RECOVERY OF LICHEN DIVERSITY DURING FOREST RESTORATION IN NORTHERN THAILAND

AURATHAI PHONGCHIEWBOON

MASTER OF SCIENCE
IN BIOLOGY

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RECOVERY OF LICHEN DIVERSITY DURING FOREST RESTORATION IN NORTHERN THAILAND

AURATHAI PHONGCHIEWBOON

A THESIS SUBMITTED TO THE GRADUATE SCHOOL

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MASTER OF SCIENCE

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Thesis Title Recovery of Lichen Diversity During Forest Restoration in Northern Thailand

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ABSTRACT

This study investigated the recovery of lichen diversity during forest restoration work in northern Thailand. Lichen diversity and species frequencies were recorded within experimental plots, planted by Forest Restoration Research Unit (FORRU) in year 1998, 2000 and 2002 (8, 6 and 4 years since planting) near Ban Mae Sa Mai in Doi Suthep-Pui National Park. Lichen floras in these plots were compared with those of natural forest (Dong Seng forest on Doi Mea Sa). The objectives of the study were to observe the recovery of lichen communities on trees of different ages in the reforestation plots and to provide baseline information on lichen species as bioindicators for forest recovery in Northern Thailand. Four framework tree species; *Hovenia dulcis* Thunb, *Melia toosendan* Sieb & Zucc, *Prunus cerasoides* D. Don and *Spondias axillaris* Roxb were chosen and lichens on their tree trunks were collected. Lichen data were recorded using a commercial frame 20 centimeter wide, subdivided in smaller squares of 2.5 x 2.5 cm. The frame was wrapped horizontally around each tree's girth, 1 meter above ground level.

Forest restoration using the framework species method resulted in a 57% recovery of the lichen flora (plot 1998 compared with natural forest) within 8 years following tree planting (by Sorensen's similarity index); *Buellia* sp.1, *Diorygma* cf. *epiglaucum, Dirinaria confluens, Graphis* sp.2, *Graphis* sp.4, *Graphis* sp.5, *Graphis* sp.9, *Graphis* sp.10, *Graphis* sp.11, *Graphis* sp.13, *Haematomma puniceum, Lecanora* sp.1, *Lecanora* sp.5, *Malcolmiella* sp.5, *Malcolmiella* sp.2, *Malcolmiella* sp.7, *Pertusaria* sp.1, *Porina* sp.1. Recovery of lichen diversity increased in plots with longer reforestation age. Some

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Lichens species might be served as bioindicators for forest recovery in this study; *Graphis* sp.9, *Haematomma puniceum*, *Malcolmiella* sp.2 and *Hypotrachyna* sp.1.

A total of 795 epiphytic lichen samples were collected. The samples were divided into two main types: foliose and crustose and they represented 6 orders, 14 families, 31 genera and 70 species. The highest lichen diversity (by Shannon's diversity index) was found on *P. cerasoides* (2.80) in Dong Seng Forest, whereas the lowest value (0.25) was on *M. toosendan* in plot 2002. Some crustose lichen genera, such as *Chrysothrix*, tended to be pioneers, whereas foliose lichen genera, such as *Bulbothrix*, occurred more in the older plots and in natural forest.

Sorensen's similarity index showed that the lichen communities on all selected tree species were most similar between plots 1998 and 2000 (0.69 or 69%). The least similar plots were plot 2002 and Dong Seng forest (0.23 or 23%). Within plot 1998, lichen communities on *H. dulcis* and *S. axillaris* were most similar (0.85 or 85%). Lichen communities on *H. dulcis* in plot 2000 and *P. cerasoides* in plot 2002 were least similar (0.13 or 13%). Light intensity and air temperature in plot 1998 and Dong Seng were not significantly different. In plots 2000 and 2002, these parameters were not significantly different ($p<0.05$). Relative air humidity among all sites were not significantly different ($p<0.05$). Correlation between lichen communities and environmental factors were analyzed by Principal Coordinate Analysis (PCA) and Detrended Correspondence Analysis (DCA), using the Multivariate Statistical Package (MVSP3.1) program. There was correlation between lichen communities and environmental factors. Environment factors such as temperature, light intensity, pH of bark, and elevation above sea level, influenced the distribution and diversity of lichens. While studies on lichen communities and environmental factors as a model system were intensively performed in temperate forest, study in this aspect in the tropical forest was less known. This study as an initiative study may provides some understanding on the recovery of lichen diversity in reforestation areas in Thailand. However, more and intensive studies in the future on this topic of recovery of lichen diversity in tropical forest and reforestation areas are needed to find a suitable bioindicator of forest recovery.

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ชื่อเรื่องวิทยานิพนธ์ การฟื้นตัวของความหลากหลายของไลเคนระหว่างการฟื้นฟูป่าในภาคเหนือของประเทศไทย

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บทคัดย่อ

การศึกษานี้วิจัยเรื่องการฟื้นตัวของความหลากหลายของไลเคนระหว่างการฟื้นฟูป่าในภาคเหนือของประเทศไทยของกลุ่มไลเคนบนต้นไม้ที่ช่วงอายุต่างๆ ของการฟื้นฟูป่า ทำการรวบรวมความหลากหลาย, ความชุก และชนิดของไลเคนที่วิเคราะห์จำแนกได้จากแหล่งที่ทำการศึกษา 4 แห่ง คือ จากแปลงปลูกป่าใกล้บ้านแม่สาใหม่ที่อุทยานแห่งชาติ ดอยสุเทพ-ปุย ที่ปลูกโดยหน่วยวิจัยการฟื้นฟูป่า (FORRU) จำนวน 3 แปลง คือที่ปลูกในปี พ.ศ. 2541, ปี พ.ศ. 2543 และ ปี พ.ศ. 2545 (นับอายุแปลงได้ 8 ปี, 6 ปี และ 4 ปี ตามลำดับโดยนับจากปีที่ปลูก) และนำมาเปรียบเทียบกับไลเคนที่พบตามธรรมชาติที่ป่าดงเซ็งบนดอยแม่สา วัตถุประสงค์ในการศึกษาครั้งนี้เพื่อตรวจดูการฟื้นคืนของกลุ่มไลเคนบนต้นไม้ที่มีอายุต่างกันตามอายุแปลงปลูกป่าและให้ได้ข้อมูลเบื้องต้นของชนิดไลเคนที่สามารถใช้เป็นดัชนีชี้วัดการฟื้นตัวของป่าในภาคเหนือของประเทศไทย เลือกใช้และเก็บไลเคนบนพรรณไม้โครงสร้าง 4 ชนิดคือ หมอนหิน (*Hovenia dulcis* Thunb) เลี่ยน (*Melia toosendan* Sieb & Zucc) นางพญาเสือโคร่ง (*Prunus cerasoides* D.Don) และ มะกัก (*Spondias axillaris* Roxb) ข้อมูลไลเคนใช้การเก็บตัวอย่างด้วยกรอบศึกษามาตรฐานที่ทำจากตาข่ายลวดเชิงพาณิชย์สำเร็จรูปขนาดความกว้าง 20 เซนติเมตรที่มีช่องเล็กภายในขนาดหน่วยละ 2.5 x 2.5 ตารางเซนติเมตร มาพันรอบต้นไม้ที่แนวระนาบสูงจากพื้นดิน 1 เมตร

การฟื้นฟูป่าด้วยวิธีใช้พรรณไม้โครงสร้างให้ผลการฟื้นคืนของไลเคนมีค่าความเหมือนเมื่อเทียบกับป่าธรรมชาติ 57 % (Sorensen's similarity index) ที่ป่ามีอายุปลูก 8 ปี(แปลง พ.ศ 2541) เทียบกับป่าดงเซ็ง พบชนิดของไลเคนดังนี้ *Buellia* sp.1, *Diorygma* cf. *epiglaucum, Dirinaria confluens, Graphis* sp.2, *Graphis* sp.4, *Graphis* sp.5, *Graphis* sp.9, *Graphis* sp.10, *Graphis* sp.11, *Graphis* sp.13,

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Haematomma puniceum, Lecanora sp.1, *Lecanora* sp.5, *Malcolmiella* sp.5, *Malcolmiella* sp.2, *Malcolmiella* sp.7, *Pertusaria* sp.1, *Porina* sp.1 การฟื้นคืนของความหลากหลายของไลเคนเพิ่มขึ้นตามอายุของแปลงปลูกป่า ไลเคนบางชนิดอาจใช้เป็นดัชนีชีวภาพบ่งชี้ถึงการฟื้นคืนของป่าในการศึกษานี้ ได้แก่ *Graphis* sp.9, *Haematomma puniceum*, *Malcolmiella* sp.2 และ *Hypotrachyna* sp.1

รวบรวมตัวอย่างไลเคนบนเปลือกไม้ได้ 795 ตัวอย่าง แบ่งออกได้ 2 กลุ่มหลักคือ ไลเคนชนิดครัสโตส และไลเคนชนิดโฟลิโอส จำแนกเป็น 6 อันดับ 14 วงศ์ 31 สกุล และ 70 ชนิด ค่าของความหลากหลาย (Shannon's diversity index) สูงสุดพบบนต้น *P. cerasoides* (2.80) ในป่าดงเซ็งและพบค่าต่ำสุดบนต้น *M. toosendan* ในแปลงปลูกพ.ศ.2545 (0.25) พบไลเคนชนิดครัสโตสบางสกุล เช่น *Chrysothrix* มีแนวโน้มที่จะเป็นไลเคนกลุ่มบุกเบิก และไลเคนชนิดโฟลิโอส บางสกุลเช่น *Bulbothrix* พบมากขึ้นในแปลงปลูกที่มีอายุมากขึ้นและในป่าธรรมชาติ

จากดัชนีความเหมือน (Sorensen's index) แสดงว่ากลุ่มไลเคนบนชนิดต้นไม้ที่เลือกทั้งหมดมีความเหมือนมากที่สุดระหว่างแปลงปลูกปี พ.ศ. 2541 และปี 2543 มีค่า 0.69 (69%) แปลงที่ค่าความเหมือนที่ต่ำสุดคือ 0.23 (23%) พบที่แปลงปลูกปี พ.ศ. 2545 และป่าดงเซ็ง เมื่อเปรียบเทียบในปีปลูกเดียวกันพบว่าในแปลงปลูกปีพ.ศ. 2541 บนต้น*H. dulcis* และ*S. axillaris*มีค่าความเหมือนสูงสุดคือ 0.85 (85%) ค่าความเหมือนต่ำสุดคือ 0.13 (13%) พบบนต้น *H. dulcis* ในแปลงปลูกที่ปี 2543 และต้น *P. cerasoides* ในแปลงพ.ศ. 2545 . ความเข้มของแสงและอุณหภูมิในแปลงปลูกปีพ.ศ.2541และป่าดงเซ็งไม่แตกต่างกันอย่างมีนัยสำคัญเช่นเดียวกับในแปลงปลูกปี พ.ศ. 2543 และ 2545 ที่ความเชื่อมั่น95% ในแหล่งศึกษาทั้งหมดความชื้นสัมพัทธ์ไม่แตกต่างอย่างมีนัยสำคัญที่ความเชื่อมั่น95% และใช้ วิธีวิเคราะห์ Principal Coordinates Analysis (PCA) และ Detrended Correspondence Analysis (DCA)ด้วยโปรแกรมMVSP3.1(Multivariate Statistical Package) เพื่อหาความสัมพันธ์ระหว่างกลุ่มไลเคนและปัจจัยแวดล้อมต่าง ๆ พบว่า ค่าความเป็นกรด-ด่างของเปลือกไม้, อุณหภูมิ, ความชื้นสัมพัทธ์, ปริมาณความเข้มแสงและความสูงจากระดับน้ำทะเล ต่างมีผลต่อการกระจายและความหลากหลายของไลเคนในแต่ละแหล่งที่ศึกษา พบว่าการศึกษาในป่าเขตอบอุ่นเรื่องกลุ่มไลเคนและปัจจัยสภาพแวดล้อมมีมาก แต่การศึกษาในป่าเขตร้อนยังมีน้อยมาก การศึกษานี้อาจเป็นจุดเริ่มต้นพยายามทำความกระจ่างที่จะเข้าใจกระบวนการฟื้นคืนความหลากหลายของไลเคนในแหล่งที่มีการฟื้นฟูป่าในประเทศไทย อย่างไรก็ตาม ในอนาคตจำเป็นที่จะต้องเพิ่มการศึกษาให้มากขึ้นเรื่องการฟื้นคืนความหลากหลายของไลเคนในป่าเขตร้อนและการฟื้นฟูป่าเพื่อหาดัชนีชีวภาพที่เหมาะสมใช้ติดตามการฟื้นคืนของป่า

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ABBREVIATIONS AND SYMBOLS

° C	Degree celsius
°	Degree
95%CI	95 percentage of confidential interval
cm	Centimeters
ed. (eds.)	Editor (editors)
et al.	*et alii*; and others
etc	*et cetera*; and the others, or and so forth
g	Grams
GBH	Girth at breast height (cm)
m	Metre (SI unit of length)
ml	Milliliters
no.	Number
p. (pp.)	Page (pages)
sp.	Species (usually a single species)
spp.	Species (usually many species)

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CHAPTER 1

INTRODUCTION

Tropical forests support a large portion of the world's biological resources, richness and diversity. Although tropical forest contains many important natural resources, it is continuing to be lost and degradation, by many causes such as fire; both natural and man-made, over-logging; both legal and illegal and over-exploitation of forest resources by the rapid growth of the human population and other development projects (Elliott, 2000)

Thailand at present has only about 18 % forest cover, compared with 53 % cover in 1961, and lately reported 22.8% or 111,010 km^2 (FAO, 1997). These figures, however, do not represent true image or proportions of plantations and natural forest. Thailand's natural forest cover is unofficially estimated to be 20% (Leungaramsri and Rajesh, 1992). The rate of forest loss peaked in 1977 and fell to its lowest level in 1989 when commercial logging was banned. National parks and wildlife sanctuaries cover 14.2 % of the country, but large areas of these invaluable national treasures are deforested and fragmented (Bontawee *et al.*, 1995).

Habitat loss affects plant species in many ways, for example, by reducing population sizes, altering the density of reproductive individuals, reducing reproductive success, increasing isolation and reducing genetic diversity. Founder effects, genetic drift and restricted gene flow increase inbreeding, genetic isolation and divergence (Bawa, 1994). Such processes may also influence the evolutionary potential of populations and species, particularly if adaptive genetic variation declines to a point where populations can no longer adapt to changing environmental conditions (Young *et al.*, 1993). Most

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remaining forest is located in the northern region where the rate of reforestation is highest (Wood and Elliott, 2004).

In northern Thailand, large areas in national parks and wildlife sanctuaries have been deforested. Solving this problem needs all efforts and the involvement of both government and non-governmental organizations and local communities in the processes of reforestation and restoration of these forests. While the continuation of forest loss in the tropics destroys biological resources, forest restoration is becoming an important tool to conserve biodiversity. Deforestation is one of the most serious threats to biodiversity in developing countries. It causes floods, soil erosion, diseases (owing to the loss of organisms that help to control vector populations), and degradation of watersheds and destruction of wildlife habitats. Deforestation may extirpate populations and reduce genetic diversity within populations (Kanowski, 1999).

The framework species method of forest restoration has been successfully used to accelerate biodiversity recovery on degraded forest land in northern Thailand (Wood and Elliott, 2004). The Forest Restoration Research Unit (FORRU) has successfully restored evergreen forest in upland sites in the areas of Chiang Mai, Thailand. FORRU carries out research to develop appropriate methods to accelerate regeneration of natural forest ecosystems on degraded land (Wood and Elliott, 2004).

In 1997, FORRU established field plots to test potential "framework tree species" at Mae Sa Mai village located within Doi Suthep-Pui National Park. The planted trees were all native forest species (Wood and Elliott, 2004). This method involves planting 20-30 indigenous, forest tree species, selected for their ability to accelerate forest regeneration and biodiversity recovery. The planted trees restored forest structure and functioning, while animals attracted by the planted trees brought in the seeds of non-planted tree species (recruit species). This method was tested by establishing experiment

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plots in Doi Suthep Pui National Park from 1998 to 2006. The plot system was increased each year since 1997, so that in 2006 the plots range in age from recently planted to 9 years old. Therefore, this area is suitable for a study of how lichens communities change at the different stages of forest restoration.

Lichens are important components of biodiversity. They are very responsive to environmental stressors, including changes in forest structure, air quality, and climate. The diversity of lichens depends on many factors including climate, forest types, forest age, tree density, spatial arrangement of trees and proximity to lichen propagule sources (Gries, 1996). Epiphytic lichens also have important biological roles in many forests, including nitrogen fixation, food for animals and nesting material for small mammals and birds (Nash III, 1996). Lichens tend to be long-lived and are highly habitat-specific organisms. They tolerate extremes of heat and cold environments and grow on all types of substrata and habitats. Thus, they make ideal monitors and can be used to estimate species diversity and habitat potential at all times of the year. Lichens differ substantially from higher plants because of their poikilohydrous nature this, combined with other physiological processes, makes lichen growth particularly susceptible to climatic variations, pollution and other environmental factors and liable to changes at genetic, individual, population and community levels. Lichens have been used as predictive tools for investigating land forming processes and rates of environmental change. They have also been used to resolve environmental issues, involving management of natural resources, such as the effects of fragmentation and habitat alteration; the structure and management of forested stands, the ecological continuity on space and time of the natural or semi-natural forests, effects of development on biodiversity, the effectiveness of conservation practices for rare or endangered species, and the protection of genetic resources. Because of their excellence as predictive organisms, lichens have been used in

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different countries as bioindicators of high value forests for conservation and to identify important biodiversity sites, with thousands of papers published in the last decades. The significant correlations found between stand age and lichen species-richness in several forests substantiates the importance of old or died trees, and related factors, as a habitat for lichens (Wolseley and Aguirre-Hudson, 1991; Will-Wolf, 2000).

However, while most studies have been done in temperate zones very few have been done in tropical regions. Previous studies and research of lichen diversity in northern Thailand, suggest that lichens can be used for estimating rates of change in a seasonal tropical forest environment (Wolseley and Aguirre-Hudson, 1991).

