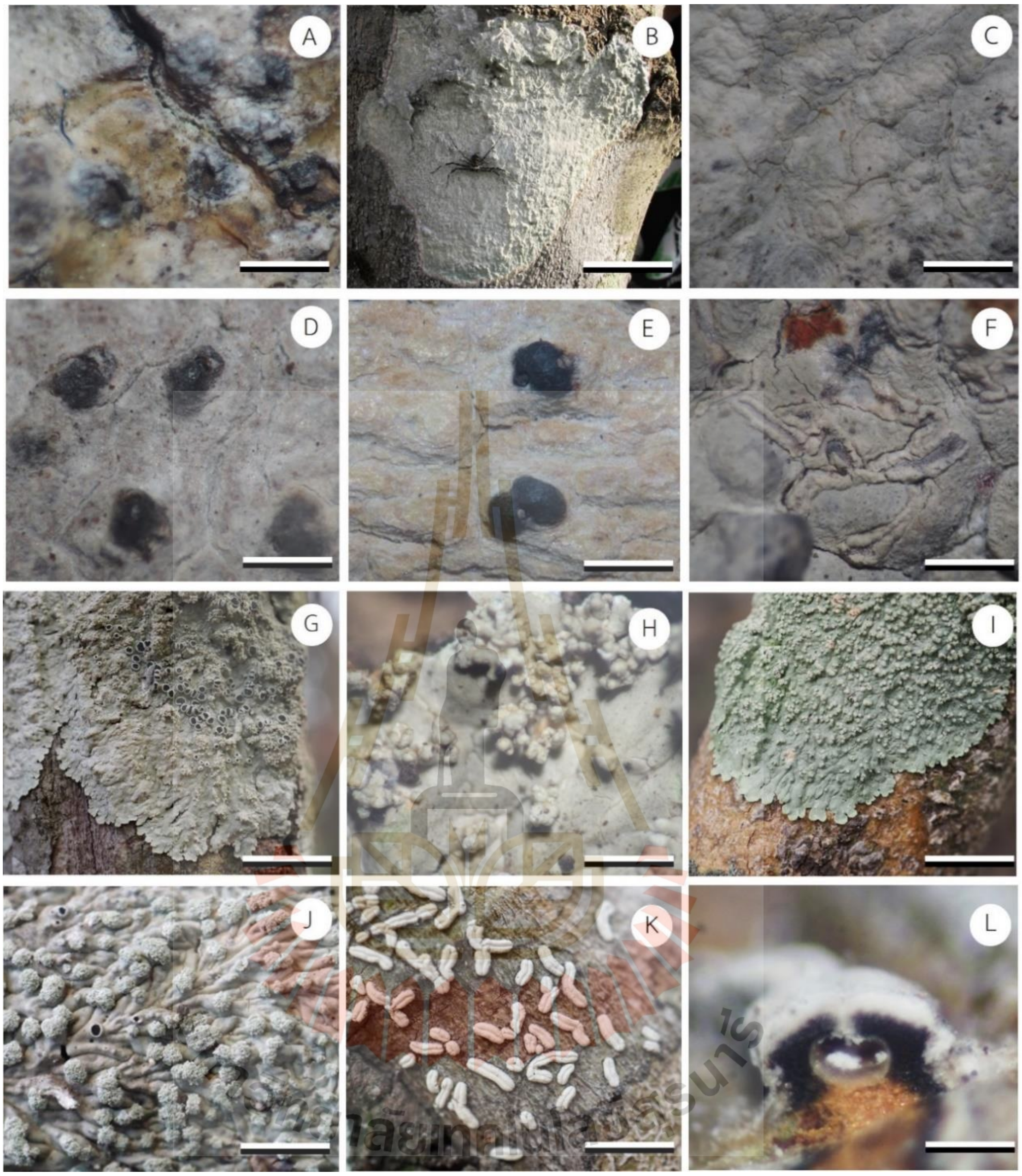

Figure 7F Habitus of *Cruentotrema*, *Cryptothecia*, *Dictyomeridium*, *Diorygma*, *Dirinaria* and *Dyplolabia* (A: *Cruentotrema kurandense,* B-C: *Cryptothecia polymorpha,* D: *Dictyomeridium amylosporum,* E: *Dictyomeridium proponens*, F: *Diorygma junhuhnii,* G-H: *Dirinaria aegialita* [thallus with dactyl], I-J: *Dirinaria picta* [thallus with capitate soredia], K-L: *Dyplolabia afzelii,* [Scale; A = 1 mm, B = 20 mm, C = 1 mm, D = 0.8 mm, E = 0.8 mm, F = 0.5 mm, G = 10 mm, H = 1 mm, I = 10 mm, J = 2 mm, K = 5 mm, L = 0.5 mm]).

Figure 8F Habitus of *Enterographa*, *Fissurina, Gassicurtia, Glyphis* and *Graphis* (A: *Enterographa* sp.1, B: *Fissurina* sp.1, C: : *Gassicurtia* cf. *caririensis*, D: *Gassicurtia* sp.1 E: *Glyphis scyphulifera,* F: *Graphis albissima,* G: *Graphis caesiella,* H: *Graphis copelandii,* I: *Graphis descissa,* J: *Graphis dracaenea,* K: *Graphis dendrogramme,* L: *Graphis furcate,* [Scale; A = 0.2 mm, B = 1 mm, C = 1 mm, D = 5 mm, E = 0.7 mm, F = 1 mm, G = 1.5 mm, H = 0.8 mm, I = 0.5 mm, J = 0.5 mm, K = 0.3 mm, L = 10 mm]).