Research in evergreen and deciduous plots in limited areas of forest in northern Thailand suggests that much of the lichen diversity in deciduous dipterocarp forest is of recent origin. These forests support very low lichen diversity, absence of indicator species of this forest type, combined with a low frequency of relict species of the former evergreen forest (Wolseley and Aguirre-Hudson, 1997a). Fire in tropical dry forests affects corticolous lichens diversity which can be used as indicators of recent ecological changes in Thailand (Wolseley and Aguirre-Hudson, 1994).

The investigation reported here provides information on how lichen species can be used as monitoring indicators of forest recovery. Thus, lichen diversity in reforestation plots of different ages, was studied and compared with that in nearby natural forest, to observe similarity and lichen diversity in each study sites.

The main objectives of this study were; (a) to classify lichen taxa present in forest restoration plots of different ages, (b) to determine the effects of tree species on lichen colonization, and (c) to determine the effects of tree age on lichen colonization.

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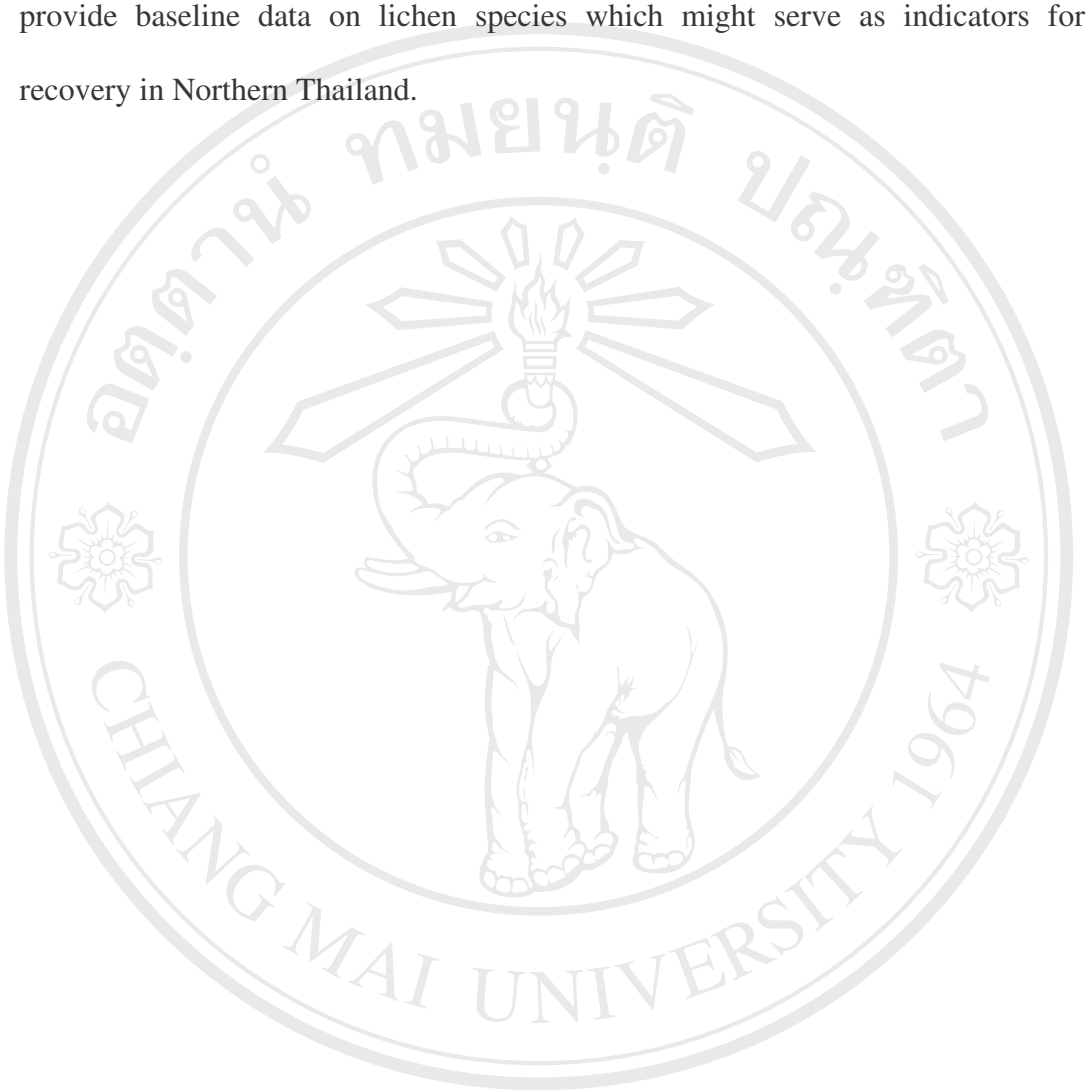
The usefulness expected from this study was to provide information on the recovery of lichen communities on trees at different forest restoration stages and to provide baseline data on lichen species which might serve as indicators for forest recovery in Northern Thailand.



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CHAPTER 2

LITERATURE REVIEW

2.1 Lichen biology

2.1.1 Introduction

Lichens are organisms composed of a fungus (Ascomycetes or seldom Basidiomycete) and an alga (green algae (Chlorophyta) and blue-green cyanobacteria (Cyanophyta)) living together in a symbiotic relationship. Symbiosis is the phenomenon of organisms sharing each other's life processes, for the benefit of both with both organisms gaining something but not always equally from the association (Baron, 1999). They form characteristic mosaics of colour, varying from yellow and red to blue-gray, to green or brown. The fungal component of lichens depends on dead organisms for their food supply, and occurs commonly as saprophytes or parasites in lichens. The algal or cyanobacteria (blue-green alga) component of lichens produce a food source for the fungus, carbohydrates, by photosynthesis (Wolseley and Aguirre-Hudson, 1997a). The alga provides the fungus with carbohydrates, some vitamins and even fixes nitrogen from the air (Campbell, 1990).

Whereas free–living green algae (e.g. bright green *Trebouxia* or orange-yellow *Trentepohlia*) or a blue-green to grey cyanobacterium (e.g. *Nostoc*) are more frequent in habitats with high moisture content, fungi are found in a great variety of habitats, and are often tolerant of extreme conditions of drought or heat. Lichens with cyanobacteria are more frequent in montane forests, where relative humidity is high. These taxa also fix nitrogen in moist conditions, and the subsequent production of amino compounds often

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gives them a fishy smell when wet. Lichens with green trebouxioid algae are light-demanding and are usually more frequent in open well-lit situations, whereas lichens with *Trentepohlia* are more frequent in shaded, moist forests. The thallus shape is mainly determined by the fungus (mycobiont). The same fungus may be found in two or more forms in partnership with another alga or cyanobacterium, but growth of the lichen thallus is dependent on the photosynthetic products of the photobiont. The fungus must expose the photobiont to the best conditions for photosynthesis, and provide protection from extreme conditions. This successful combination in lichens allows the photobiont to exist in extreme habitats and the fungus to obtain nutrients (Wolseley and Aguirre-Hudson, 1997a). Lichens do not have flowers, seeds or true roots, no protective cuticle and rely completely on atmospheric sources for nutrients, making them sensitive to environmental stressors (Gries, 1996). Lichens are long-living, sessile organisms with a low dispersal potential and a high sensitivity to environmental influences, changes in landscape management and past regional ecological disturbances such as fire and forest clearance. Epiphytic lichens depend on a range of climatic parameters, which are related to forest stand, structure and history (Asta *et al.,* 2002).

2.1.2 Morphology and growth pattern

Lichens grow on many difference substrates; on the bark and leaves of trees, on rocks and earth and on man-made objects. Lichens have a very wide range of growth forms. They are categorized by main five morphological types (Hale, 1979; Wolseley and Aguirre-Hudson, 1997b; Baron, 1999);

1) Crustose is the simplest form of lichen which is a crust growing on substrate. Crustose lichens are highly variable in anatomy. However, they all tend to be adnated or

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attached directly to their substrate. Their growth is radial, in that the mitotic regions are at the margins, and the centre is more likely to be dying.

2) Foliose lichens have a sheet-like structure, and are often attached to their substrate by root-like rhizines. The thallus is highly differentiated, with the lower surface being an absorptive tissue and the photobionts being held in a manner that maximizes photosynthesis. Commonly, the upper surface is fungal tissue, with the mid-layer containing the photobionts. Their growth is lobed at the margins.

3) Fruticose lichens attach to their substrate by a holdfast. The main body of the lichen is either erect or pendulous, and is commonly highly branched. Growth takes place at the ends of the "stems" and may be quite complex.

4) Squamulose lichens consist of small scale-like structures in separate thalli or lobes, lacking a lower cortex, scattered on hypothallus of fungal hyphae or directly on the substrate.

5) Placodioid lichens have disc-like thalli closely appressed to the substrate, with lobes that extend radially. In structure they are often crustose in the center with appressed foliose marginal lobes.

However, mostly lichens are divided into three main types (Figure 2.1). Foliose and fruticose lichen thalli are sometimes referred as *macrolichens* and crustose and other smaller types as *microlichens*. A section through a typical foliose lichen thallus has four layers of interlaced filaments (fungus). The upper layer is formed by densely agglutinated fungal hyphae, forming a protective outer layer called the cortex. Cyanobacteria may be held in small eruptions or under the surface, called cephalopodia. Beneath the upper cortex is an algal layer, composed of algal cells embedded in rather densely interwoven fungal hyphae. Each cell or group of cells of the photobiont is usually individually wrapped in hyphae, and in some cases penetrated by a haustorium. Beneath the algal layer

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is a layer of loosely interwoven fungal hyphae without algal cells. This layer is called the medulla. Beneath the medulla, the bottom surface resembles the upper surface and is called the lower cortex, consisting of densely packed fungal hyphae (Figure 2.2). The lower cortex often bears structures, such as rhizines or a tomentum, which attach the thallus to the substratum on which it grows. Lichens also sometimes contain structures made from fungal metabolites, for example crustose lichens sometimes have a polysaccharide layer in the cortex. Although each lichen thallus generally appears homogeneous, it may consist of several different species of fungus and photobiont living together.

(a) (b) (c)

Figure 2.1 Three main types of lichen (a) crustose (b) foliose and (c) fruticose

Figure 2.2 Cross-section of lichen thallus (http://www.ru.ac.th/lichen/Th/lichenLife.htm)

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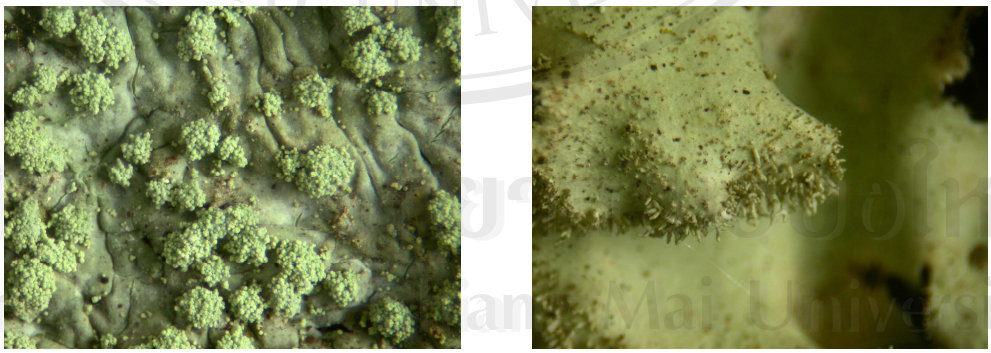
2.1.3 Reproduction and dispersal

Lichen reproduction occurs by germination of spores or multiplication of the cells of the soredia and isidia. Lichens most frequently reproduce asexually, either by vegetative reproduction or through the dispersal of diaspores containing algal and fungal cells. Soredia (sing. soredium) are small groups of algal cells surrounded by fungal filaments that form in cavities called soralia, which open when the lichen dries or surrounding tissues die and release the soredia to be dispersed by wind or bird and insects. Another form of diaspore is isidia, elongated outgrowths from the thallus that breaks off for dispersal by wind or bird and insects (Figure 2.3). Fruticose lichens in particular can easily fragment. Many lichens break up into fragments when they dry, dispersed by wind or bird and insects. to resume able to growth when moisture returns (Baron, 1999; Seaward, 1977). These reproductive structures are dispersed in the atmosphere by wind or transported by birds and insects. If they fall into cracks, pores or cavities that retain water, new growth may arise (Garty, 1992).



(a) (b)

Figure 2.3 Asexual reproductive structures (a) soredia (b) isidia

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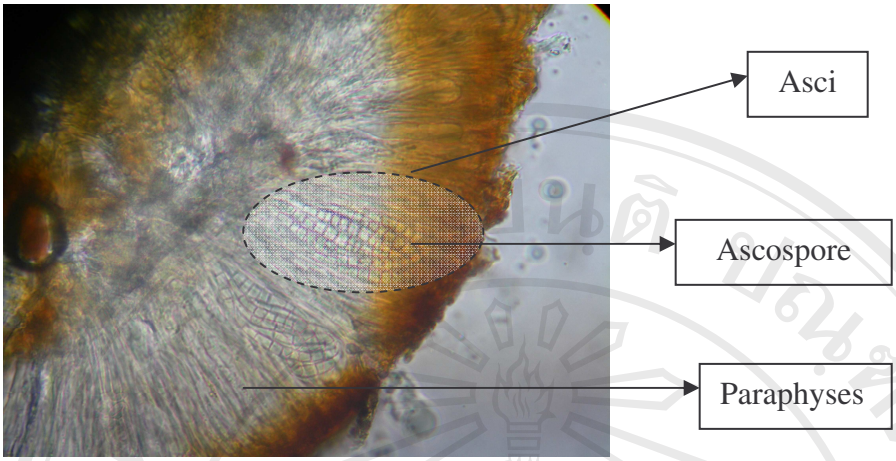

Figure 2.4 Cross-section of fruiting body of crustose lichen

Lichens also reproduce sexually by spores arising from fruiting bodies, formed by sexual reproduction of the fungal partner only (Figure 2.4). Dispersed in the environment, they reconstitute a symbiosis if they encounter suitable phycobionts. This is not a common means of reproduction for most lichens, though it is more common in basidiomycetous lichens, since they lack specifically evolved structures for asexual reproduction. Spores are produced in spore-producing bodies (fruiting bodies); the three most common spore body types are the apothecia, perithecia and the pycnidia (Baron, 1999; Seaward, 1977) (Figure 2.5).

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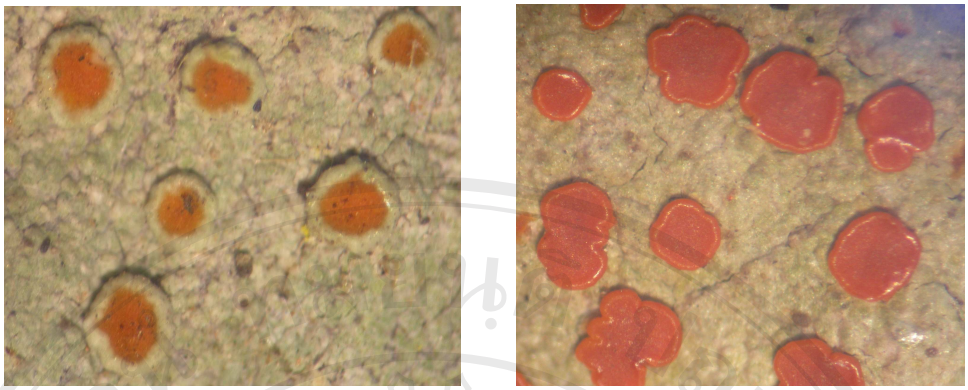

(a) (b)

(c) (d)

Figure 2.5 Sexual reproductive structures (a) Lecanorine apothecium (b) Lecideine apothecium (c) Perithecium (d) Lirellate apothecium

Lichens can tolerate almost any environment from tropical rain forest to arctic conditions. Their diversity in cool or temperate climates is equaled or surpassed by their diversity on tropical climates (Lucking, 1999a). Various lichen species respond differently to changes in forest structure, air quality and climate. These attributes enable researchers to use lichen community composition as a biological indicator of forest ecosystem dynamics (Longton, 1992). However, they are species sensitive to differing ecosystems. The microclimatic abiotic parameters and limiting factor important to lichen growth such as light intensity, humidity, altitudinal and the chemical nature and the

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texture of the substrate and microclimatic variables are seem to have the greatest effect on lichen diversity (Hawksworth and Rose, 1976 ; Lucking 1999b).

2.1.4 Ecology of lichens

Lichens are "functionally photosynthetic" symbioses, meaning that, like plants, they derive their energy for growth and reproduction directly from sunlight throught the photosynthetic activities of the algal partner (Ahmadjian, 1993). Lichens must compete with plants for access to sunlight, but because of their small size and slow growth, they thrive in places where higher plants have difficulty growing. A major ecophysiological advantage of lichens is that they are poikilohydric (poikilo- variable, hydric- relating to water), meaning that they have little control over their hydration status and can tolerate irregular and extended periods of severe desiccation. Like some mosses, liverworts, ferns, and a few "resurrection plants", upon desiccation, lichens enter a metabolic suspension or stasis (known as cyptobiosis) in which the cells of the lichen symbionts are dehydrated to a degree which halts most biochemical activity. In this cryptobiotic state, lichens can survive wider extremes of temperature, radiation and drought in the harsh environments they often inhabit. Lichens do not have roots and do not need to tap continuous resevoirs of water like higher plants, thus they can grow in locations impossible for most plants, such as bare rock, sterile soil or sand, and various man-made structures such as walls, roofs and monuments. Many lichens also grow as epiphytes (epi- on the surface, phyte- plant) on other plants, particularly on the trunks and branches of trees. When growing on other plants, lichens are not parasites; they do not consume any part of the plant nor poison it (Ahmadjian, 1993). Some ground-dwelling lichens like members of genus *Cladina* (reindeer lichens), however, produce chemicals which leach into the soil and inhibit the germination of plant seeds and growth of young plants. Stability (that is,

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longevity) of their substratum is a major factor of lichen habitats. Most lichens grow on stable rock surfaces or the bark of old trees, but many others grow on soil and sand. In these latter cases, lichens are often an important part of soil stabilization; indeed, in some desert ecosystems, vascular (higher) plant seeds cannot become established except in places where lichen crusts stabilize the sand and help retain water.

Lichens are an ideal group to monitor for changes in diversity in ecosystems. Factors tending to enhance diversity of lichens are late-successional status, open structure with high light levels, lack of dominance by bryophytes (e.g., mosses and liverworts), and high moisture levels (Wolseley and Aguirre-Hudson, 1997a). Factors tending to decrease diversity are early successional status, dense stands with poor light, and either very dry climates or extremely wet climates promoting dominance by bryophytes (Longton, 1992). Lichens often occur at the bases of trees which have higher humidity and nutrient enrichment (Pirintsos *et al*., 1993).

Eversman, *et al.* (1987) studied vertical distribution of epiphytic lichens on three tree species in Yellowstone National Park. Their work suggested that different tree species had different hosting qualities which determined the groups of lichens living on them. The different hosting qualities included levels of water retention by outer bark, bark pH, and bark texture (smoothness, scaliness), and barks' ability to prevent fast desiccation, all of these qualities contributed to microhabitat variations of lichens.

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2.1.5 Colonization and succession of lichens

Lichens are classic pioneer and colonizers in a wide range of environments. They grow on the bark of temperate trees or as epiphytes on the leaves of tropical rain forest trees. Others occupy some of the most inhospitable environments on earth, growing on

cooled lava flows and bare rock surfaces, where they help in the process of soil formation, and on desert sands where they help to stabilize the surface and enrich it with nutrients (Nash, 1996).

Lichens are amongst the slowest-growing organisms, but their tolerance of environmental extremes enables them to colonize habitats where few other macroscopic organisms can grow (Nash, 1996). They grow where neither the fungal partner nor the photosynthetic partner could survive alone, because they benefit from their unique symbiotic association

The responses of single lichen species to changes in the environment vary considerably, indicating differences in competitive ability and ecological strategy between the species (Armstrong, 1988; Topham, 1977). Successful regeneration of lichens depends on germination of spores, or establishment of vegetative propagules under proper conditions. The floristic composition of epiphytic lichen communities is determined by substratum qualities such as age (of the part of the tree where the lichen is growing), bark texture, and bark chemistry and by habitat conditions such as age and history of forest, forest productivity, aspect and climate (Barkman, 1958 , Brodo ,1974).

The ecological strategies in lichen may reflect variety of community and their habitats. Rogers (1990) found that ecological strategies relate to growth from, mode of asexual reproduction, substratum reference, family relationship, diversity and quality of chemistry. These prove to be important for lichens to establish and survive in different ecosystems. Strategies may be defined as a grouping of similar or related genetic characteristics with recur widely among species or populations and cause them to exhibit similarities in ecology (Rogers, 1990). In natural ecosystem, Dale and John (1999) found habitats diversity and environment factors influence on pattern of lichen dispersal and their communities.

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Positive interaction among plants seems to be a fundamental process in plant communities. There are many examples in the literature as to how a plant may facilitate other plants and other organisms, either directly by improving the environmental characteristics (e.g. increasing the availability of the resource) or indirectly (e.g. providing protection against herbivores, or shade) (Callaway, 1995). Therefore, trees clearly act as facilitators for epiphytic lichens, as they provide them with a substratum, and with access to light or other ecological factors, such as a specific pH of bark, or humidity (Callaway, 1995). Facilitation mechanisms are better observed in the early stages of primary successions, but also of secondary successions in disturbed ecosystems. Facilitation increases diversity and productivity and is important in recovery from disturbances (Callaway, 1995). Epiphytic lichens, as with other epiphytes, may depend on plant and microhabitat facilitation to become established during early stages of a plant community. However, the few studies on the colonization of new substrata by epiphytic lichens do not provide data on facilitation, as they have been carried out in already established forest habitats (Degelius, 1978; Stone, 1989).

2.2 Benefit of lichens

Lichens are a part of the food available for many animals, such as reindeer, living in arctic regions. The larvae of a surprising number of Lepidoptera species feed exclusively on lichens. However, Lichen is very low in protein and high in carbohydrates, making it unsuitable for some animals. Lichen is also used by the Northern Flying squirrel for nesting and a water source during winter (Brodo *et.al*, 2001). Because of their association with cyanobacteria, lichens can provide themselves with nitrogen compounds (Ahmadjian, 1993). Lichens contribute to the nitrogen cycle by converting the nitrogen in the air into nitrates that contribute to their growth and development. Their ability to fix

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atmospheric nitrogen is beneficial to other plant life as well. When it rains, nitrogen is leached from both living and dead lichens and is available to plant life in the immediate areas. When lichens die, they contribute decayed organic matter to the area they inhabited, which enables mosses and seeds from vascular plants to begin developing among the pockets of new soil. Animals utilize lichens in many ways (Brodo *et.al*, 2001). It is well documented that numerous animals use lichens for either food or shelter. Some 50 species of birds are known to regularly use fruticose-type lichen as their preferred nesting material. Small animals commonly use lichens to hide from natural predators through camouflage and direct cover (Brodo *et.al*, 2001).

Historically, lichens have had economic benefit. For many years, over different parts of the world, they have been a source of natural dyes for wool and fabric. These dyes were distinguished by the type of lichens used and the way the color was extracted. Lichen dyes are extracted by the boiling-water method or the fermentation method. Today, they are still used by local artisans as they demonstrate their crafts (Adrosko, 1971). Some lichens have antibiotic properties that are valuable commercially. The genus *Usnea* is used in Europe in ointments and other commercial products and aid healing in superficial wounds. Lichens have been used in such preparations as deodorants, laxatives, expectorants, tonics, and healing pastes throughout the years (Lawrey, 1984). Research with lichens around the world is suggesting these organisms hold promise in the fight against certain cancers and viral infections, including HIV (Vartia, 1973). In the ornamental horticulture profession, lichens are preserved in glycerine, painted different colors, and made available commercially to the floriculture industry for dried-flower decorative arrangements (Grae, 1974; Kramer, 1972).

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2.3 Lichens as indicators of environmental conditions

Although lichens typically grow in harsh environments in nature; many lichens are sensitive to man-made pollutants. Hence, they have potential as pollution indicator organisms (Brodo *et.al*, 2001). Lichens are sensitive to changes in atmosphere and micro-climate conditions and have long been used as environmental bioindicators for air pollution and environmental changes in seasonal tropical forests (Wolseley and Aguirre-Hudson, 1997a)

Generally, the most important ecological factors are light availability, bark pH, level of eutrophication and precipitation. Besides the fact that in extensively managed habitats the lichen flora can often be more species rich than vascular plant flora, lichens can be monitored during the entire year, making them a potential tool for a biodiversity assessment (Scheidegger *et al*. 2002)

High diversity of lichens in the tropical forest was mostly influenced by different host trees species. Heterogeneity and high diversity of host trees is more important for having high biodiversity of lichens. Therefore, lichen-host relationship needs to be further explored in order to establish a baseline for conservation priority. With high diversity of host trees related to high numbers of lichens species of these habitats. From this point, lichens can be used as bioindicators of habitat change in the future. Lichens should be included in research and monitoring studies because they tend to be more responsive to environmental changes and more sensitive to disturbance than vascular plant and lower plant (Nash, III and Olafsen, 1995).

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Comparative studies of lichen communities can be conducted in many ways depending on the purposes of the studies and suitable methods specific for data collection in the field. McCune and Lesica (1992) suggest various field methods for measuring

lichen coverage. For example, the whole plot ocular can be used to record cover class for each species encountered. The belt-transect can be used for estimating coverage of all species encountered in each tree belt transects detained by the sampling lines. Whereas the microplot plots to estimate all species encountered in microplots placed along each of the sampling lines. However, they recommend sub sampling with small quadrates when vegetation is relatively dense, or belt transects with sparse vegetation to represent effectively both species diversity and coverage. The recent study on lichen communities has been focusing on thallus covered. The recommended method to use is Microplot sampling for assessment (McCune and Lesica, 1992). The size of quadrate must be considered in relation to the size of the studied organisms (McCune and Lesica 1992).

However, Wolseley and Aguirre-Hudson (1997) used many varied sampling plots (13 x 19 cm or 247 cm^2, 10 x 15 cm or 150 cm^2, and 5 x 20 cm or 100 cm^2) to study lichen communities in tropical dry forest as indicators of recent ecological changes in Thailand. Use of several sizes of sampling plot for investigation of lichen communities depended on purpose of the study.

Studies in temperate zones have shown that lichens are found in healthy forest but in tropical zone there have been few studies on this subject. However, the distribution of lichens in lowland deciduous and evergreen forests in Thailand has been used to interpret recent changes in forest (Wolseley and Aguirre-Hudson, 1997a). The role of lichens in ecosystem processes and biodiversity also makes them a useful group to monitor. Lichens represent a significant proportion of biodiversity in many ecosystems (McCune, 2000). A study in boreal forests of Scandinavia showed increasing diversity of spiders with increasing lichen diversity (Pettersson, 1996). It has been suggested that forest bird diversity may also be associated with lichen diversity (Pettersson, 1996).

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Furthermore, the lichen communities provide information relevant to several key assessment questions, including those concerning contamination of natural resources, biodiversity, and sustainability of timber production (Wolseley and Aguirre-Hudson, 1994). Corticolous or epiphytic lichens are slow-growing and slow to colonize new environments and their sensitivity makes them useful tools in interpreting changes over long periods of time (Wolseley and Aguirre-Hudson, 1994). Lichens not only indicate the health of our forests and forest productivity, but there is also a clearly established linkage to environmental stressors. Lichens have been used as predictive tools for investigating land-forming processes and rates of environmental change (Will-Wolf, 2000). They have also been used to resolve environmental issues, involving management of natural resources, such as the effects of fragmentation and habitat alteration; the structure and management of forest stands; ecological continuity on space and time of natural or semi-natural forests; effects of development on biodiversity; the effectiveness of conservation practices for rare or endangered species, and the protection of genetic resources (Gradstein, 1992).

2.4 Edge effects on epiphytic lichen in fragmented forests

Most forest ecosystems in the world have been fragmented by logging and other human disturbance, resulting in a highly dissected landscape pattern. Loss of interior forest, increased isolation, decreased size of remnant stands and increased of edge habitat may have severe effect on biodiversity (Forman, 1995; Peterken, 1996; Turner, 1996; Zuidema *et al.*, 1996). The forest edges in the landscape rapidly increases in the phase of the fragmentation process but may eventually decrease the natural forest has been lost (Franklin and Forman, 1987; Murcia, 1995; Laurance and Bierregaard, 1997).

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Edge effects affect the microclimate, tree mortality and increase predation on bird nests (Lovejoy *et al.*, 1986; Saunders *et al*., 1991; Chen *et al*., 1993; Esseen, 1994; Paton, 1994; Andrén, 1995; Coutts and Grace , 1995; Ferreira and Laurance, 1997).

Forest fragmentation over a landscape affects both habitat quality and quantity. By reducing the total area of continuous forest cover, forest fragmentation decreases the quantity of available habitat, and by changing the physical environment of the remaining forest fragments; it affects the quality of the remaining habitat. Changes in the physical environment of forest fragments include increased wind exposure and higher levels of solar radiation (Camargo and Capos, 1995; Sillet *et al.*, 1995; Malcolm, 1998). As a result, conditions for plant growth often become warmer and drier and shade-tolerant species are replaced by shade intolerant species (Smith, 1996). The understanding of plant and animal responses to edges to formulate adequate guidelines for conservation of biodiversity (Yahner, 1988; Laurance and Yensen, 1991). Unfortunately, progress in understanding edge-related patterns and processes has been slow for several reasons, including lack of replication, inconsistent methodology, and oversimplification of the definition of edge and edge effects (Malcolm, 1994; Murcia, 1995). Edge effects are difficult to study because of the many variables involved, such as orientation, physiognomy, matrix characteristics, forest structure, and climate. In addition, edge phenomena also may vary strongly with edge age, but this has received only limited attention. For example, the density of forest birds may initially increase after isolation of forest patches because of displacement of individuals, and thereafter decrease over time (Lovejoy *et al.*, 1986; Hagan *et al.*, 1996). The complex nature of the forest edge environment calls for studies designed to analyze interactions among the factors influencing edge effects (Esseen and Renhorn, 1998; Murcia, 1995).

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Lichens are particularly sensitive to climate changes because they gain most of their nutrients from atmospheric sources and because they are poikilohydric, lacking mechanisms for regulating uptake and loss of water (Nash and Olafsen, 1995). Epiphytic lichens may also be strongly affected by altered forest microclimate. For example, the threatened foliose lichen *Erioderma pedicellatum* vanished from its single location in Sweden apparently because of altered microclimate following cutting of the surrounding forest (Jørgensen, 1978).

Sillett (1994) found marked growth reductions in two foliose cyanobacterial species transplanted to the edge of a temperate Douglas-fir forest and attributed this to desiccation reducing the time for photosynthetic activity. Large, pendulous lichens may be particularly sensitive to edge effects because the thalli are prone to fragmentation by wind. For example, in *Usnea longissima*, which can reach a length of several meters, Esseen and Ericson (1982) observed damaged thalli up to 40 m from a clearcut edge at an exposed location. *Evernia divaricata*, which mainly occurs in humid forests, disappeared from nine populations within a few years following cutting of the surrounding forest (Sjöberg and Ericson, 1992). Unfortunately, most previous studies of lichen response to edges have been made at a single location and thus constitute a weak basis for generalization. Fruticose lichen *Alectoria sarmentosa* is a widespread, circumboreal species that grows mainly on conifers was significantly influenced by edge effects at multiple sites in fragmented boreal coniferous forests (Esseen and Renhorn, 1998). *A. sarmentosa* should be particularly sensitive to fragmentation by wind and has been shown to be more sensitive to forest cutting than *Bryoria* spp. (Lesica *et al.*, 1991; Esseen *et al.*, 1996). Epiphytic lichens have large potential as indicators of forest edge effects (Esseen and Renhorn, 1998).

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2.5 Monitoring biodiversity and ecosystem function of lichen in forests

Lichens behave as natural sensors of atmospheric pollution because the symbiosis between fungus and alga has its weak points. High pollution, particularly by sulfur dioxide, damages the lichen thallus, first leading to retarded growth and then to death (Hawksworth and Rose, 1976). However, only a few studies (Holien, 1997) deal with the relationship between epiphytic lichens and potential biodiversity indicators, based on habitat and substratum variables. However, tree stand were will able to explain highly significant variation in lichen species diversity in both richness and composition (Pharo, 1997). In temperate and more recently in tropical regions, lichens have been used as reliable biological monitors of man-induced changes in forest ecosystems (Rose, 1992; Wolseley and Aguirre-Hudson, 1997a; Galloway, 1992; Stork and Samways, 1995). Preliminary investigations in seasonal tropical forest of northern Thailand suggest that corticolous lichens: (1) corticolous lichens are clearly associated with forest type; (2) corticolous lichens are vary in species-richness and composition within the range of forest types investigated; (3) corticolous lichens can be used to assess rate of change in forest types and to identify contributing factor (Wolseley and Aguirre-Hudson, 1991; 1994).

2.6 Lichens conservation

Some lichens, like many other living things on this planet are adversely affected by the human activities. Mostly, this is a result of habitat destruction by atmospheric and aquatic degradation. In other words the air and water are polluted, can be made these organisms that live almost entirely on air and water with directly relationship are continue decreasing. Although maintaining large areas of viable habitat in nature reserves, and protection against damage is important, ultimately only purification of the air and water

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will bring lichens back to their full potential. This will of course benefit every other living creature as well, particularly ourselves and should therefore be a top priority for all thinking human beings. Such organisms make up much of the biodiversity and often play critical roles in forested ecosystems. For example, old-growth temperate forests support a diverse array of epiphytic macrolichens and bryophytes (Lesica *et.al.*, 1991; Peterson and McCune, 2001; Price and Hochachka, 2001) whose diversity can exceed that of vascular plants in the same forest (McCune *et al*., 2000). Kantvilas, James & Jarman (1985) and Kantvilas & Jarman (1993) found that reduction in the size of native forest stands, especially rainforest, can destroy lichens and their habitats.

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CHAPTER 3

MATERIALS AND METHODS

3.1 Apparatus

3.1.1 20 cm width surveying grid frame with small units size of 2.5 x 2.5 cm^2

3.1.2 Study area map

3.1.3 Pocketknife

3.1.4 Hand lenses

3.1.5 Compass

3.1.6 Wet and dry thermometer

3.1.7 Altimeter

3.1.8 Measuring tape

3.1.9 Paper sampling bags

3.1.10 Dropper

3.1.11 Lichen identification keys

3.1.12 Pencil and waterproof pen

3.1.13 Recording form

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3.2 Chemicals

3.2.1 Potassium hydroxide (KOH) (10% solution)

3.2.2 Calcium hypochlorite

3.2.3 Paraphenylenediamine (Crystals)

3.2.4 Lugol's iodine (1g iodine with 2g potassium iodine in 300ml of water)

3.2.5 Iodine solution

3.2.6 Alcohol solution

3.2.7 Distilled water

3.3 Instruments

3.3.1 Compound microscope (Olympus model CH-BI45-2, Japan)

3.3.2 Stereo microscope (Olympus model SZ 3060, Japan)

3.3.3 pH meter (Scientific Instrument model IQ150, USA)

3.3.4 Oven (Scientific model 9000, USA)

3.3.5 Ultraviolet Lamp (Vilber Lourmat model VL-6.LC, France)

3.3.6 Global Positioning Systems (GPS) (eTrex, Garmin, Taiwan)

3.3.7 Digital lux meter (BEHA-93421, Germany)

3.4 Description of study area

The study area was situated within the north of Doi Suthep-Pui National Park, in a degraded watershed (18° 52´N, 98° 51´E) at 1,207-1,310 m elevation, near Ban Mae Sa Mai (an Hmong hilltribe community), Amphur Mae Rim, Chiang Mai, Thailand. The location of the plantation plots was decided in collaboration with the Forest Restoration Research Unit (FORRU) and the villagers of Ban Mae Sa Mai, a Hmong hill tribe community which is located about 2-3 km below the plots. About 10 rai of plots was planted every year with candidate framework tree species by FORRU and the villagers of Ban Mae Sa Mai since 1997 until 2006 , monitoring and plantation with new plants have been continually replanted. All trees are labeled so that their species and ages are known. Four sites; plots planted in 1998, 2000 and 2002 include Dong Seng forest were selected in this study (Figure 3.1 and Table 3.1).