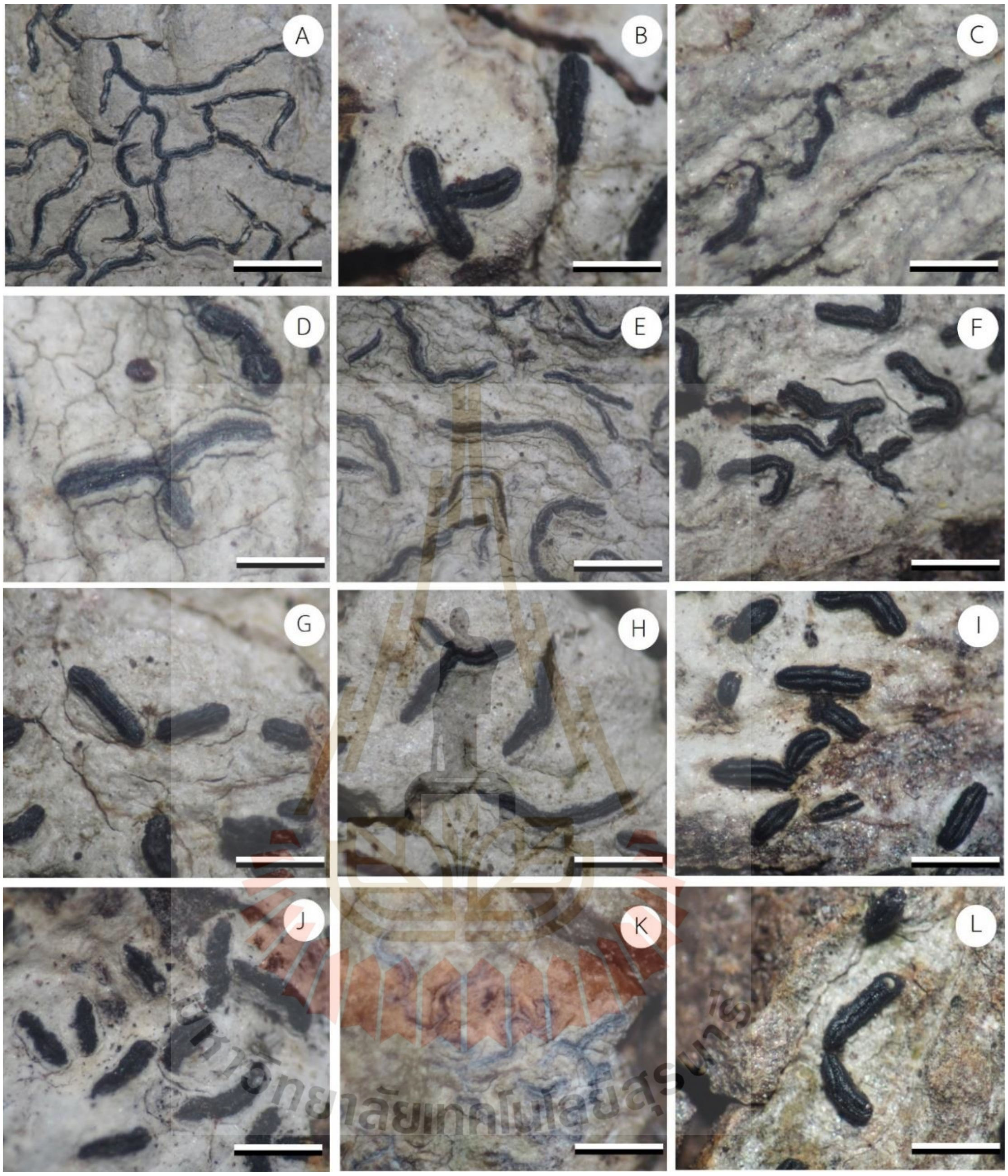

Figure 9F Habitus of *Graphis* (A: *Graphis glorisensis,* B: *Graphis handelii*, C: *Graphis immersella,* D: *Graphis immersicans*, E: *Graphis inspersoradians,* F: *Graphis intricate,* G: *Graphis lineola*, H: *Graphis nanodes*, I: *Graphis nuda*, J: *Graphis strblocarpa,* K: *Graphis* sp.1, L: *Graphis* sp.2, [Scale; A = 2 mm, B = 0.7 mm, C = 0.6 mm, D = 0.5 mm, E = 1.5 mm, F = 0.5 mm, G = 0.6 mm, H = 1.5 mm, I = 0.7 mm, J = 0.5 mm, K = 0.6 mm, L = 0.5 mm]).

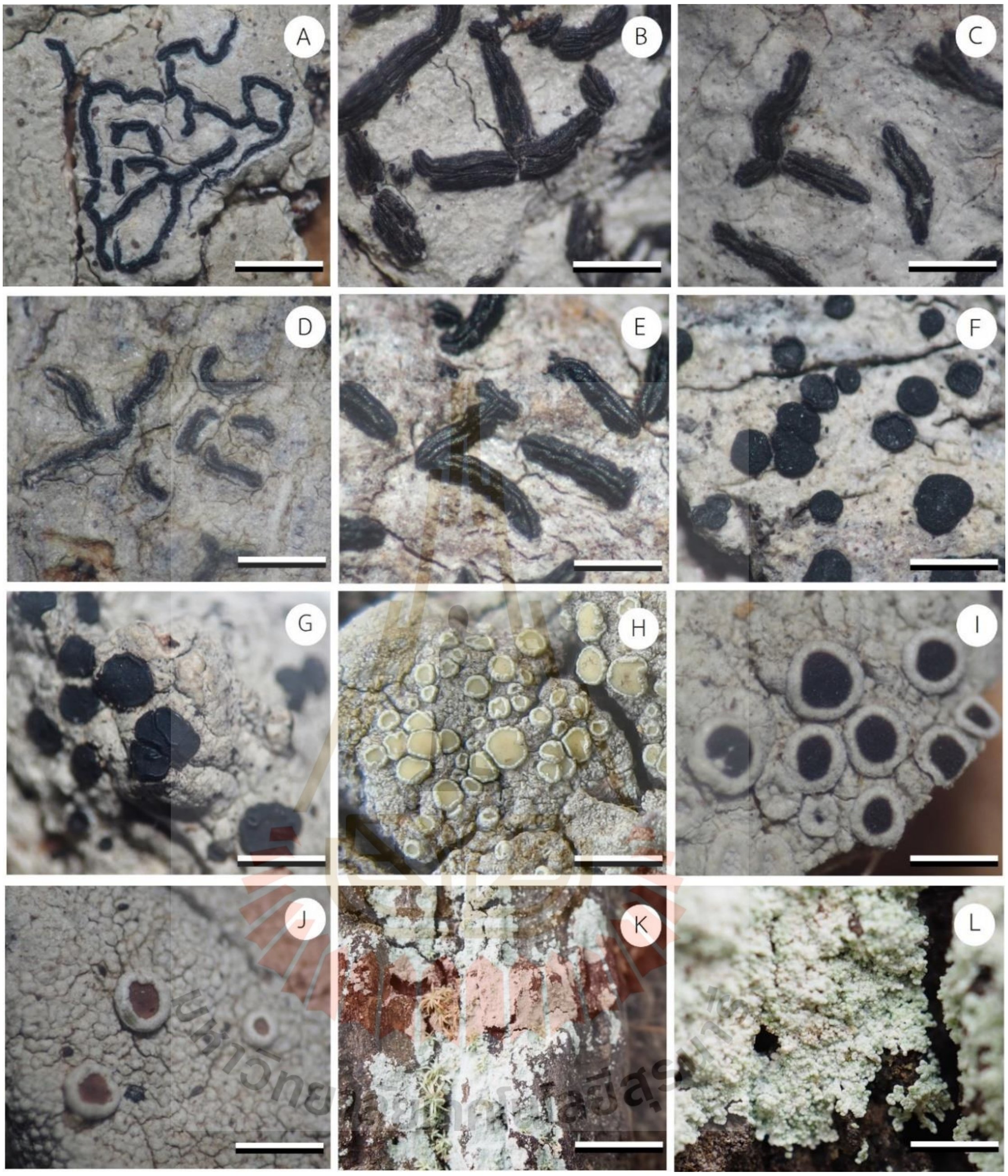

Figure 10F Habitus of *Graphis, Hafellia, Lecanora* and *Lepraria* (A: *Graphis* sp.3, B: *Graphis* sp.4, C: *Graphis* sp.5, D: *Graphis* sp.6, E: *Graphis* sp.7, F: *Hafellia bahiana,* G: *Hafellia subnexa*, H: *Lecanora achroa*, I: *Lecanora phaeocardia,* J: *Lecanora* sp.1, K-L: *Lepraria* sp.1, [Scale; A = 1 mm, B = 1 mm, C = 0.5 mm, D = 0.6 mm, E = 0.3 mm, F = 0.7 mm, G = 1.5 mm, H = 1 mm, I = 0.5 mm, J = 1 mm, K = 10 mm, L = 1 mm]).