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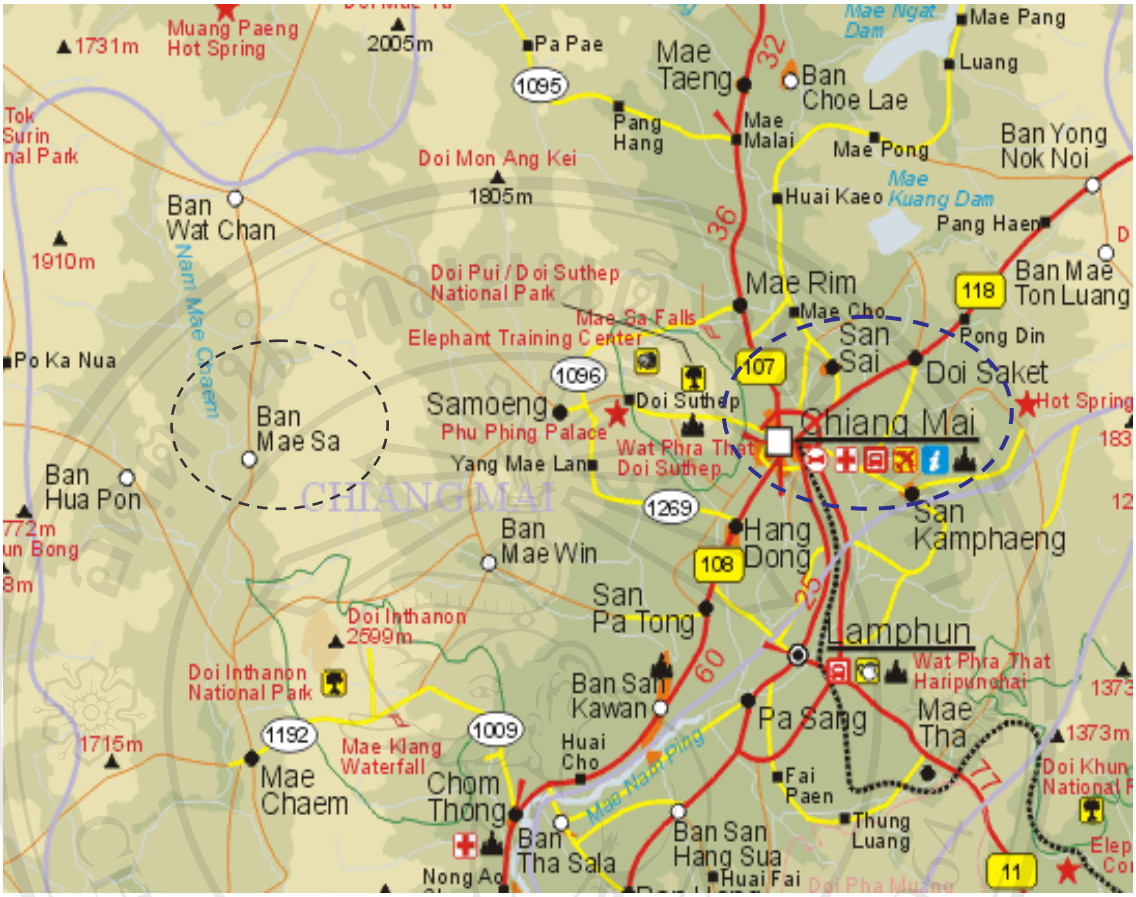

Figure 3.1 Map of Ban Mae Sa Mai (in the north of Doi Suthep-Pui National Park, Amphur Mae Rim, Chiang Mai, Thailand.)

(www.clickthai.de/Bilder/Karten/ThaiN70.gif)

Table 3.1 The location of four study sites

Study sites	Abbreviation	Elevation (mASL)	Location
Reforestation plot 2002	S1	1,260	N 18°51´579 ˝ E 098°50´983 ˝
Reforestation plot 2000	S2	1,300	N 18°51´768 ˝ E 098°50´895˝
Reforestation plot 1998	S3	1,330	N 18°51´446 ˝ E 098°50´879 ˝
Dong Seng forest	S4	1,370	N 18°51´26.5 ˝ E 098°52´194 ˝

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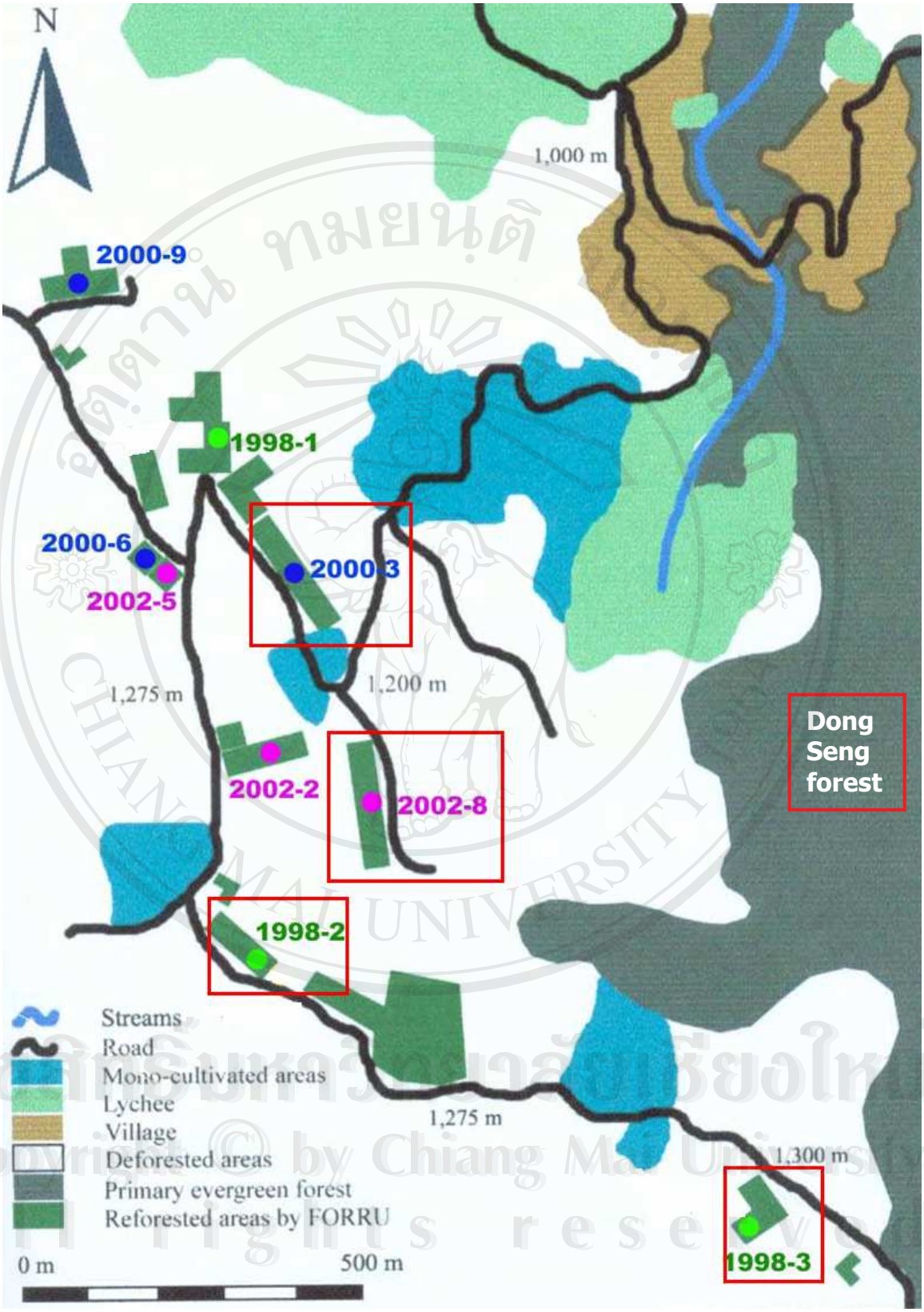

Figure 3.2 Drawing map of four study sites (from FORRU)

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3.5 General climatic condition

The local climatic data was measured during January 2005 to June 2006 by the Ban Mae Sa Mai Royal Project Center, at elevation of 880 m; about 4 km from this Ban Mae Sa Mai Royal Project Center to the study sites. The area has two main seasons: the wet season (March to April and September to October) and dry season (mean monthly rainfall below 100 mm in May to February except September and October). The dry season is subdivided into the cool-dry season (November to January) and the hot-dry season (February to March) (Figure 3.2).

The average temperatures in each month were not so much different, the lowest average temperature was in December 2005 and the highest average temperature was in April 2005 (Figure 3.2). The relative humidity from June 2005 to January 2005 was not so much different, lowest relative humidity was in May 2005, and the highest relative humidity was in September 2005 and November 2005 (Figure 3.2).

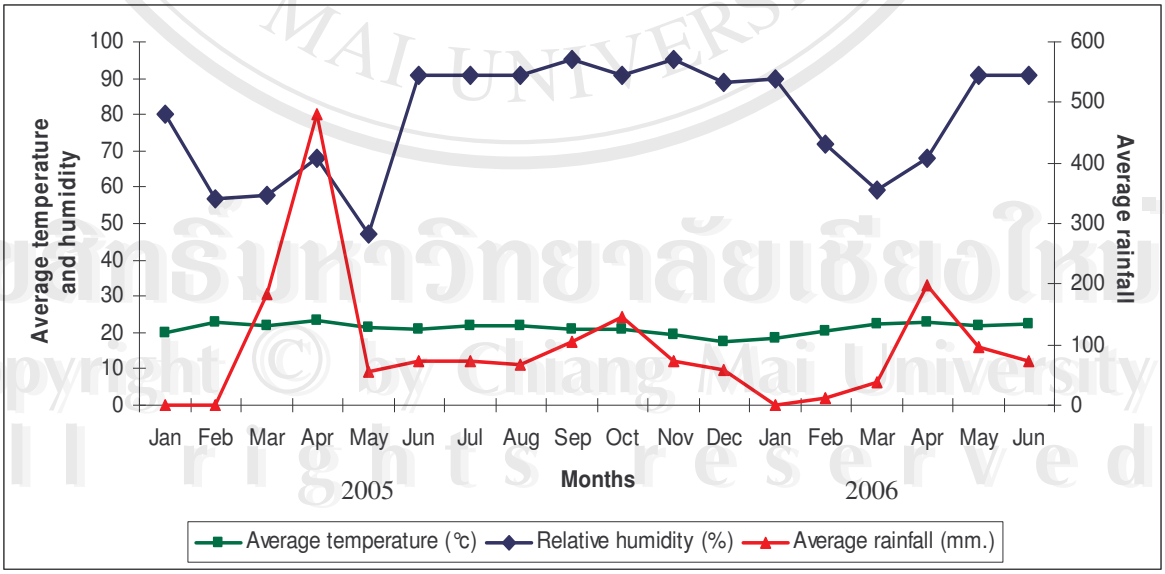

Figure 3.3 The average temperature, average rainfall and relative humidity during January 2005 to June 2006 (from Ban Mae Sa Mai Royal Project Centre)

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3.6 Sampling procedure

Tree species for lichen investigation in selected plots were randomly chosen from FORRU's planted tree species list database (Tree species and their ages). Free-standing trees were randomly selected in each plot. Injured or dead trees were not selected. The inclinations of trees did not exceed 10° from the vertical (Scheidegger *et al.*, 2002). Tree species were chosen to determine the effects of tree species on lichen colonization by using lichen diversity on the tree trunks of four proven framework tree species; *Hovenia dulcis* Thunb., *Melia toosendan* Sieb. & Zucc, *Prunus cerasoides* D. Don and *Spondias axillaris* Roxb planted by Forest Restoration Research Unit (FORRU) near Ban Mae Sa Mai Village. Ten trees of each species were investigated within each restored plots, enough to be representative of each plot. The number of investigated trees in natural forest (Dong Seng forest on Doi Mae Sa) depended on the number of selected tree species found (Figure 3.4). The lichen floras on these tree species in three reforestation plots planted in 1998, 2000 and 2002, were investigated and compared with that of nearby natural forest. A total of 150 sample trees were selected for lichen investigation: 120 trees in the reforestation plots and 30 trees in Dong Seng forest.

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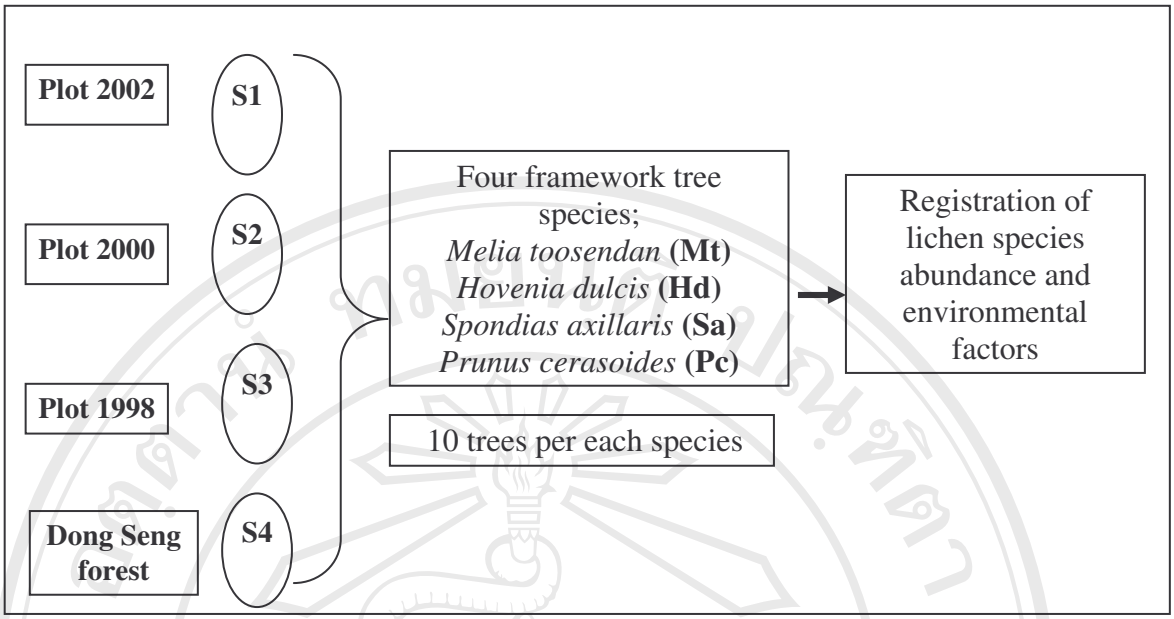

Figure 3.4 Sampling procedure

3.7 Registration of lichen species abundance and environmental factors

3.7.1 Registration of lichen species abundance

The sampling was done from December 2005 to June 2006. The lichen data were recorded using a commercial frame of 20 cm wide with a grid of small subunits 2.5x2.5 square centimeters. The frame was wrapped horizontally around each tree's girth 1 m above ground level. Lichen species, frequency of each species and percentage cover of each lichen species in each small unit of the sampling frame were recorded (Figure 3.6). Sterile crusts were separated into a sterile crust group and were not used for data analysis because it was not possible to identify the species. However, their percentage cover was recorded. Lichen data and additional data were recorded by using a record form (Appendix A) Lichen frequencies were recorded and percentage cover was calculated (Appendix B). Sampling method was standardized over the whole study area.

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The percentage cover of lichen was calculated as following;

$$\text{Percentage cover of lichen} = \frac{\text{Number of thallus within small units x 100}}{\text{Total number of small units}}$$

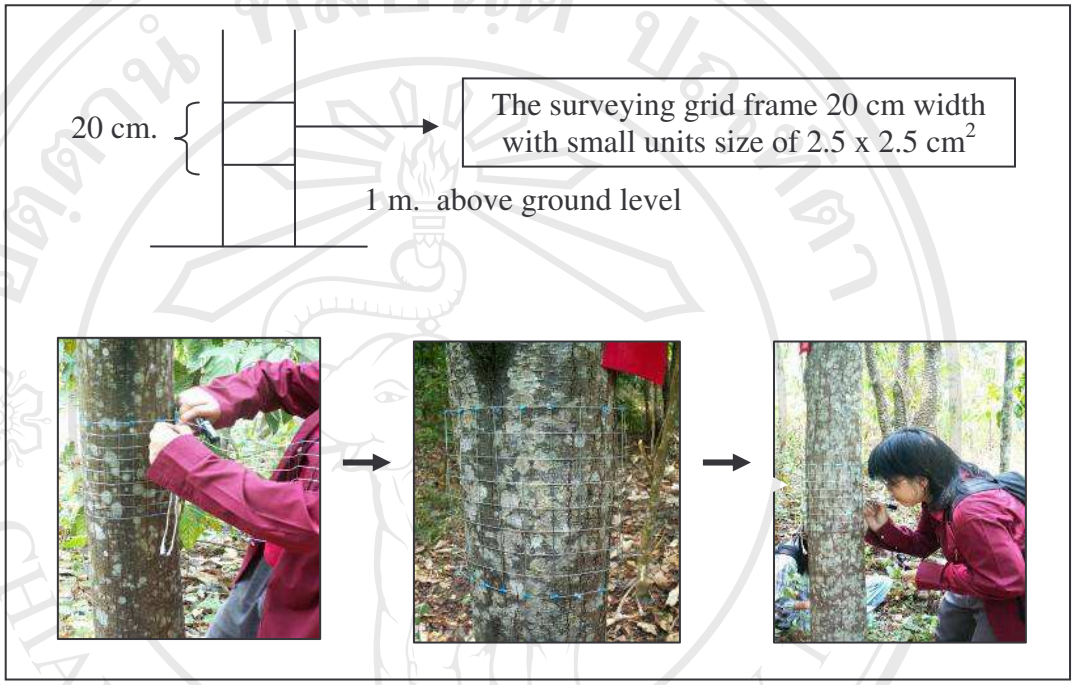

Figure 3.5 Registration of lichen species abundance

3.7.2 Recording of environmental factors

Environmental factors which influence lichen growth, such as elevation, temperature, light intensity, relative humidity, pH of bark, tree ages and tree species were recorded, using a record form (Appendix A).

3.8 Lichen identification

Easily recognized lichen species were determined in field, but if it was difficult to identify in field, chips of bark containing lichens were removed from the tree trunk with a pocket knife. Samples were identified later in the laboratory by using a stereo-microscope, a compound-microscope and chemical methods, using spot test technique.

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Lichens were identified using a field key of characteristic epiphytic lichens in northern Thailand (Wolseley and Aguirre-Hudson, 1997b) and other lichen identification keys (Sipman, 2003a, b, c; Malcolm and Galloway, 1997; Swinscow and Krog, 1988.; Awasthi, 1991). Some lichens were sent for identify by lichenologists (Dr.Andre Aptroot, Dr. Harrie Sipman, Dr. Laurens Sparrius and Dr.Patricia Anne Woseley).

3.9 Analysis of bark pH

Pieces of bark 2-3 mm thick without lichens were removed around respective tree trunk at 1 m above the ground using a pocket knife. Chips of bark were collected in plastic bags and stored in a freezer until analysis. The bark samples were dried at 80˚ C for 24 hours and then grounded. Samples of 2 g of ground bark were soaked with 10 ml distilled water. After 24 hours, pH of the solution was determined by using pH meter (Staxäng, 1969).

3.10 Data Analysis

3.10.1 Lichen diversity index

Biological diversity can be quantified in many different ways. The two main factors taken into account when measuring diversity are richness and evenness. Richness is a measure of the number of different kinds of organisms present in a particular area. For example, species richness is the number of different species present. However, diversity depends not only on richness, but also on evenness. Evenness compares the similarity of the population size of each of the species present (Ludwig and Reynolds, 1988). Lichens diversity in each study site was calculated by Shannon's diversity index, evenness and specie richness.

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a. Shannon-Weaver information function

Combines the number of species present and evenness into a single index (Ludwig and Reynolds, 1988):

$$D = -\Sigma\, p_i \ln p_i$$

Where:

D = diversity index

i = an index number for each species present in a sample

$p_i = n_i/N$ = the number of individuals within a species (n_i) divided by the total number of individuals (N) present in the entire sample

ln = natural log

Multiply the proportion (p_i) of each species in the sample times the natural log of that same value ($\ln p_i$), then sum (Σ) the values for each species, and finally multiply by minus 1.

The value of D is highest when species are equally abundant.

b. Species evenness

Separates the effect of different population sizes (numbers of individuals within species) from species diversity (number of species) (Ludwig and Reynolds, 1988):

$$E = e^D/s$$

where:

E = species evenness

e = 2.7 (constant value)

D = the value of the Shannon-Weaver Information Function

s = number of species in sample

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c. Species richness

Species Richness is the number of species in sample or study sites

3.10.2 Similarity of lichen diversity

Similarity of lichen species composition among sampling plots was examined by using the Sorensen's coefficient (Barbour *et al.* 1980; Seaward and Hawksworth, 1977) as follows:

$$\text{Sorensen's coefficient} = \frac{2C}{A + B} \quad (\text{x } 100)$$

A = Total number of species in one region

B = Total number of species in the other region

C = Total number of species common to both regions

3.10.3 Correlation of lichen and environmental factors

Environmental factors such as temperature, light intensity, precipitation, and pH of bark, tree ages and tree species were recorded. Data were analyzed by using statistic program SPSS version. 9.01, one-way ANOVA was used to test the correlation in each environmental parameter. Correlation between lichen communities and other environmental factors were analyzed by Detrended Correspondence Analysis (DCA) and Principal Coordinates Analysis (PCA) variable loading from Multivariate Statistical Package Program (MVSP3.1).

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CHAPTER 4

RESULTS

4.1. Lichen diversity and their percentage cover on selected trees species

Four framework tree species; *Hovenia dulcis* Thunb, *Melia toosendan* Sieb & Zucc, *Prunus cerasoides* D. Don and *Spondias axillaris* Roxb were selected to show how lichen species can be used as indicators of forest recovery. The lichen diversity in three reforestation plots was compared with lichen diversity in nearby natural forest. A total of 150 trees (120 trees in reforestation plots and 30 trees in Dong Seng forest: natural forest) was examined. A total of 795 epiphytic lichen specimens were identified. Two main groups of epiphytic lichens: crustose and foliose were found; 6 orders 14 families 31 genera (21 crustose and 10 foliose) and 70 species (55 crustose and 15 foliose). The list of lichen species found is presented in Table 4.1 and pictures of some lichen species are presented in Appendix D. Most of crustose lichens occurred in reforestation plots and most foliose lichens were found in Dong Seng forest (Table 4.2).

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Table 4.1 Total lichen genera found in study area

No.	Families	Genera	Types
1	Arthoniaceae	*Arthonia* sp	Crustose
2	Arthoniaceae	*Arthothelium* sp.	Crustose
3	Arthopyreniaceae	*Arthopyrenia* sp.	Crustose
4	Bacidiaceae	*Bacidia* spp.	Crustose
5	Chrysotrichaceae	*Chrysothrix* sp.	Crustose
6	Graphidaceae	*Diorygma* spp.	Crustose
7	Graphidaceae	*Glyphis* spp.	Crustose
8	Graphidaceae	*Graphis* spp.	Crustose
9	Graphidaceae	*Phaeographis* sp.	Crustose
10	Haematommataceae	*Haematomma puniceum*	Crustose
11	Lecanoraceae	*Catinaria* spp.	Crustose
12	Lecanoraceae	*Lecanora* spp.	Crustose
13	Lecanoraceae	*Pyrrhospora russula*	Crustose
14	Lecideaceae	*Malcolmiella* spp.	Crustose
15	Parmeliaceae	*Bulbothrix* spp.	Foliose
16	Parmeliaceae	*Canoparmelia* sp.	Foliose
17	Parmeliaceae	*Hypotrachyna* sp.	Foliose
18	Parmeliaceae	*Parmelinopsis* sp.	Foliose
19	Parmeliaceae	*Parmotrema* sp.	Foliose
20	Parmeliaceae	*Parmelinella* sp.	Foliose
21	Parmeliaceae	*Rimelia* sp.	Foliose
22	Pertusariaceae	*Ochrolechia* sp.	Crustose
23	Pertusariaceae	*Pertusaria* sp.	Crustose
24	Physiaceae	*Buellia* spp.	Crustose
25	Physiaceae	*Rinodina* sp.	Crustose
26	Physiaceae	*Heterodermia* sp.	Foliose
27	Physiaceae	*Dirinaria confluens*	Foliose
28	Physiaceae	*Pyxine cf. reticulata*	Foliose
29	Pilocarpaceae	*Byssoloma* spp.	Crustose
30	Pyrenulaceae	*Pyrenula* spp.	Crustose
31	Trichothelisceae	*Porina* spp.	Crustose

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Table 4.2 Average percentage cover of lichen species on selected trees in all study sites

Lichens species	S1				S2				S3				S4			
	Mt	**Hd**	**Sa**	**Pc**	**Mt**	**Hd**	**Sa**	**Pc**	**Mt**	**Hd**	**Sa**	**Pc**	**Mt**	**Hd**	**Sa**	**Pc**
Number of trees	10	10	10	10	10	10	10	10	10	10	10	10	6	10	4	10
Arthonia sp.1		0.63							1.06	0.63						
Arthopyrenia sp.1												1.51				
Arthothelium sp.1						1.59										
Bacidia sp.1									0.15		0.08	0.33				
Bacidia sp.2												0.29				
Bacidia sp.3					0.15					0.13	0.39					
Buellia sp.1	1.66	6.11	8.62	2.32				3.39	0.28	1.05	1.61	0.54	1.82	0.81	8.08	0.18
Buellia sp.2					0.37	5.22	0.28		1.04		1.01	3.18	0.06			
Buellia sp.3						0.81	0.31		0.13	1.68	0.10					
Bulbothrix cf. *meizospora**																
Bulbothrix cf. *setschawensis**																0.17
*Bulbothrix isidiza**																0.10
Bulbothrix sp.1*	0.39		0.11			0.11	0.52					0.17	0.11		0.13	0.10
*Bulbothrix tabacina**								0.11								0.34
Byssoloma cf. *sudiscordans*						0.16	0.16									
Byssoloma sp.1												0.14				
Canoparmelia sp.1*																0.30
Catinaria sp.1																0.29
Catinaria sp.2						0.78			0.16	0.23		0.29				0.86
Chrysothrix sp.1	66.75	57.98	35.06	2.08	9.87	16.51	13.44	6.74	8.76	10.00	7.97	5.67	25.05		21.11	
Diorygma cf. *epiglaucum*						0.68			1.14	1.99	0.71	0.45	0.60			
Diorygma cf. *poitaei*													0.20			
Diorygma sp.1					0.42								0.12			
*Dirinaria confluens**						0.11						0.94	0.27			0.09
Glyphis cf.*cicatricosa*										0.28						
Glyphis scyphuliferum									0.13							
Graphis sp.1					1.88	1.90			0.07	0.88	0.57					

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Table 4.2 (continued)

Lichens species	S1				S2				S3				S4			
	Mt	**Hd**	**Sa**	**Pc**	**Mt**	**Hd**	**Sa**	**Pc**	**Mt**	**Hd**	**Sa**	**Pc**	**Mt**	**Hd**	**Sa**	**Pc**
Number of trees	10	10	10	10	10	10	10	10	10	10	10	10	6	10	4	10
Graphis sp.2						1.35		2.79	1.81	1.09	0.11	2.25	0.19			
Graphis sp.3		1.15	0.23			0.42			2.38	2.11	0.34			0.16	0.25	0.62
Graphis sp.4						0.21			1.01	1.02	0.42	0.80	0.15			
Graphis sp.5					0.54	0.54				1.40	0.49		0.25			
Graphis sp.6													0.40			
Graphis sp.7												0.36				
Graphis sp.8					0.15	0.31			0.36	3.48	0.88	0.34				
Graphis sp.9					3.76	3.62	0.54	1.66	1.85	7.82	3.29	0.23	0.65	0.40		
Graphis sp.10																
Graphis sp.11	0.52				6.32	8.99	3.02			0.63	2.28	0.23	0.62	0.62	0.06	
Graphis sp.12																
Graphis sp.13						1.99			0.47		0.45				0.22	
Haematomma puniceum						1.33			1.56	3.60	1.55					0.31
Heterodermia cf. *diademata**																0.21
Hypotrachyna sp.1*																0.28
Lecanora sp.1					0.36	2.27		0.63	3.82	5.95	2.77	0.23	0.44			0.24
Lecanora sp.2						3.06										
Lecanora sp.3																0.17
Lecanora sp.4									0.57	0.13						
Lecanora sp.5										0.36			0.41	1.13		
Malcolmiella sp.1															0.11	
Malcolmiella sp.2						0.73				2.90	0.23		0.33	2.07		
Malcolmiella sp.3							0.51									
Malcolmiella sp.4														0.07		
Malcolmiella sp.5										0.38	0.08	0.07		0.16		
Malcolmiella sp.6	0.83	4.09	6.29			0.73				1.62	0.40		0.08	0.00	0.63	
Malcolmiella sp.7					0.08					0.25						
Ochrolechia sp.1						0.10										

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Table 4.2 (continued)

Lichens species	S1				S2				S3				S4			
	Mt	**Hd**	**Sa**	**Pc**	**Mt**	**Hd**	**Sa**	**Pc**	**Mt**	**Hd**	**Sa**	**Pc**	**Mt**	**Hd**	**Sa**	**Pc**
Number of trees	10	10	10	10	10	10	10	10	10	10	10	10	6	10	4	10
Parmelinella sp.1*																0.07
Parmelinopsis sp.1*																0.25
Parmotrema sp.1*					0.15											0.52
*Parmotrema tinctorum**						0.31						0.07				
Pertusaria sp.1						4.43						0.09	0.13	0.22		
Phaeographis sp.1														0.19		
Porina sp.1									0.88	6.67	0.68				0.42	
Porina sp.2																0.06
Pyrenula sp.1														0.31	0.12	
Pyrenula sp.2														0.36	0.19	
Pyrenula sp.3														0.30		
Pyrrhospora russula					1.16	0.57			3.44	1.15	0.14	0.18				
Pyxine cf. *reticulata**													0.4			
Rimelia sp.1*																0.17
Rinodina sp.1										0.31						
Sterile Crustose	41.14	51.32	26.61	21.90	18.68	28.89	21.95	10.32	20.91	27.62	14.74	9.52	17.88	4.53	18.25	0.96
Number of lichen species	**5**	**5**	**5**	**2**	**13**	**27**	**8**	**6**	**21**	**27**	**25**	**23**	**21**	**13**	**12**	**22**
Total % cover of lichen	**70.14**	**69.94**	**50.31**	**4.40**	**25.11**	**58.81**	**18.77**	**15.31**	**31.05**	**57.71**	**26.64**	**18.36**	**31.88**	**6.80**	**31.30**	**5.32**
Total % cover of lichen (+ Sterile crustose)	**111.28**	**121.25**	**76.92**	**26.30**	**43.79**	**87.71**	**40.72**	**25.63**	**51.95**	**85.33**	**41.37**	**27.88**	**49.77**	**11.33**	**49.55**	**6.27**

Note: S1 = Reforestation plot 2002, S2 = Reforestation plot 2000, S3 = Reforestation plot 1998, S4 = Dong Seng forest,

Mt = *Melia toosendan* Sieb and Zucc, Hd = *Hovenia dulcis* Thunb, Sa = *Spondias axillaris* Roxb, Pc = *Prunus cerasoides* D. Don

* = Foliose lichens

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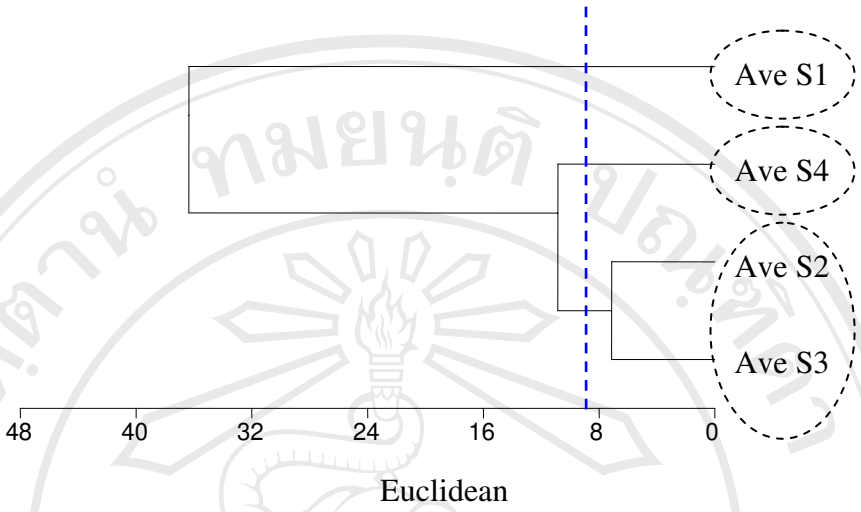

Figure 4.1 Dendrogram of average percentage cover of all lichen species and their frequency on all selected trees species in each study sites (Ave = Average percentages cover of all lichen species on all selected trees species)

Average percentage cover of all lichen species on all selected trees species in each study sites (Figure 4.1) was divided into three groups; group 1 composed of plot 1998 and plot 2000 which had high number of crustose lichen, group 2 was Dong Seng forest which had moderate number of crustose and high number of foliose especially on *P. cerasoides*. Group 3 was plot 2002, which was the youngest plot and had less number of crustose and foliose lichens (Figure 4.1).

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4.2 Distribution of crustose and foliose lichens

Crustose lichens were mostly found in reforestation plot 1998, 2000 and Dong Seng forest. The highest numbers of crustose lichens were found in reforestation plot 1998, especially on *H. dulcis*. The young reforestation plot 2002 had fewer crustose lichens. The highest number of foliose lichens was found in Dong Seng forest especially on *P. cerasoides* (Table 4.3 and Figure 4.2-4.6). Crustose and foliose were different in number on each tree species in each study sites (Figure 4.2-4.6). The youngest plot 2002 had less lichens species number in both crustose and foliose. The highest average number of crustose lichens was found in plot 1998 whereas plot 2000 had the lowest number of crustose lichens (Figure 4.3).