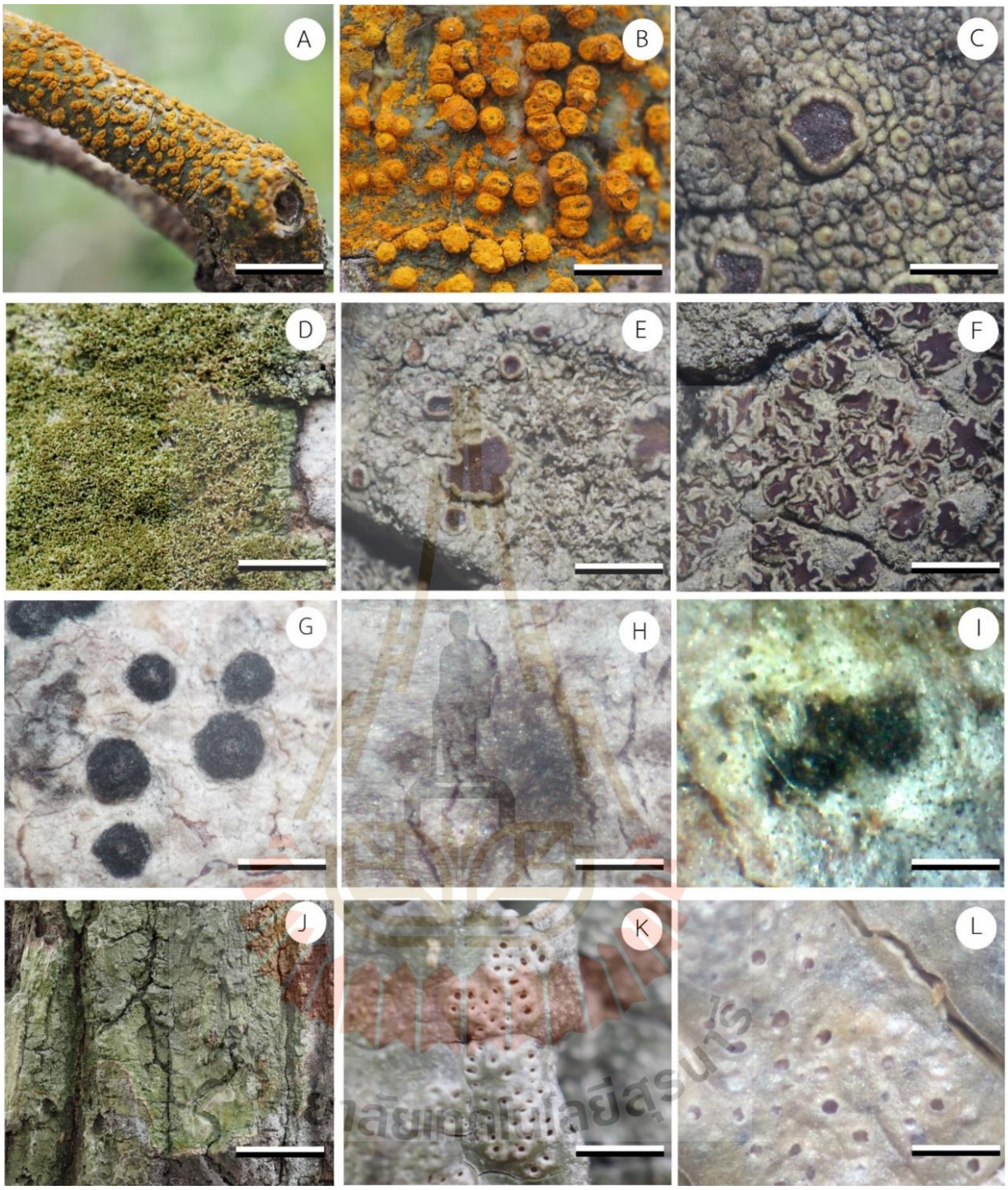

Figure 11F Habitus of *Marcellaria, Maronea, Maronina, Mycomicrothelia, Mycoporum* and *Myriotrema* (A-B: *Marcellaria bengulensis,* C: *Maronea* sp.1, D-F: *Maronina corallifera,* G: *Mycomicrothelia subfallens,* H: *Mycoporum deplanatum,* I: *Mycoporum lacteum,* J-L: *Myriotrema subconforme,* [Scale; A = 10 mm, B = 3 mm, C = 1 mm, D = 5 mm, E = 1.6 mm, F = 3 mm, G = 1 mm, H = 1 mm, I = 0.2 mm, J = 20 mm, K = 1.8 mm, L = 1 mm]).