Table 4.3 Number of crustose and foliose lichens species in all study sites

Study Sites	Tree Species	Crustose	Foliose	Total
S1	*Melia toosendan*	3	1	4
	Hovenia dulcis	5	0	5
	Spondias axillaris	4	1	5
	Prunus cerasoides	2	0	2
Average		3.5	0.5	4
S2	*Melia toosendan*	12	2	14
	Hovenia dulcis	26	2	28
	Spondias axillaris	7	1	8
	Prunus cerasoides	5	2	7
Average		12.5	1.75	14.25
S3	*Melia toosendan*	22	0	22
	Hovenia dulcis	28	0	28
	Spondias axillaris	25	0	25
	Prunus cerasoides	20	3	23
Average		23.75	0.75	24.50
S4	*Melia toosendan*	15	3	18
	Hovenia dulcis	13	0	13
	Spondias axillaris	7	0	7
	Prunus cerasoides	10	12	22
Average		11.25	3.75	15

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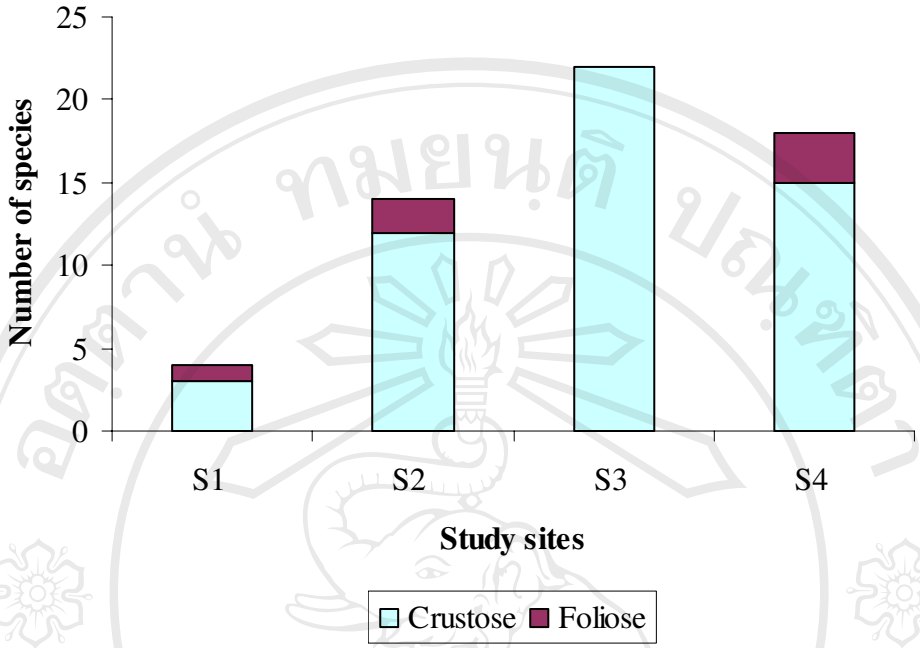

Figure 4.2 Number of crustose and foliose lichens species on *Melia toosendan*

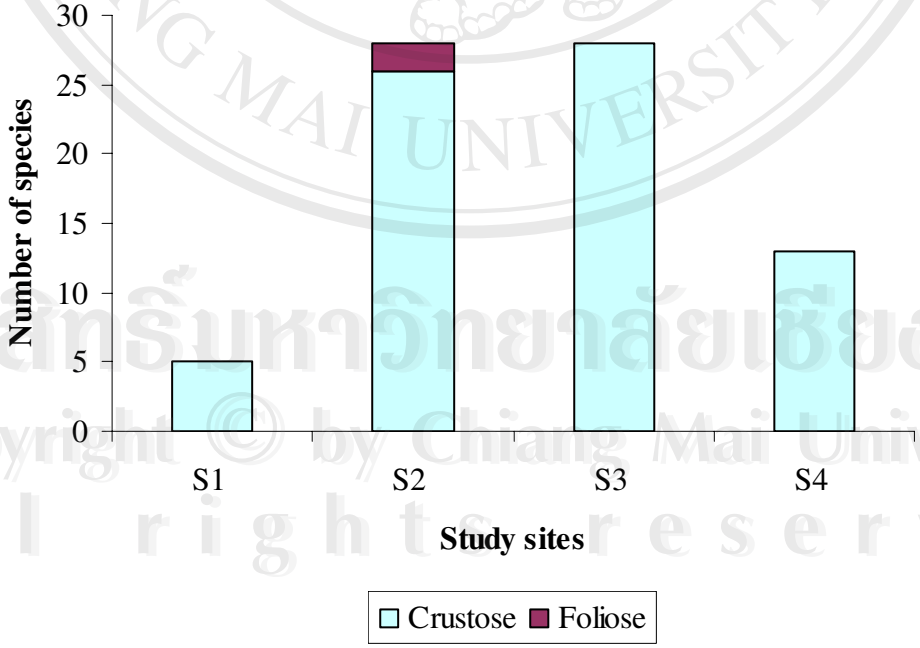

Figure 4.3 Number of crustose and foliose lichens species on *Hovenia dulcis*

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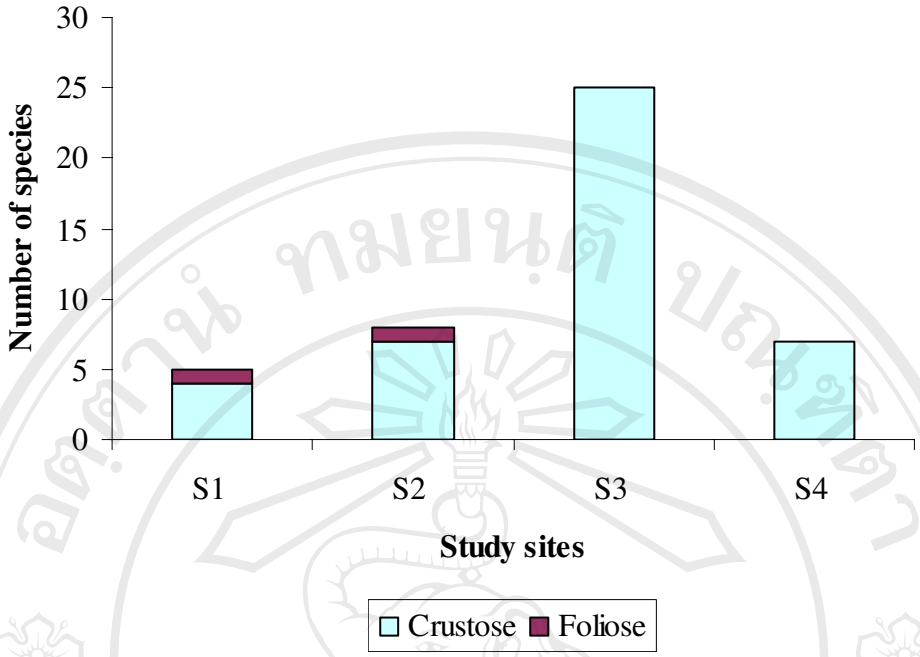

Figure 4.4 Number of crustose and foliose lichens species on *Spondias axillaris*

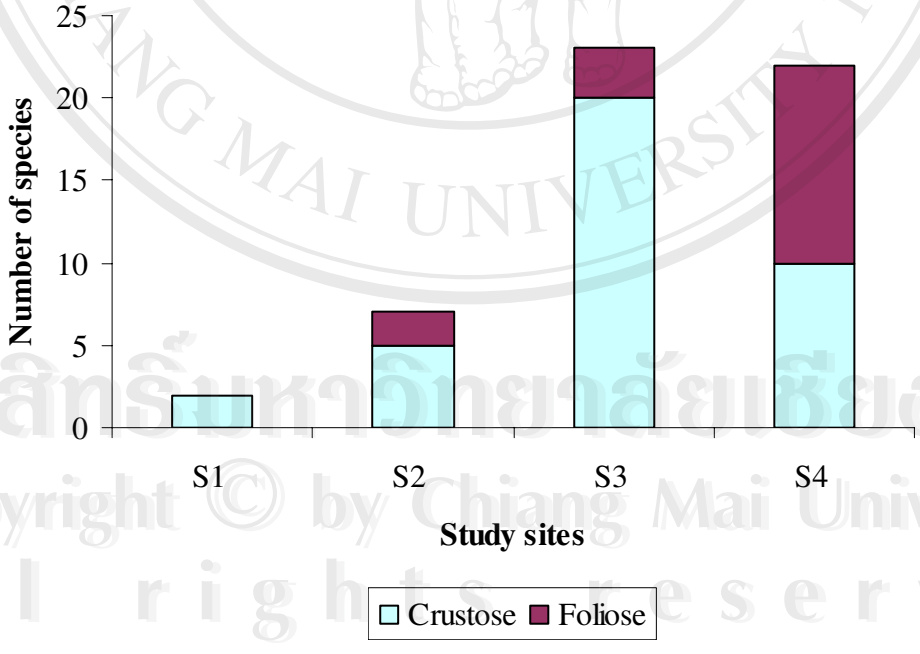

Figure 4.5 Number of crustose and foliose lichens species on *Prunus cerasoides*

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Figure 4.6 Average number of crustose and foliose lichens found in all study sites

Note: Mt = *Melia toosendan* Sieb and Zucc, Hd = *Hovenia dulcis* Thunb, Sa = *Spondias axillaris* Roxb, Pc = *Prunus cerasoides* D. Don

Chrysothrix sp. was commonest in the young reforestation plot 2002 cover decreased with increasing in plot age except on *Prunus cerasoides* in plot 2002 and it was also low in the natural forest (Figure 4.7). Consequently, *Chrysothrix* sp. can be categorized as a pioneer lichen species during reforestation and might be the indicator for the initiate of lichen succession on trees. Sterile crusts declined with increasing forest development (Figure 4.8).

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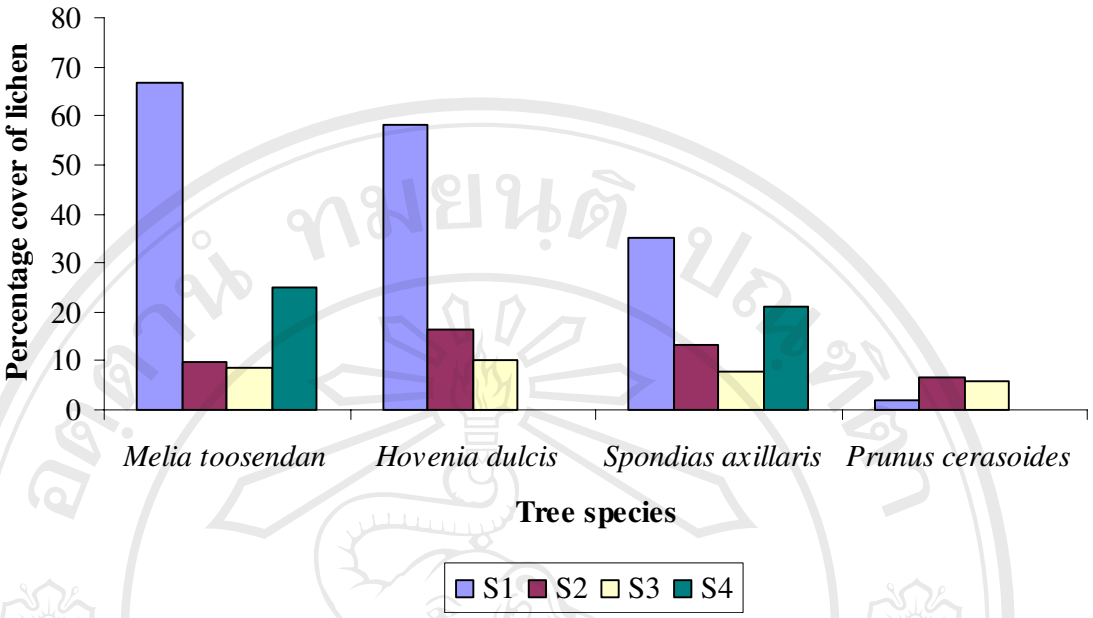

Figure 4.7 Percentage cover of *Chrysothrix* sp.

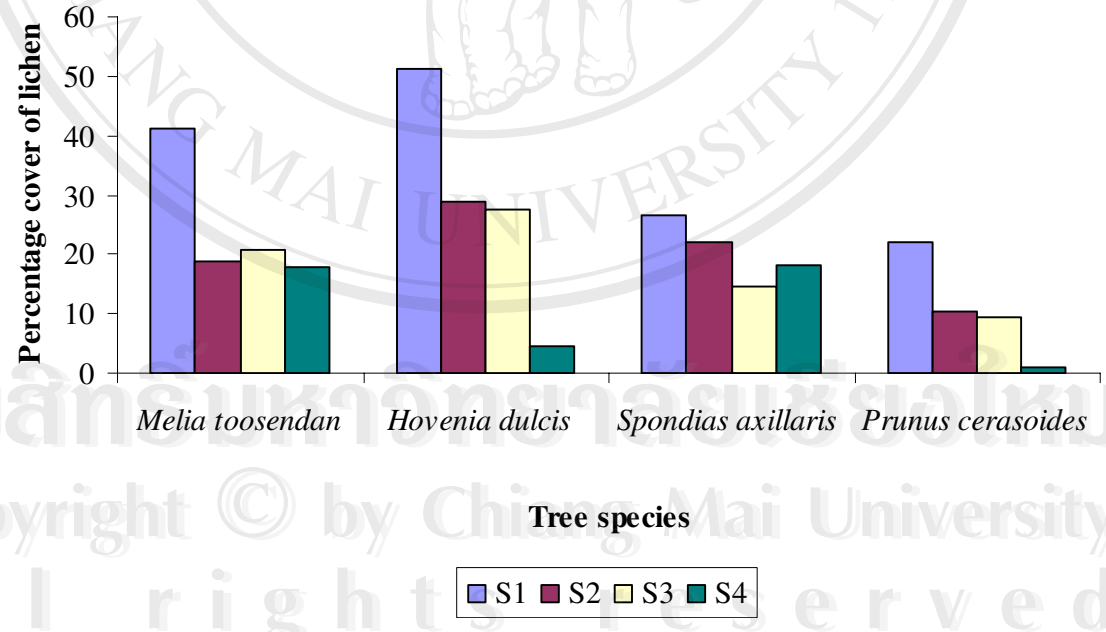

Figure 4.8 Percentage cover of sterile crust

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In contrast, foliose lichens increased with increasing forest development (Figure 4.9), especially on *P. cerasoides*.

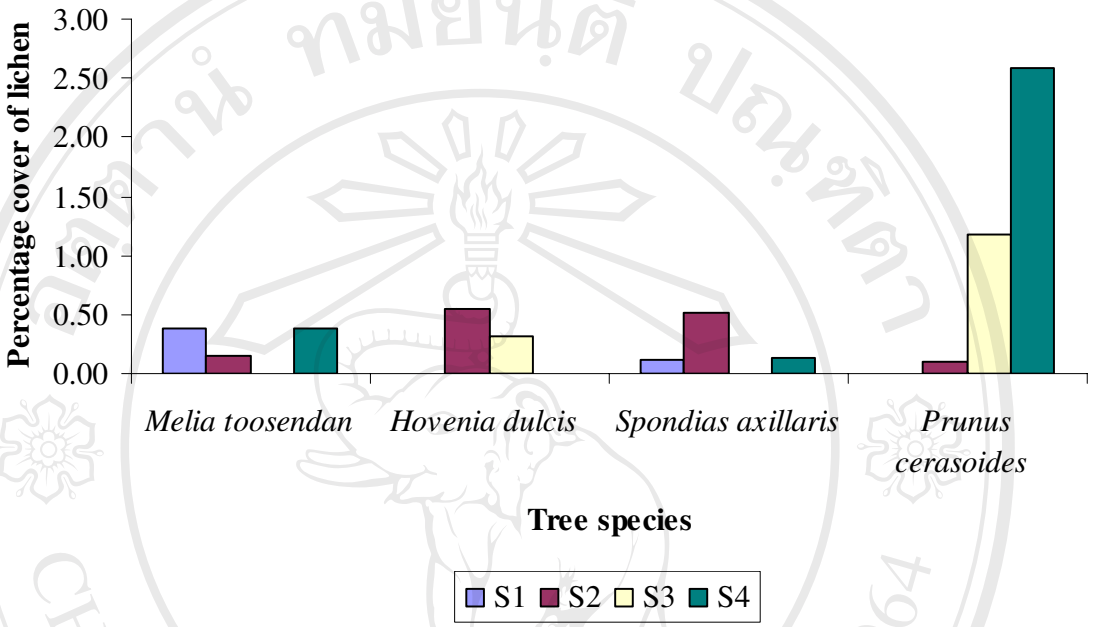

Figure 4.9 Percentage cover of foliose lichen

4.3 Lichen diversity indices

Highest lichen species diversity was recorded in reforestation plot 1998, followed by plot 2000, Dong Seng forest and 2002, respectively. Highest evenness occurred in reforestation plot 1998, followed by plot 2000, 2002 and Dong Seng forest, respectively. Highest species richness occurred in Dong Seng forest, followed by reforestation plot 1998, plot 2000 and 2002 respectively (Table4.4).

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Table 4.4 Shannon's diversity index, evenness and specie richness of lichens diversity on all selected trees species in each study sites

Study sites	Diversity index	Evenness	Species richness
S1	1.04	0.50	6
S2	2.06	0.58	34
S3	2.50	0.68	39
S4	1.77	0.46	44

In Dong Seng forest *P. cerasoides* support the highest Shannon's diversity index and evenness was also high. In plot 2002 on *M. toosendan* had the lowest diversity index. In plots 1998 and 2000 *H. dulcis* had the highest species richness. Species richness in Dong Seng forest was less than that of plot 1998 and its evenness was less than that of plot 2002 (Table 4.5 and Figure 4.10).

Table 4.5 Shannon's diversity index, evenness and specie richness of lichens diversity on each tree species in each study sites

Tree species	Study sites	Diversity index	Evenness	Specie richness
Melia toosendan	S1	**0.25**	**0.16**	5
	S2	1.79	0.70	13
	S3	2.44	0.80	21
	S4	1.07	0.35	21
Hovenia dulcis	S1	0.64	0.40	5
	S2	2.52	0.77	**27**
	S3	2.73	0.83	**27**
	S4	2.17	0.84	13
Spondias axillaris	S1	0.85	0.53	5
	S2	1.00	0.48	8
	S3	2.47	0.77	25
	S4	0.96	0.39	12
Prunus cerasoides	S1	0.69	**0.99**	**2**
	S2	1.41	0.79	6
	S3	2.36	0.75	23
	S4	**2.80**	0.91	22

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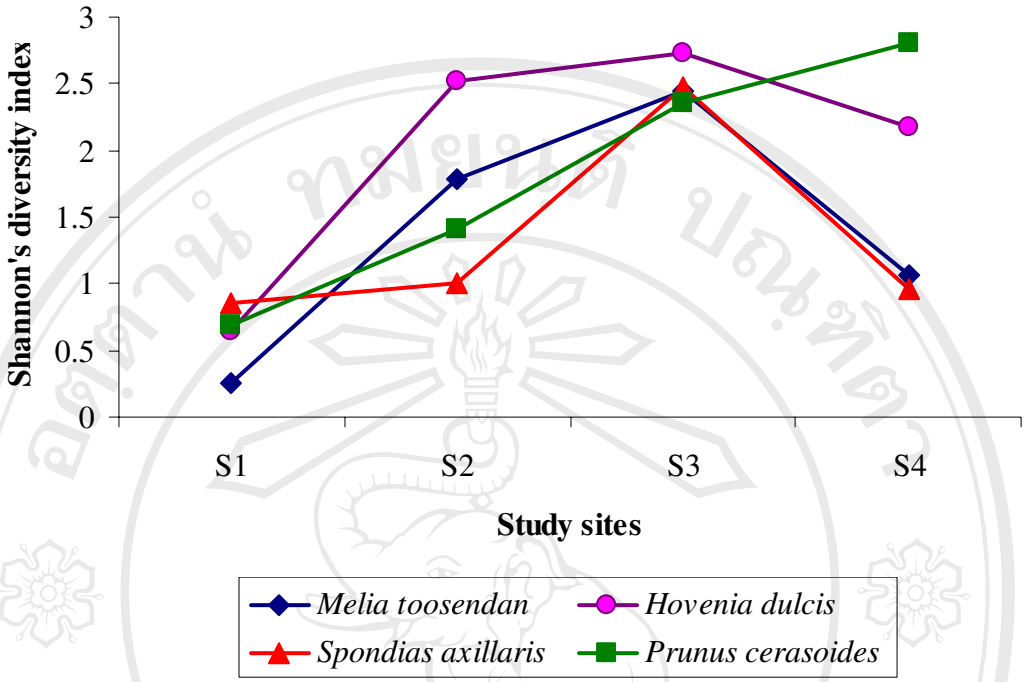

Figure 4.10 Shannon's diversity index of lichens diversity on each tree species in each study sites

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4.4 Similarity of Lichen Diversity

Similarity in the lichen community across all selected tree species between each study sites by using Sorensen's coefficient shown that similarity between plot 1998 and 2000 was the highest with 0.69 (69 %) and between plot 1998 and Dong Seng forest was also high with 0.57 (57 %). Lowest similarity of 0.23 (23%) was between plot 2002 and Dong Seng forest (Table 4.6).