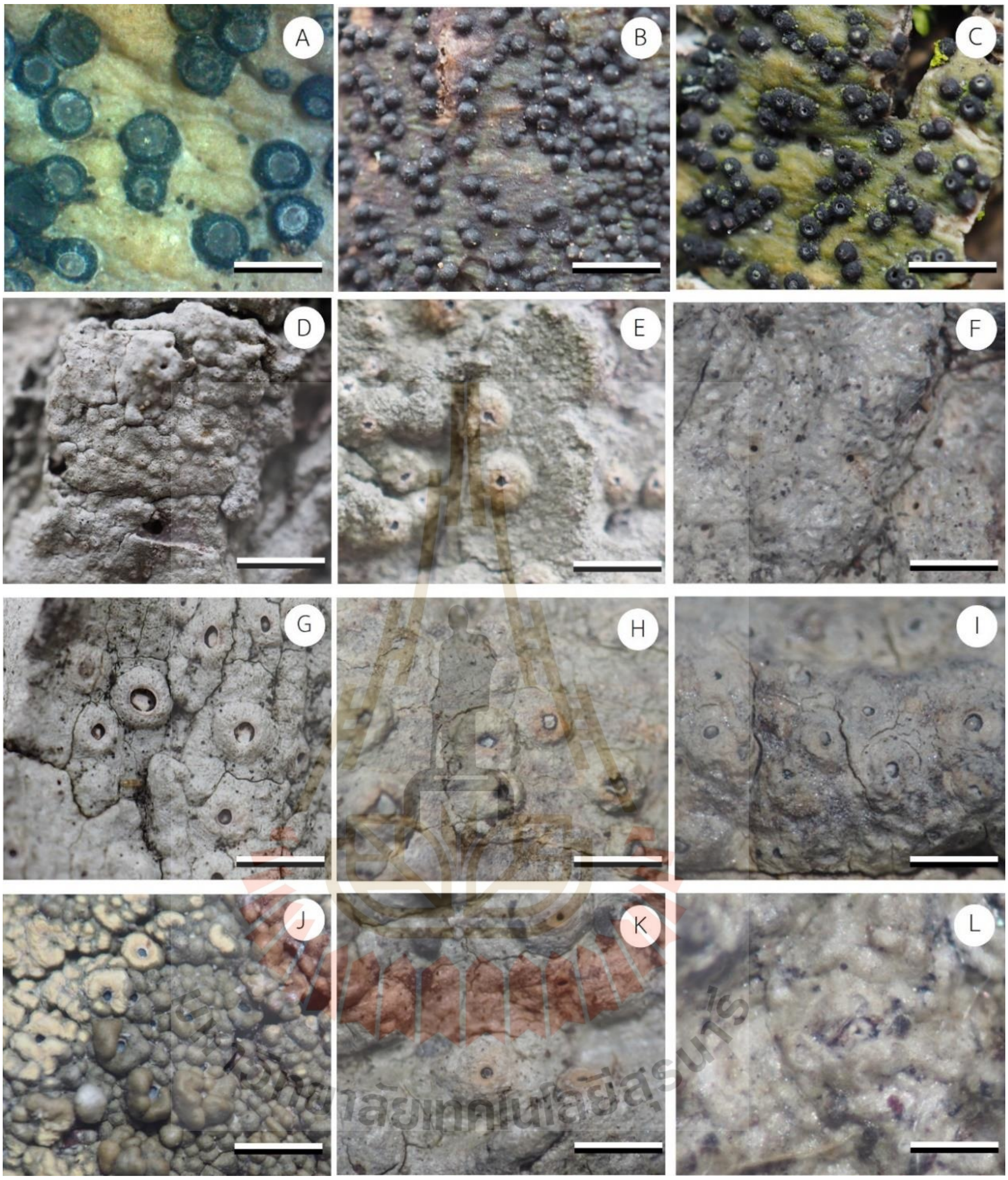

Figure 12F Habitus of *Nigrovothelium* and *Ocellularia* (A: *Nigrovothelium bullatum,* B-C: *Nigrovothelium tropicum,* D-E: *Ocellularia arecae*, F: *Ocellularia eumorpha*, G: *Ocellularia exuta*, H: *Ocellularia massalongoi,* I: *Ocellularia meiosperma,* J: *Ocellularia punctulate,* K: *Ocellularia* sp.1*,* L: *Ocellularia* sp.2, [Scale; A = 1 mm, B = 1.5 mm, C = 1 mm, D = 5 mm, E = 6 mm, F = 1 mm, G = 1 mm, H = 1.5 mm, I = 1 mm, J = 1 mm, K = 1 mm, L = 0.2 mm]).

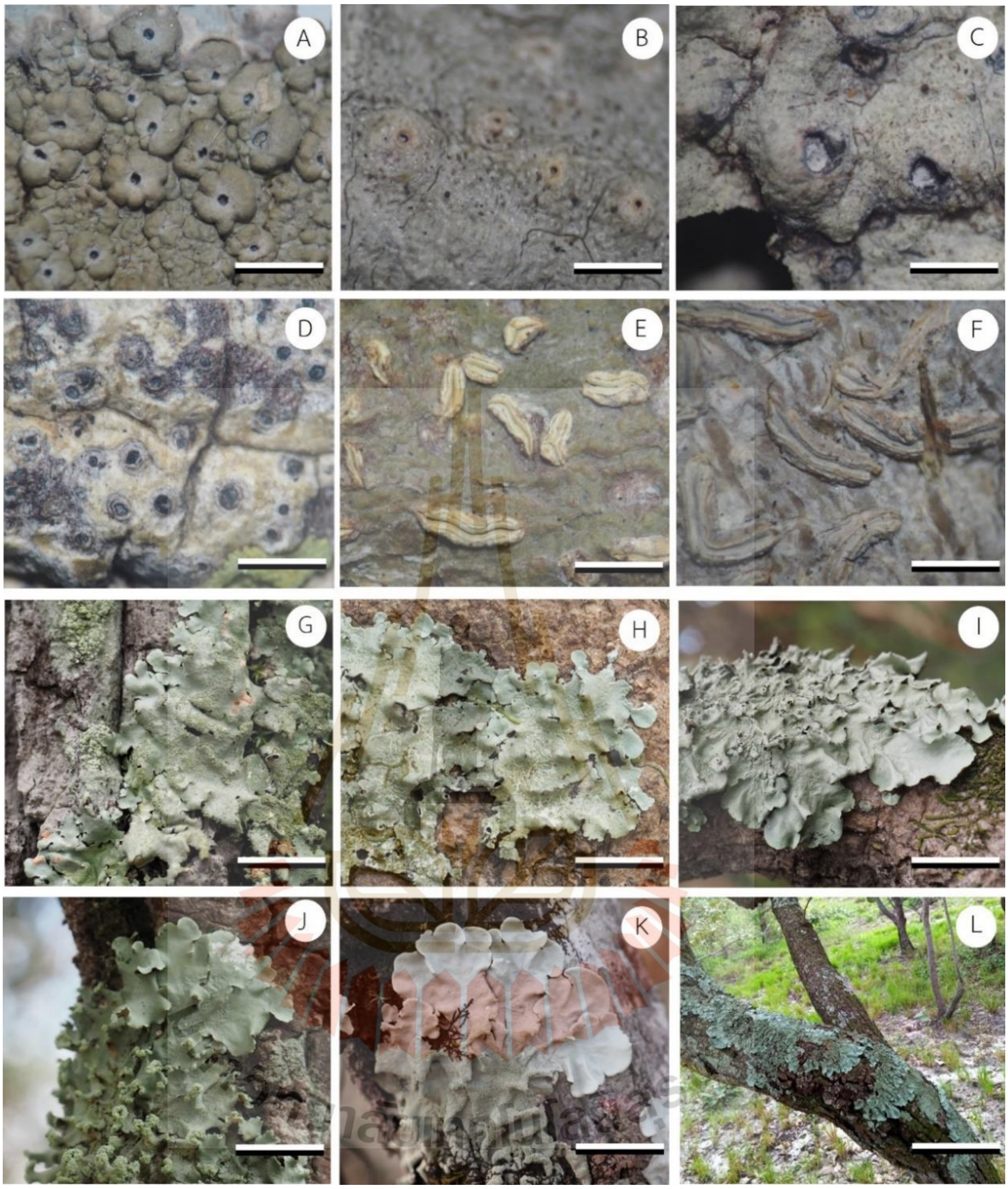

Figure 13F Habitus of *Ocellularia*, *Pallidogramme*, *Parmelinella* and *Parmotrema* (A: *Ocellularia* sp.3, B: *Ocellularia* sp.4, C: *Ocellularia* sp.5, D: *Ocellularia* sp.6, E: *Pallidogramme chlorocarpoides*, F: *Pallidogramme chrysenteron,* G: *Parmelinella wallichiana,* H: *Parmotrema merrillii,* I: *Parmotrema overeemii*, J: *Parmotrema praesorediosum*, K-L: *Parmotrema tinctorum*, [Scale; A = 2.2 mm, B = 1.2 mm, C = 1 mm, D = 0.5 mm, E = 1.5 mm, F = 2 mm, G = 15 mm, H = 10 mm, I = 10 mm, J = 10 mm, K = 25 mm, L = 200 mm]).

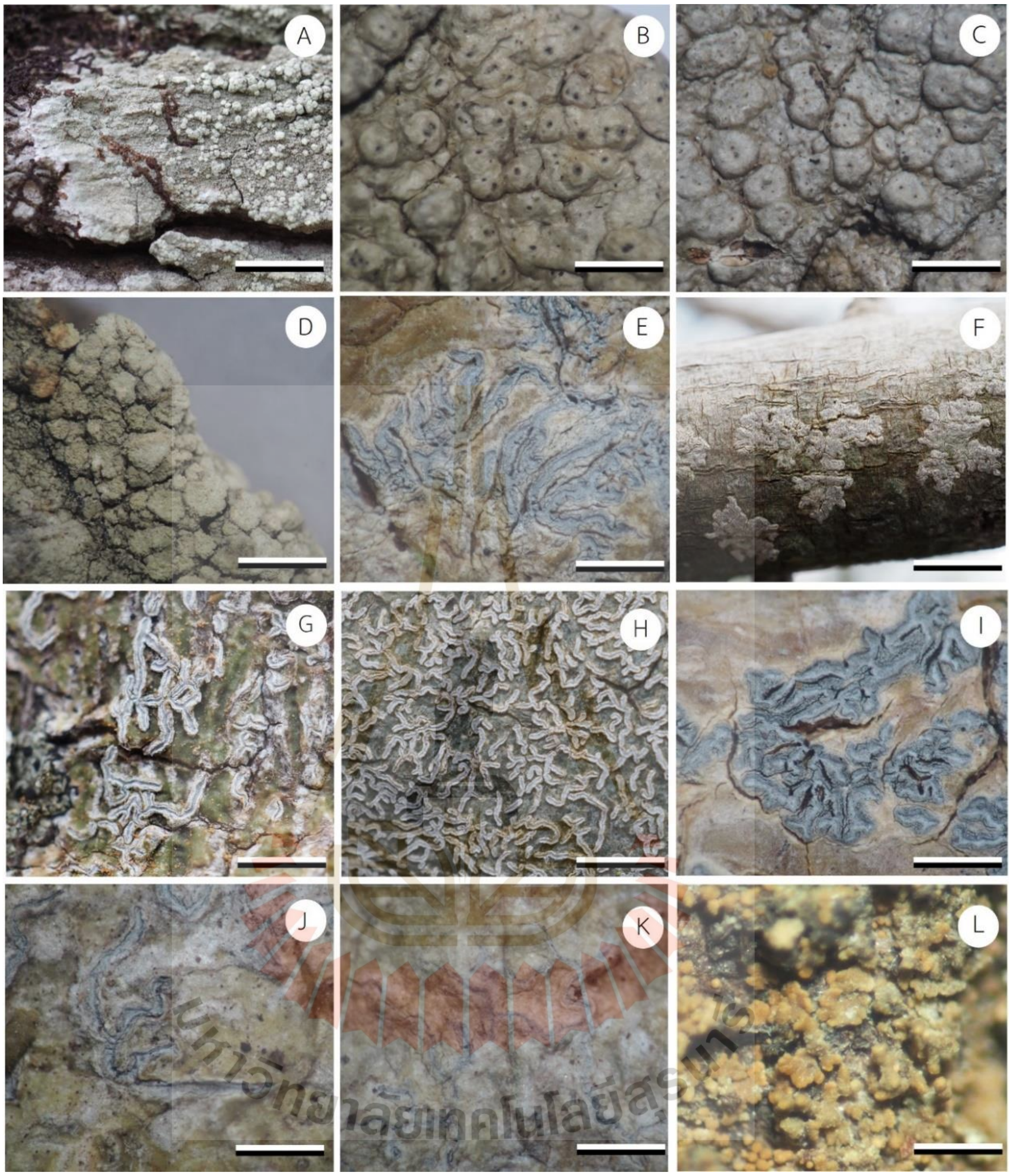

Figure 14F Habitus of *Pertusaria*, *Phaeographis* and *Phyllopsora* (A: *Pertusaria amara,* B: *Pertusaria tetrathalamia* var. *plicatula,* C: *Pertusaria* sp.1, D: *Pertusaria* sp.2, E-F: *Phaeographis brasilensis*, G-H: *Phaeographis caesioradians*, I: *Phaeographis intricans*, J: *Phaeographis* sp.1, K: *Phaeographis* sp.2, L: *Phyllopsora corallina,* [Scale; A = 5 mm, B = 1 mm, C = 1.3 mm, D = 2 mm, E = 0.7 mm, F = 2 mm, G = 3 mm, H = 5 mm, I = 0.7 mm, J = 1.5 mm, K = 1 mm, L = 0.5 mm]).