Table 4.6 Sorensen's coefficient of lichen diversity on all selected tree species between each study sites

	Lichen similarity			
Study sites	**S1**	**S2**	**S3**	**S4**
S1	1	0.30	0.30	**0.23**
S2		1	**0.69**	0.52
S3			1	0.57
S4				1

From a cluster analysis of the combined lichen communities on all selected trees across all study sites (Figure 4.7) based on percentage cover showed that the sites could be divided into 2 groups; Group 1 composed of S1, S2 and S4 (the more developed sites), Group 2 was S3 (the youngest plot).

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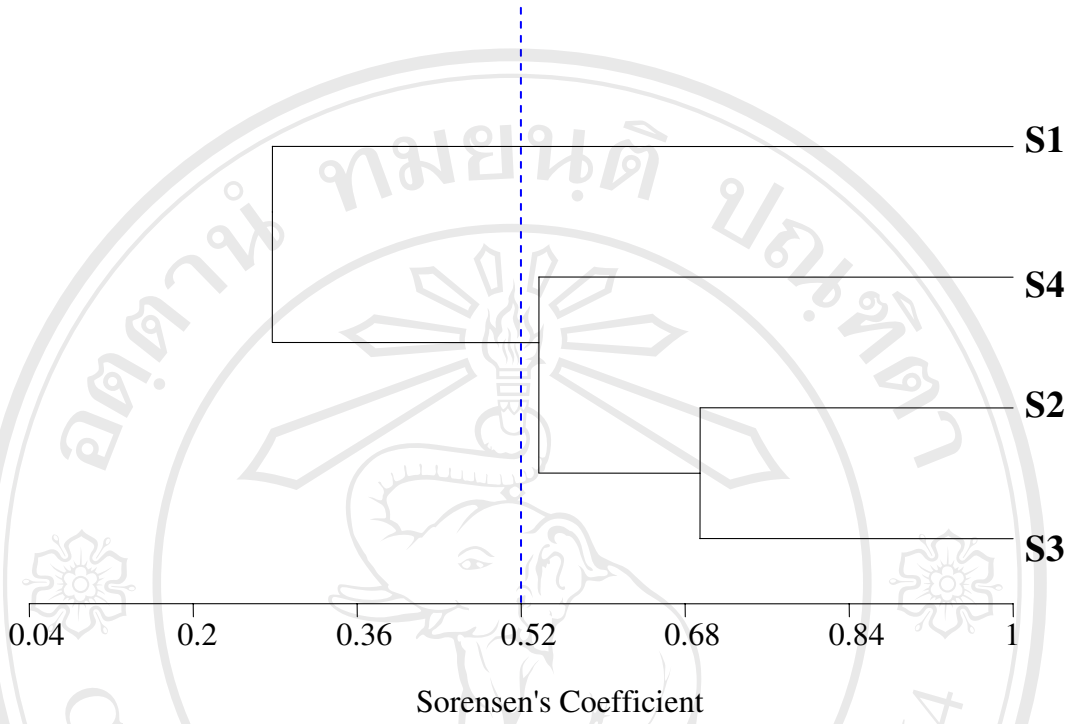

Figure 4.11 Cluster analysis of the combined lichen communities on all selected trees across all study sites

Sorensen's coefficient showed that the lichen communities on *H. dulcis* and *S. axillaris* in plot 1998 had the highest similarity at 0.85 (85%) (Table 4.7); *Buellia* sp.2, *Bulbothrix* sp.1, *Chrysothrix s*p., *Graphis* sp.1, *Graphis* sp.5, *Graphis* sp.8, *Graphis* sp.9, *Graphis* sp.11, *Lecanora* sp.1, *Lecanora* sp.2, *Parmotrema* sp.1, *Pyrrhospora russula* were found on both tree species in this site. The lowest similarity, 0.13 (13%) (Table 4.7) occurred between the lichen communities on *H. dulcis* in plot 2000 and on *P. cerasoides* in plot 2002; *Chrysothrix* sp.1*, Graphis* sp.3, *Malcolmiella* sp.6.

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Table 4.7 Sorensen's coefficient of lichen diversity

Sample units	S3Mt	S2Mt	S1Mt	S4Mt	S3Hd	S2Hd	S1Hd	S4Hd	S3Sa	S2Sa	S1Sa	S4Sa	S3Pc	S2Pc	S1Pc	S4Pc
S3Mt	1.00															
S2Mt	0.44	1.00														
S1Mt	0.21	0.30	1.00													
S4Mt	0.41	0.50	0.43	1.00												
S3Hd	0.72	0.48	0.29	0.52	1.00											
S2Hd	0.63	0.51	0.29	0.59	0.63	1.00										
S1Hd	0.36	0.20	0.67	0.29	0.35	0.23	1.00									
S4Hd	0.22	0.21	0.30	0.39	0.38	0.28	0.30	1.00								
S3Sa	0.79	0.55	0.31	0.54	**0.85**	0.69	0.31	0.35	1.00							
S2Sa	0.32	0.44	0.53	0.39	0.27	0.42	0.27	0.26	0.34	1.00						
S1Sa	0.28	0.19	0.77	0.35	0.29	0.28	0.77	0.29	0.30	0.38	1.00					
S4Sa	0.35	0.23	0.67	0.35	0.35	0.34	0.56	0.46	0.42	0.38	0.63	1.00				
S3Pc	0.58	0.43	0.35	0.58	0.51	0.62	0.21	0.32	0.57	0.38	0.27	0.29	1.00			
S2Pc	0.41	0.38	0.46	0.41	0.34	0.28	0.46	0.29	0.36	0.38	0.43	0.32	0.40	1.00		
S1Pc	0.24	0.24	0.67	0.24	0.19	**0.13**	0.67	0.24	0.21	0.33	0.60	0.40	0.23	0.60	1.00	
S4Pc	0.31	0.22	0.21	0.31	0.28	0.31	0.21	0.22	0.25	0.19	0.27	0.23	0.30	0.33	0.15	1.00

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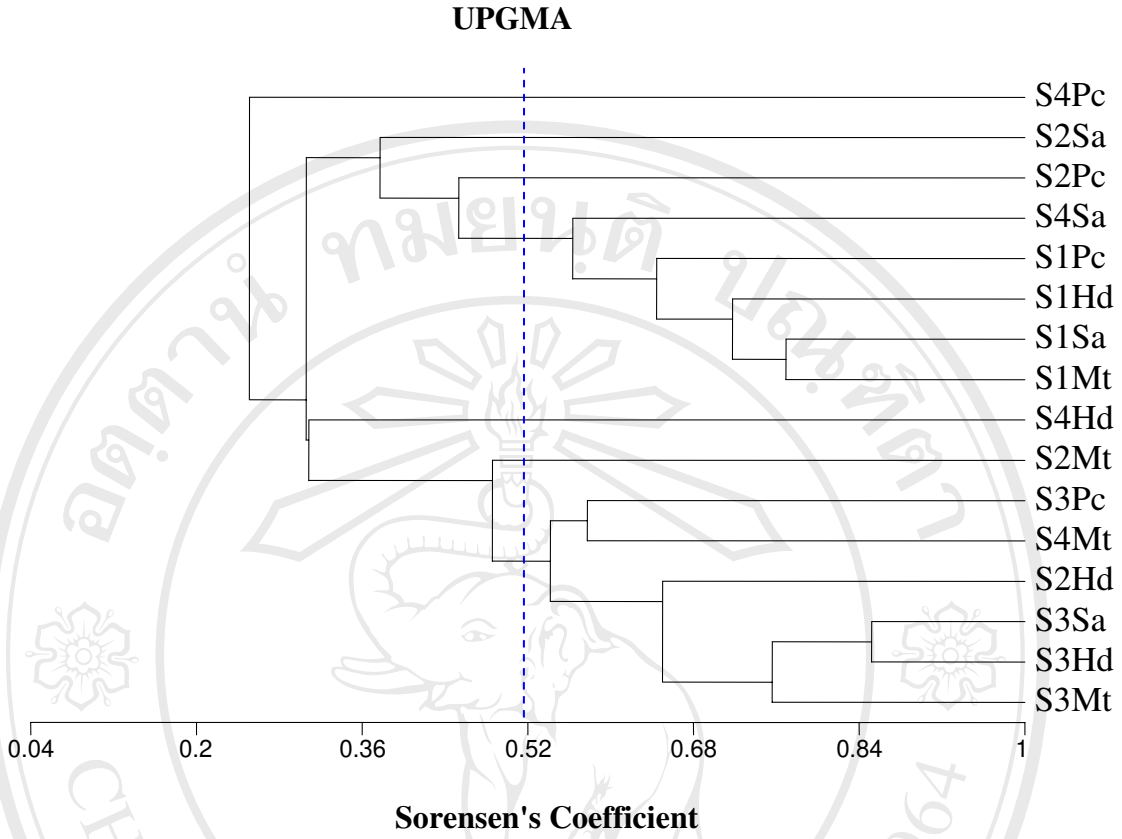

Figure 4.12 Cluster analysis of similarity of lichen communities belongs with selected trees and study sites

As the result of dendrogram of similarity (Figure 4.12), lichen communities were divided into 7 groups at Sorensen's coefficient more than 0.52 (52%); group 1 composed of S4Pc, group 2 was S2Sa, group 3 was S2Pc, group 4 composed of S4Sa, S1Pc, S1Hd, S1Sa and S1Mt, group 5 was S4Hd, group 6 was S2Mt and group 7 composed of S3Pc, S4Mt, S2Hd, S3Sa, S3Hd and S3Mt. The highest similarity was S3Sa and S3Hd at 0.85 (85%) (Figure 4.12).

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4.5 Environmental factors in study sites

Environmental factors such as temperature, light intensity, relative humidity were recorded over six months during the field work period. In addition, pH of bark, tree ages and tree species were also determined.

4.5.1 Average temperature

Results from one-way ANOVA analysis shown that average temperature in plot 2002 and Dong Seng were significantly lower different at 95%CI ($p<0.05$). However, average temperature in Dong Seng forest and plot 1998 were not significantly different at 95 % CI ($p<0.05$) as well as between those of plot 2000 and 2002 (Figure 4.13).

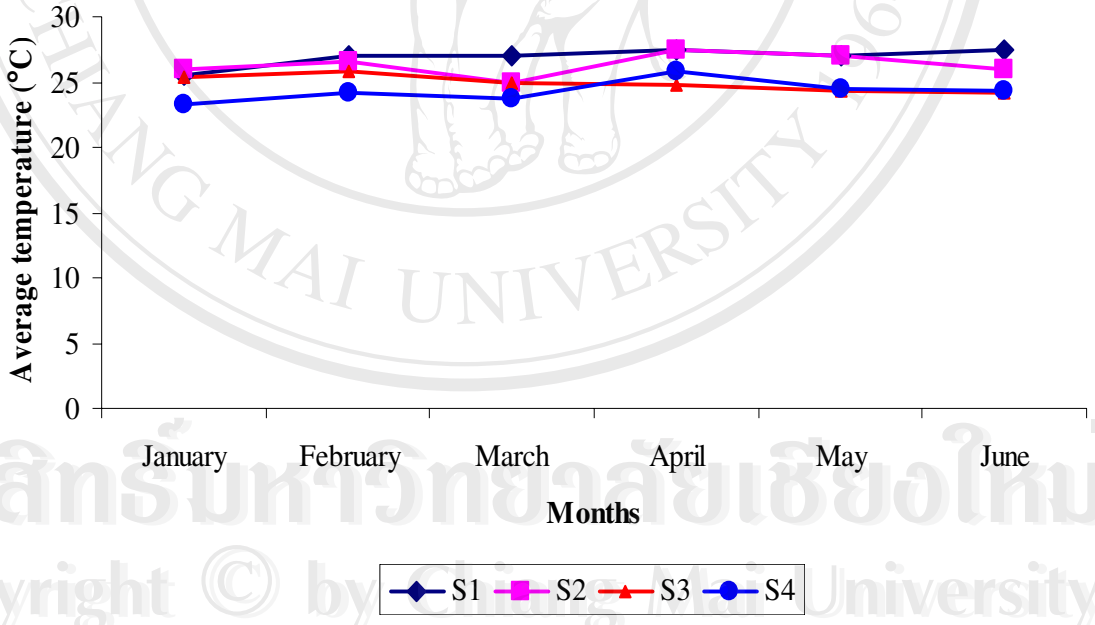

Figure 4.13 Average temperatures (°C) from January to June 2006

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4.5.2. Average light intensity

Results from one-way ANOVA showed that average light intensity (lux) among plot 2002, 2000 and Dong Seng were significantly different at 95 % CI ($p<0.05$). Light intensities in Dong Seng forest and plot 1998 were not significantly different (Figure 4.14).

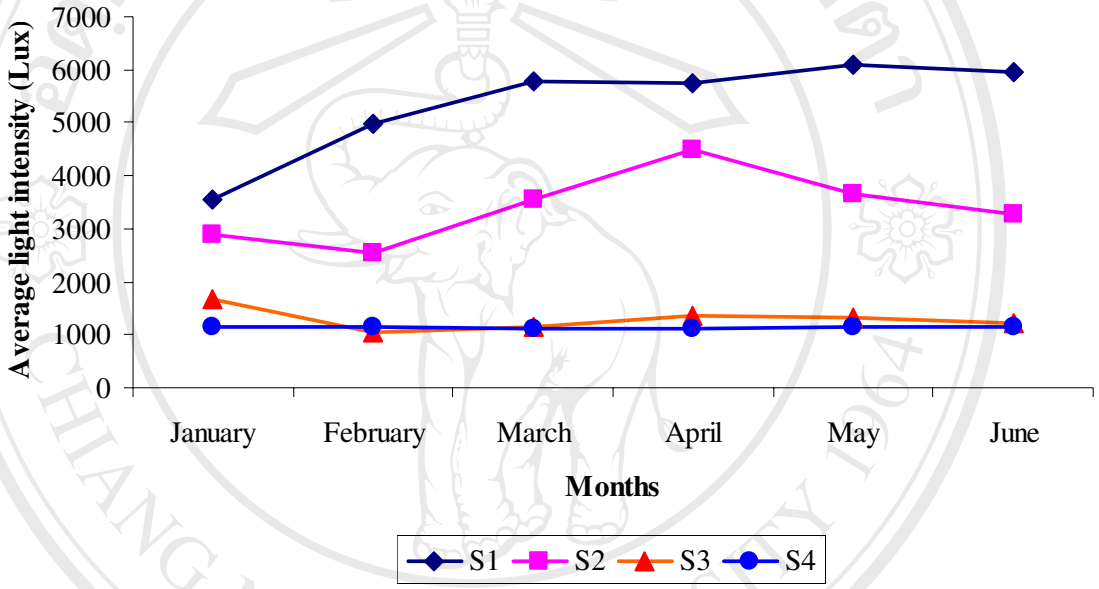

Figure 4.14 Average light intensity (lux) from January to June 2006

4.5.3. Relative humidity

Data analyses shown that relative humidity (%) of four study sites were not significantly different at 95 % CI ($p < 0.05$) by using one-way ANOVA (Figure 4.15).

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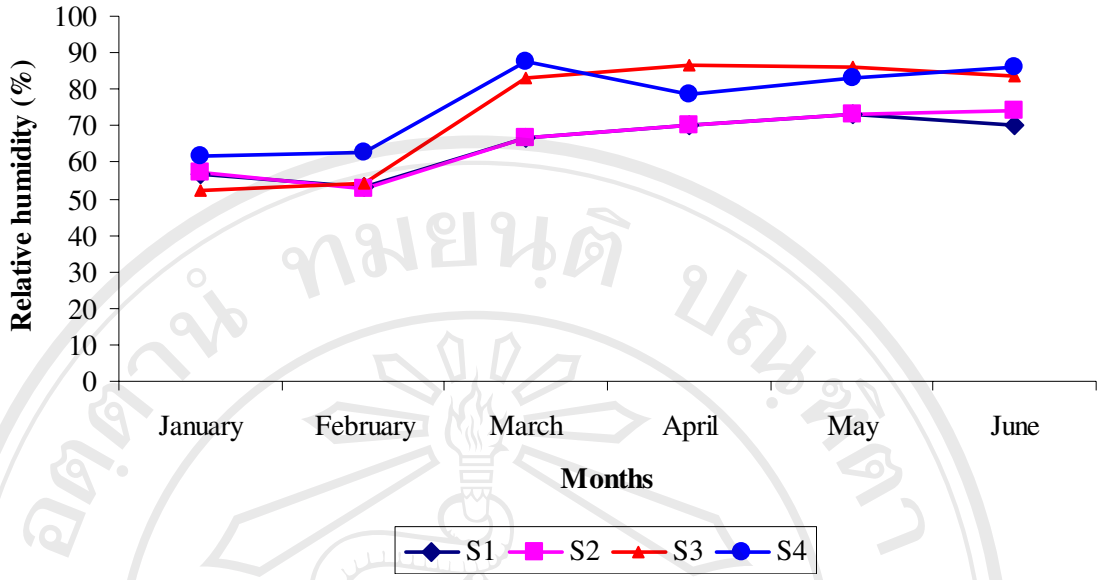

Figure 4.15 Relative humidity (%) from January to June 2006

4.5.4. Average bark pH

Average bark pH's of *M. toosenden* and *H. dulcis* in plots 1998 and 2002 were not significantly different at 95 % CI ($p < 0.05$), neither in plots 2002 and 2000. Plot 2000 and Dong Seng forest were not significantly different at 95 % CI ($p < 0.05$) (Figure 4.16).

Average bark pH of *S. axillaris* and *P. cerasoides* in Dong Seng forest and plot 1998 were not significantly different at 95 % CI ($p < 0.05$) and those of plot 2002 and plot 2000 were not significantly different at 95 % CI ($p < 0.05$) (Figure 4.16).