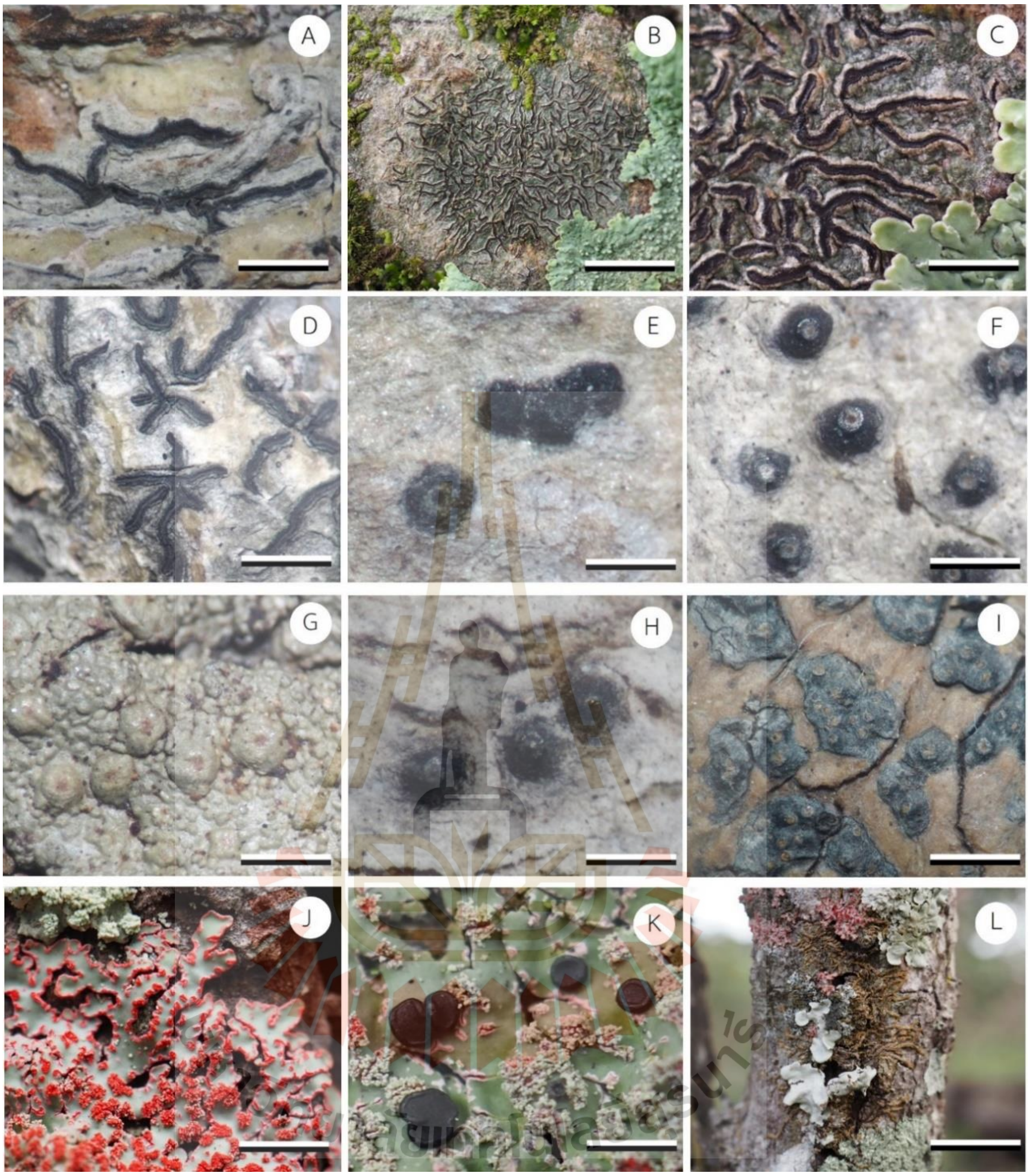

Figure 15F Habitus of *Platygramme*, *Polymeridium, Porina, Pseudopyrenula, Pyrenula,* and *Pyxine* (A: *Platygramme disscurrens*, B-C: *Platygramme pudica,* D: *Platygramme* sp.1, E: *Polymeridium quinqueseptatum*, F: *Polymeridium subcinnerium,* G: *Porina eminentior*, H: *Pseudopyrenula endoxanthoides*, I: *Pyrenula anomala*, J-K: *Pyxine coccifera*, L: *Pyxine coccifera* and other foliose lichens, [Scale; A = 0.6 mm, B = 20 mm, C = 5 mm, D = 0.5 mm, E = 0.5 mm, F = 0.7 mm, G = 1 mm, H = 0.4 mm, I = 1.3 mm, J = 2.3 mm, K = 0.5 mm, L = 20 mm]).

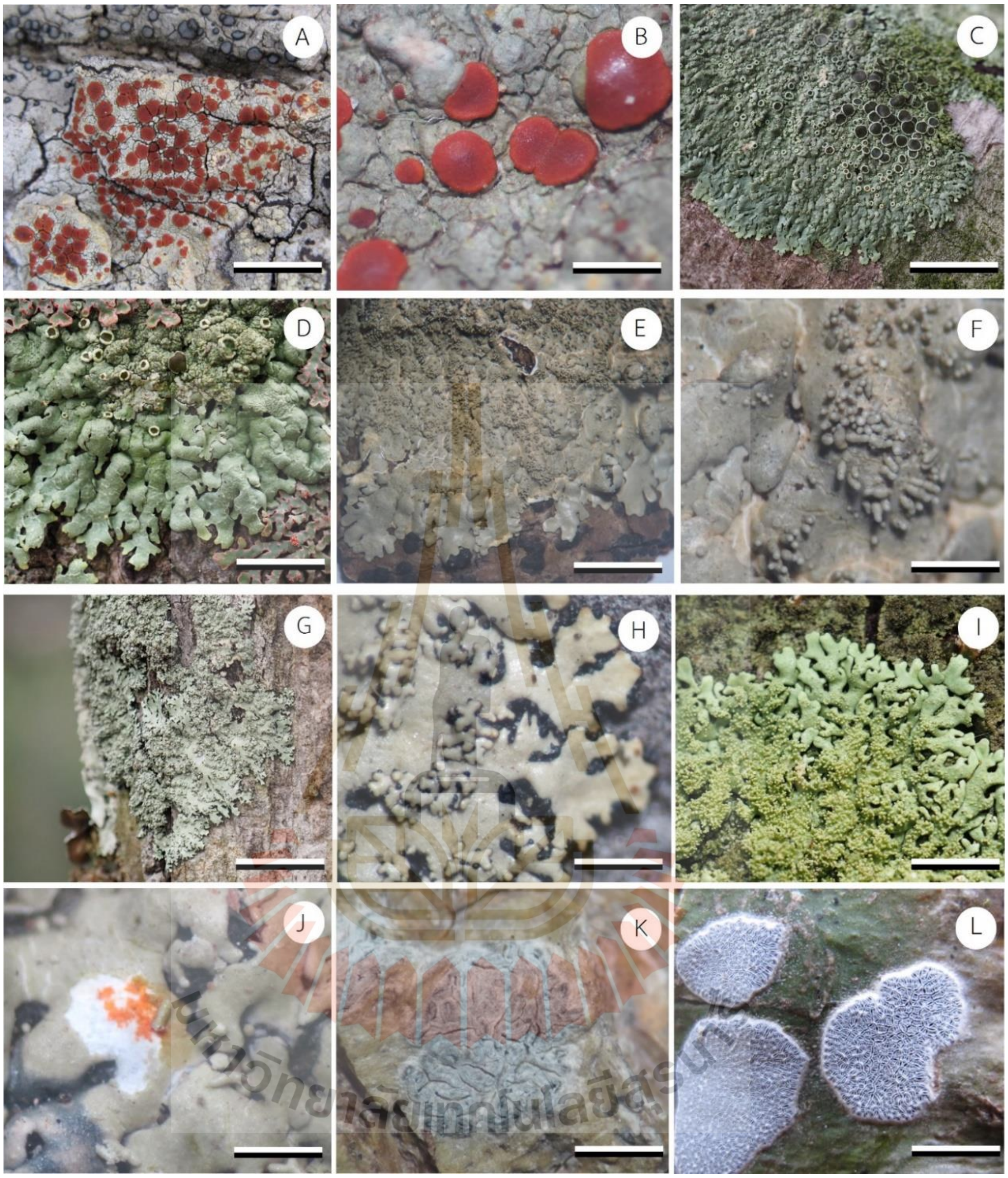

Figure 16F Habitus of *Ramboldia*, *Relicina* and *Sarcographa* (A-B: *Ramboldia russula*, C-D: *Relicina intertexta,* E-F: *Relicina malaccensis* [with isidia], G-H: *Relicina palmata* [with lobulates], I-J: *Relicina rahengensis* [spot test, medulla, kc+ orange], K: *Sarcographa glyphiza,* L: *Sarcographa labyrintheca,* [Scale; A = 3 mm, B = 0.5 mm, C = 10 mm, D = 5 mm, E = 5 mm, F = 1 mm, G = 5 mm, H = 1.5 mm, I = 6 mm, J = 1 mm, K = 0.5 mm, L = 0.5 mm]).

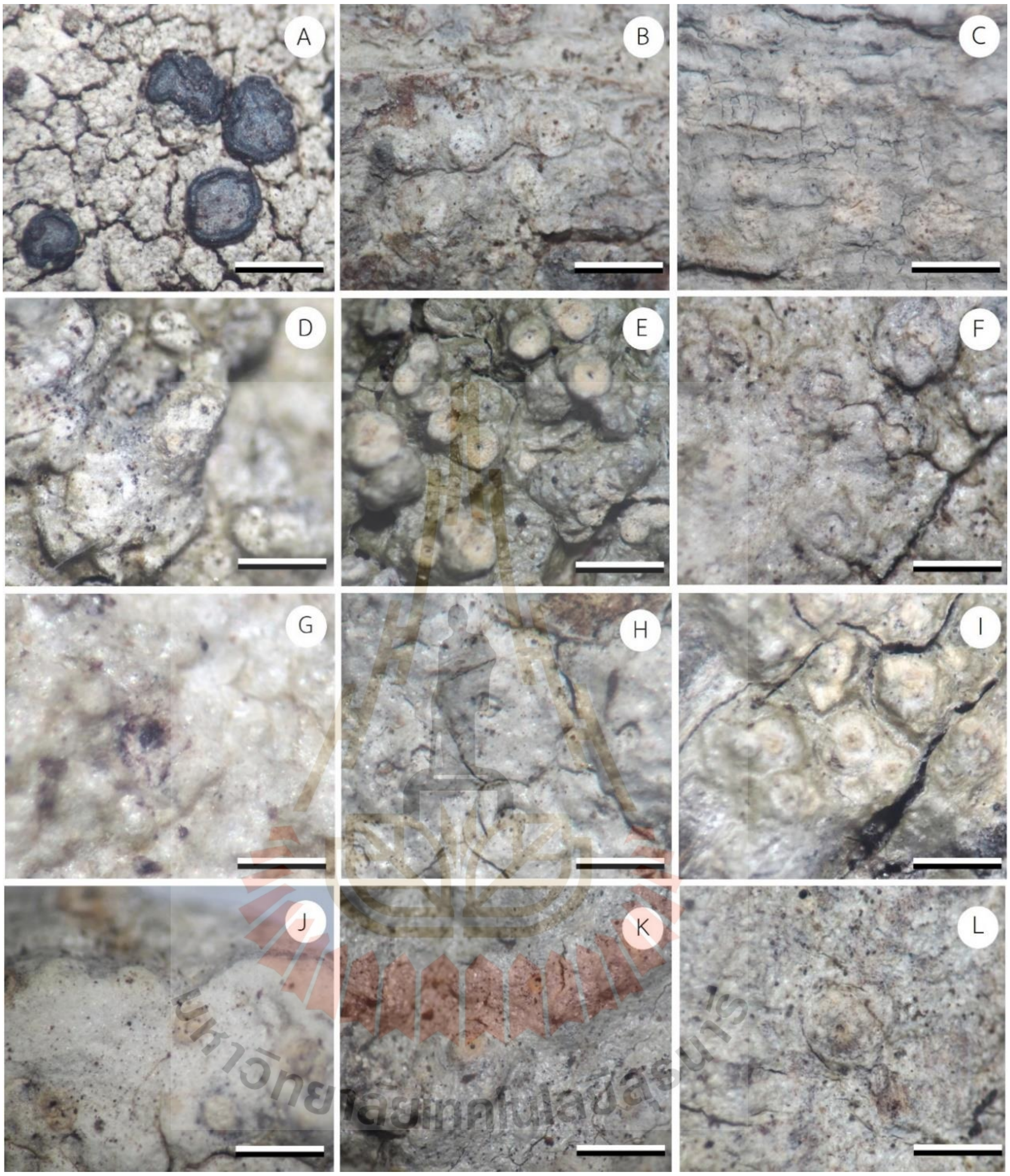

Figure 17F Habitus of *Stigmatochroma, Stirtonia, Thelenella* and *Thelotrema* (A: *Stigmatochroma glaucothecum*, B: *Stirtonia macrocarpa,* C: *Stirtonia* sp.1, D: *Thelenella* sp.1, E: *Thelotrema albo-olivaceum,* F: *Thelotrema coferendum*, G: *Thelotrema lepademersum,* H: *Thelotrema monosporum,* I: *Thelotrema platysporum,* J: *Thelotrema* sp.1, K: *Thelotrema* sp.2*,* L: *Thelotrema* sp.3, [Scale; A = 1 mm, B = 1.3 mm, C = 1.2 mm, D = 0.2 mm, E = 1.5 mm, F = 0.8 mm, G = 0.5 mm, H = 0.8 mm, I = 1 mm, J = 0.5 mm, K = 0.6 mm, L = 1.1 mm]).

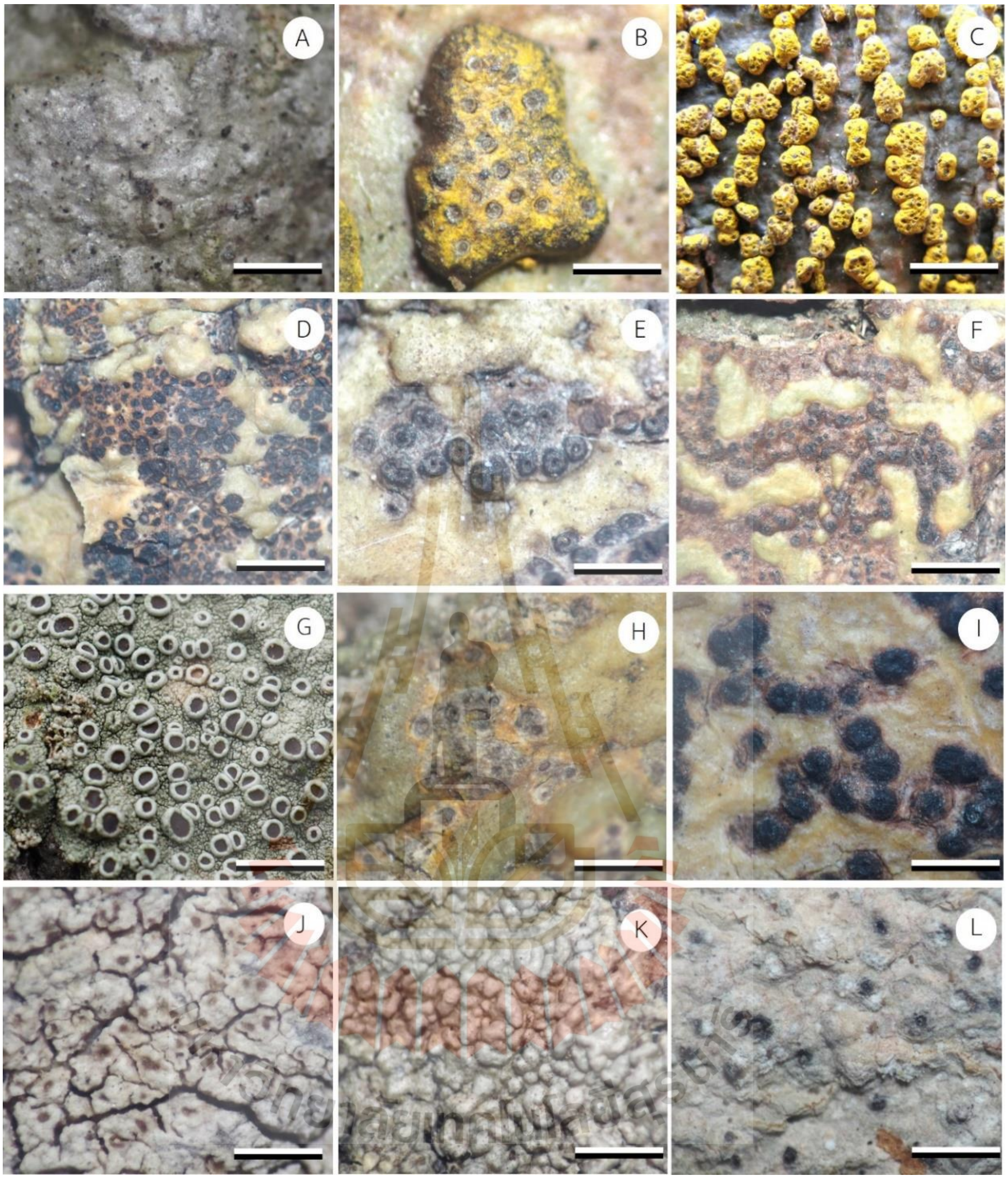

Figure 18F Habitus of *Thelotrema, Trypethelium, Vainionora, Viridothelium* and Unidentified crustose (A: *Thelotrema* sp.4, B: *Trypethelium andamandicum*, C: *Trypethelium eluteriae,* D: *Trypethelium* sp.1, E: *Trypethelium* sp.2, F: *Trypethelium* sp.3, G: *Vainionora flavidorufa,* H: *Viridothelium leptoseptatum*, I: *Viridothelium virens*, J: Unidentified crustose sp.1, K: Unidentified crustose sp.2, L: Unidentified crustose sp.3, [Scale; A = 1.1 mm, B = 1 mm, C = 5 mm, D = 1.5 mm, E = 1 mm, F = 1.5 mm, G = 3 mm, H = 0.5 mm, I = 1.5 mm, J = 0.3 mm, K = 0.2 mm, L = 0.3 mm]).

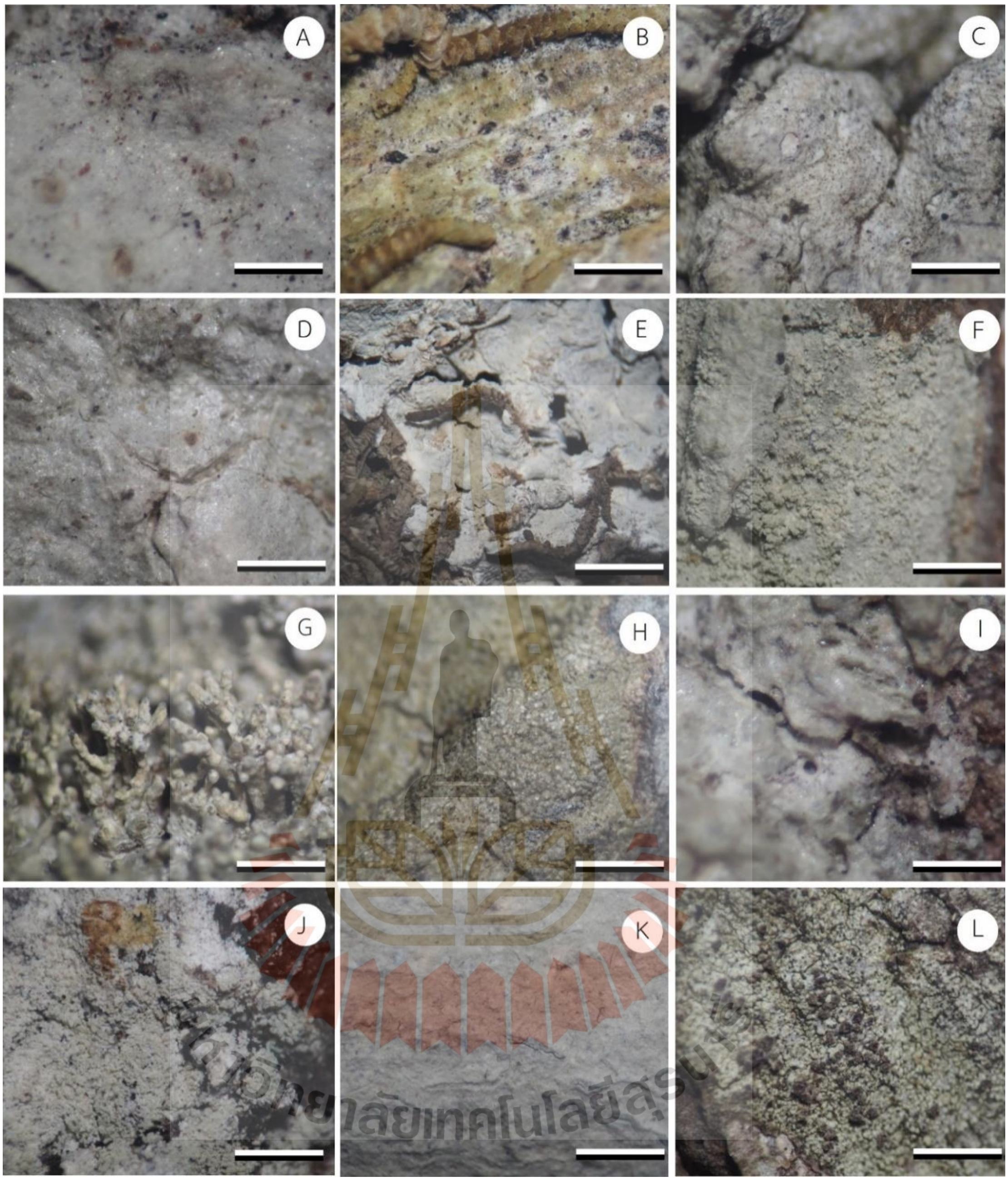

Figure 19F Habitus of Unidentified crustose (A: Unidentified crustose sp.4, B: Unidentified crustose sp.5, C: Unidentified crustose sp.6, D: Unidentified crustose sp.7, E: Unidentified crustose sp.8, F: Unidentified crustose sp.9, G: Unidentified crustose sp.10, H: Unidentified crustose sp.11, I: Unidentified crustose sp.12, J: Unidentified crustose sp.13, K: Unidentified crustose sp.14, L: Unidentified crustose sp.15, [Scale; A = 0.2 mm, B = 0.2 mm, C = 0.5 mm, D = 0.2 mm, E = 1 mm, F = 1 mm, G = 0.3 mm, H = 0.2 mm, I = 0.2 mm, J = 0.1 mm, K = 0.2 mm, L = 0.3 mm]).

CURRICULUM VITAE

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2017- Present	Doctor of Philosophy (Environmental Biology), Suranaree University of Technology, Nakhon Ratchasima, Thailand
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1996-2000	Bachelor of Science (Biology), Ramkhamhaeng University, Bangkok, Thailand