Average bark pH of the same tree species compared between ages were significantly different at 95 % CI ($p < 0.05$). Bark pH value of *M. toosendan* and *S. axillaris* were not significantly different at 95 % CI ($p < 0.05$) and had the same tend of average bark pH (Figure 4.17). Bark pH value of *H. dulcis* and *P. cerasoides* were not significantly different at 95 % CI ($p < 0.05$) and had the same tend of average bark pH (Figure 4.17).

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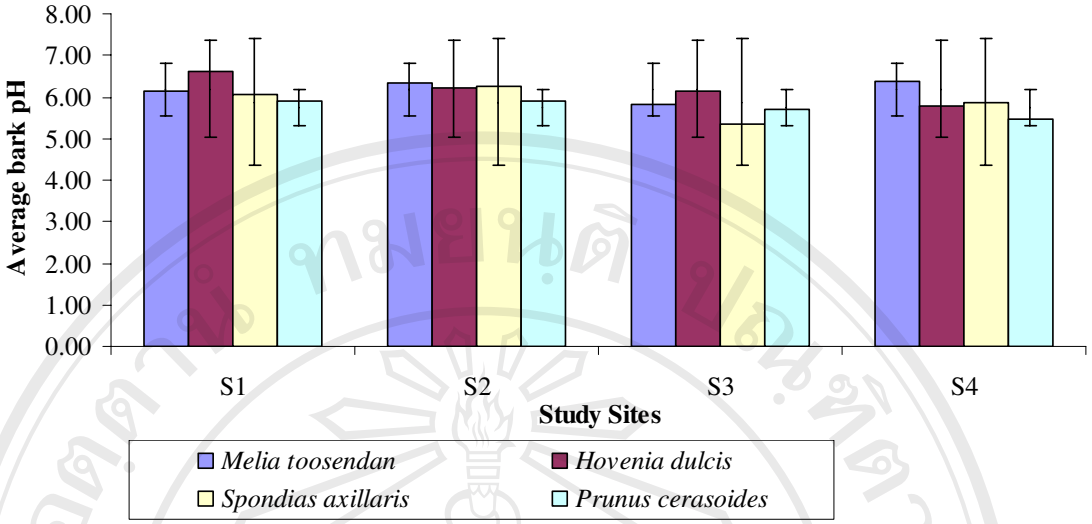

Figure 4.16 Comparison of average bark pH in different selected tree species in each study sites.

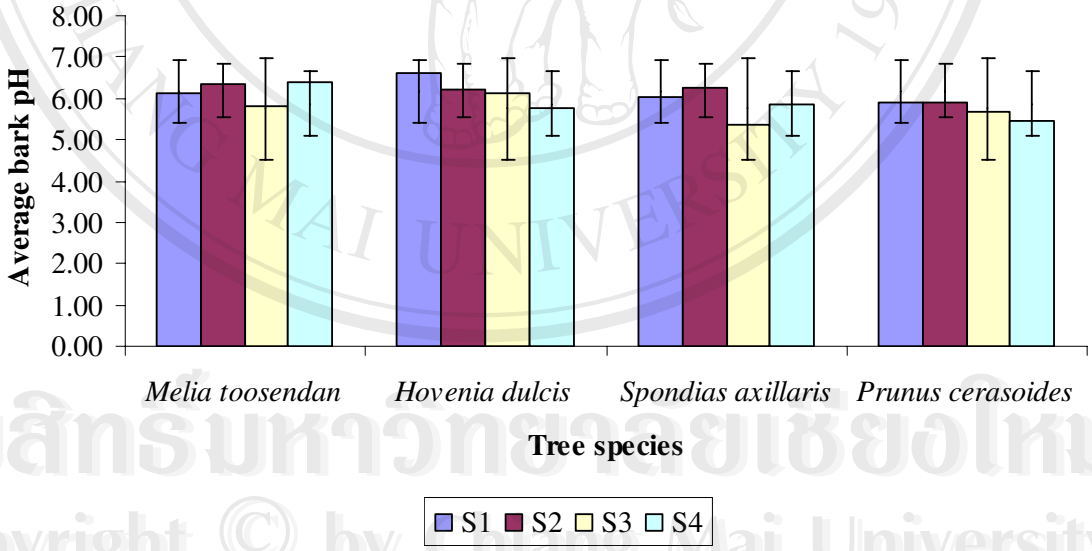

Figure 4.17 Comparison of average bark pH in same selected tree species in each study sites.

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Detrended Correspondence Analysis (DCA) is an indirect gradient analysis technique which utilizes only species occurrences and environmental information. It is based on the lichen communities' distribution, by which the lichen species has one optimal environmental condition. Those with similar requirement tend to occur together.

Applying Detrended Correspondence Analysis (DCA), lichens were divided into three groups (Figure 4.14). Group 1 included plot 1998 and Dong Seng forest. Mean light intensity and air temperature in plot 1998 and Dong Seng were not significantly different and these two sites also had highly similar lichen communities with 19 species: *Buellia* sp.1, *Diorygma* cf. *epiglaucum, Dirinaria confluens, Graphis* sp.2, *Graphis* sp.4, *Graphis* sp.5, *Graphis* sp.9, *Graphis* sp.10, *Graphis* sp.11, *Graphis* sp.13, *Haematomma puniceum*, *Lecanora* sp.1, *Lecanora* sp5, *Malcolmiella* sp.5, *Malcolmiella* sp.2, *Malcolmiella* sp.7, *Pertusaria* sp.1, *Porina* sp.1 could be indicate forest recovery with increasing forest development. Group 2 included trees from plot 2000 and group 3 included trees in the 2002 plot. These two groups were significantly different.

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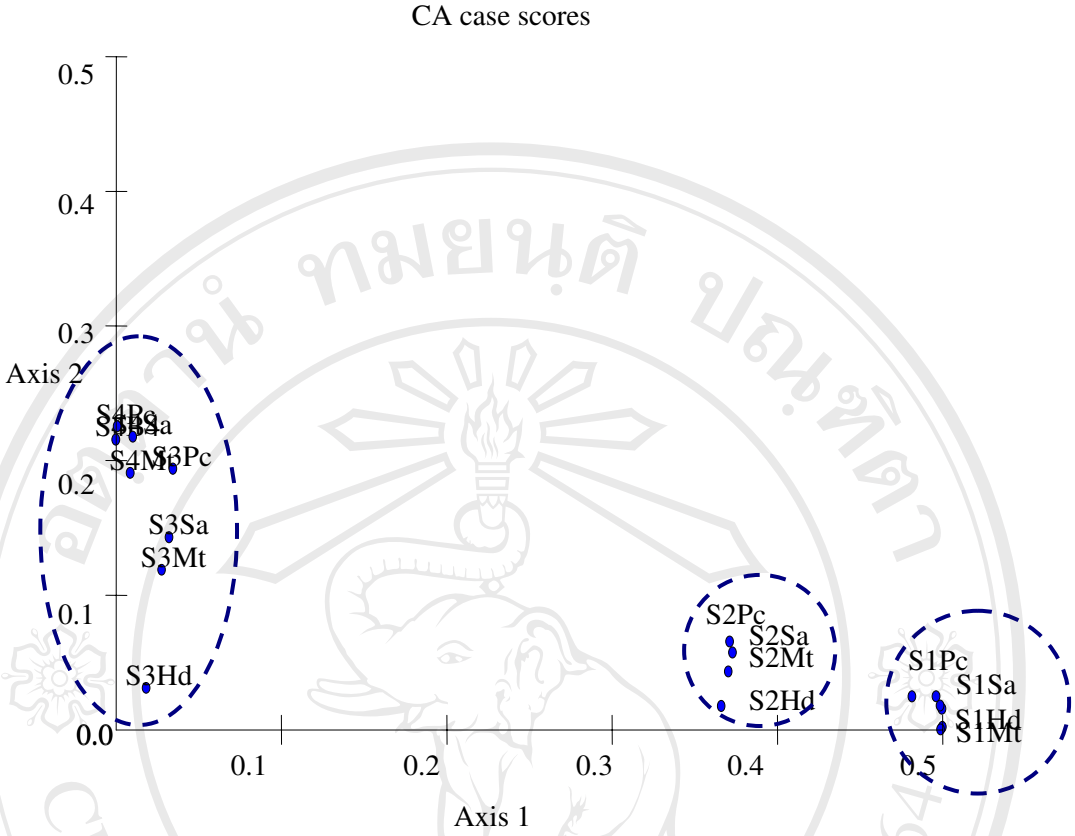

Figure 4.18 Detrended Correspondence Analysis (DCA) of lichen communities and selected tree species base on environmental factors in each study sites.

4.6 Data analysis of lichen diversity and environmental factors

The overall community structure was investigated by using different techniques of multivariate community ordination. Correlation between lichen communities and environmental factors were analyzed; indirect gradient analysis was performed by using Principal Coordinates Analysis (PCA) method in Multivariate Statistical Package (MVSP3.1) program (Figure 4.19). Bark pH, temperature, light intensity, relative humidity and elevation all affected on lichen distributions.

Radiating lines on figure 4.19 indicate the relative strength and direction, in which measured environmental variables change across the diagram. The analysis was based on

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percent cover of each species. Lichen distributions and community composition showed a positive correlation with elevation. Crustose lichen communities reached highest diversity in reforestation plots 1998, 2000, 2002 and the foliose lichen community was most diversity in Dong Seng forest.

Light intensity, temperature and bark pH all had a positive relationship with *Chrysothrix* sp., *Buellia* sp.1 and sterile crust when these factors were high made these lichens with high distribution especially in the youngest reforestation plot (plot 2002). Lichens distribution related with the elevation. The high elevation plot had high diversity of lichen especially in plot 1998 and Dong Seng natural forest. In the youngest reforestation plot 2002 with high light intensity and average temperature was found more *Chrysothrix* sp.; the one of pioneer lichen genus and might be the indicator of forest recovery at primary stage of lichen succession in youngest plot (plot 2002).

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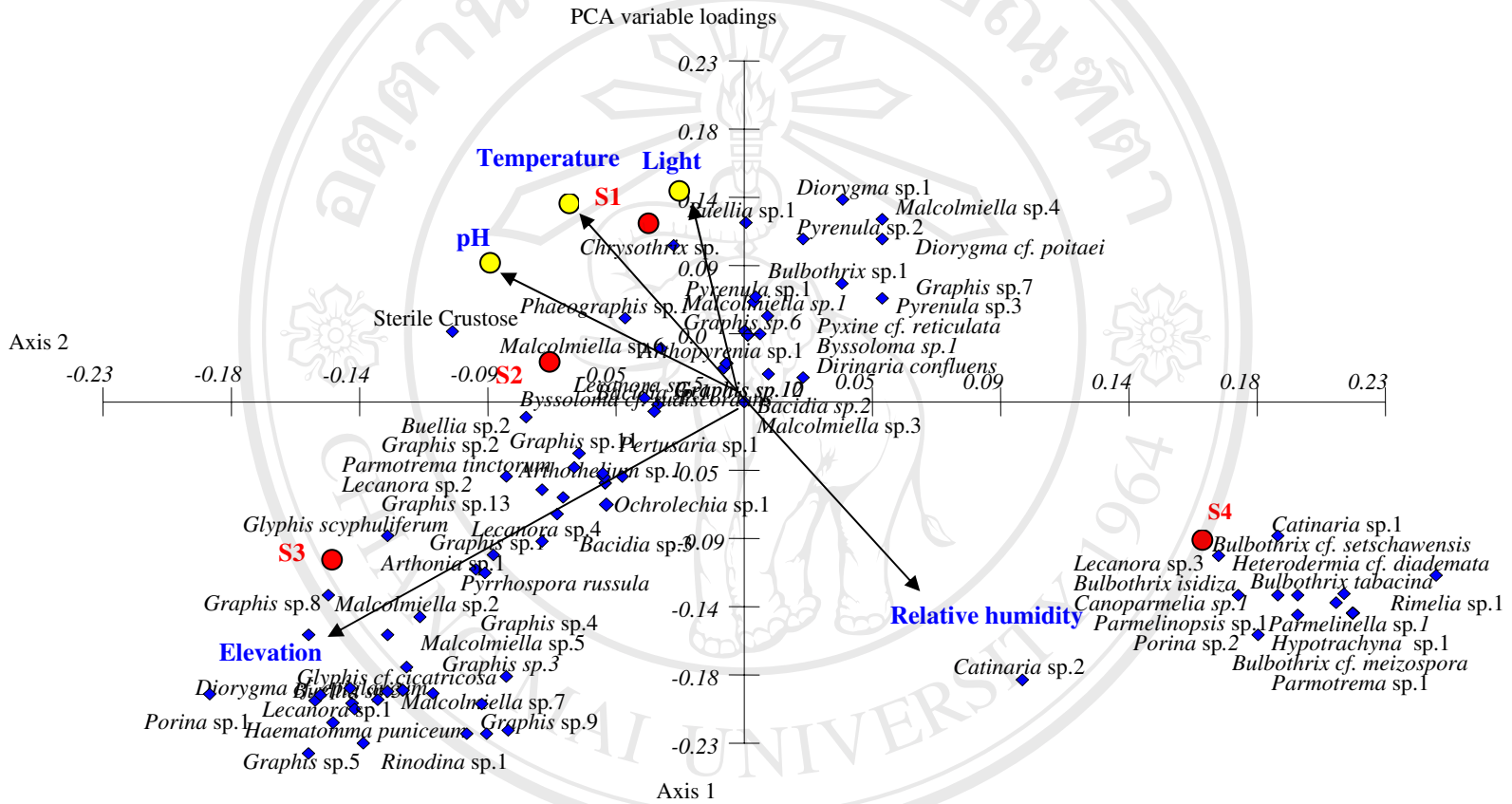

Figure 4.19 Correlation between lichen communities in their study sites and environmental factors

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CHAPTER 5

DISCUSSION

5.1 Lichen diversity and their percentage cover on selected trees species

The diversity of lichens and community composition in tropical forests is influenced by the different species of host trees. Heterogeneity of host trees is important for having high biodiversity of lichens. Over half of the taxa recorded were represented by less than two thalli indicating a rare or endangered of many status lichen species in this forest. Therefore, lichen-host tree relationship need to be further explores in order to establish a baseline for conservation priority. Lichens as well as other lower plants should be included in research and monitoring studies because they tend to be more responsive to environmental changes and more sensitive to disturbance than vascular plant (Matthes–Sears, 1999; Nash III and Olafsen, 1995).

The family Graphidaceae was the distinct group of crustose lichens with the highest percentage cover and dominated on the smooth bark of the *H. dulcis* especially genus *Graphis* sp. This might result from their better chances to establish and occupied on the substrate before the others. The lichens in family Graphidaceae were also noted as a common group in tropical forest (Sipman and Harris, 1989). The Graphidaceae lichens was relatively restricted to smooth bark and had larger proportion on *H. dulcis* and *M. toosendan* than to the rough bark of *S. axillaris* and *P. cerasoides*. It implies that Graphidaceae lichens adapt well to substrates and microclimates of wide variety of host tree species.

H. dulcis was covered most with crustose lichens. This might due to the smooth bark texture of *H. dulcis*, suitable for crustose lichen growth. The highest percentage

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cover of lichen was found in plot 2002. However, species richness in this youngest plot is the lowest. Sterile crusts and *Chrysothrix* sp. showed very high percentage cover in this plot. The environmental factors such as higher temperature and light intensity might influence on lichen distribution. Sterile crust and *Chrysothrix* sp. are tolerant group, therefore, they can establish before other in this harsh environment.

Lichens in these four study sites could be divided into three groups (Figure 4.1); group one included plot 1998 and 2000; group two was Dong Seng forest and group three was by plot 2002. Light may play an important role. Trees in plot 1998 and 2000 produced dense canopy cover. Therefore, light intensity in both plots was lower than in plot 2002, which had less dense canopy cover. Light is necessary for lichens, but lichens can be damaged by high light intensity, especially foliose lichens (Gauslaa *et al*., 2000). Plot 2002 was also the youngest plot. Colonization of lichen propagules from nearby areas might be at the beginning stage. Therefore, this plot was distinguished from other plantation plots. Dong Seng forest is natural forest with fewer disturbance. Therefore lichens in this area have had longer to establish and species composition and percentage cover are higher different to youngest reforestation plots (plot2002) except oldest reforestation plot (plot 1998). Lichens diversity and their recovery increased with increasing in age of study sites, especially in reforestation plots. Thus, forest restoration activities could recover the lichen community.

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5.2 Distribution of crustose and foliose lichens

The groups of lichen in each trees species in all study sites (Table 4.3 and Figure 4.2-4.6) showed that the highest number of crustose lichens was in reforestation plot 1998 especially on *H. dulcis* when compared with all study sites. Hale (1952) and Brodo (1973) suggested that bark with smooth surfaces is dominated by crustose lichens,

whereas rough barks support foliose growth forms. From this study, the smooth bark of *H. dulcis* was suitable for growth of crustose lichens and establishment of new thalli in contrast to the foliose lichens on the rough bark of *P. cerasoides* in Dong Seng forest. Lichens with a crustose growth form preferred smoother bark; *H. dulcis* and *M. toosendan.*

Brodo *et al.* (2001) found crustose lichen in high numbers in young forest and plantations because crustose lichens are pioneer species. Result supports my findings. The youngest plot 2002 had fewer of both crustose and foliose lichens. The number of crustose lichens in reforestation plot 1998 was the highest among the reforestation plots. This plot was the oldest plot. Therefore it allowed more lichens colonized in the area whereas plot 2002 is the youngest plot therefore less lichens can colonize there. The highest number of foliose lichens was found in Dong Seng forest which is the natural forest with closed canopy (Figure 4.6). Foliose lichens are shade tolerant and can grow better under a closed canopy area (Brodo *et al*., 2001). They might serve as indicators for late colonization stage of lichens.

A high number of the distinct group of crustose lichens, genus *Chrysothrix* sp., were found in the young reforestation plot 2002 and most dominated the smooth bark of *H. dulcis* and *M. toosendan* trees. The number of *Chrysothrix* sp. continued to decrease with increasing age of the reforestation plots and the number also decreased in natural forest (Figure 4.7). This demonstrates that *Chrysothrix* sp. is a pioneer species and might serve as indicators for the primary colonization stages of lichens in the reforestation area. The sterile crust that found with high number in the young reforestation plot 2002, especially on *H. dulcis* (Figure 4.8) was similar to *Chrysothrix* sp. in this aspect, but its highest number was on *M. toosendan* (Figure 4.7). *Chrysothrix* sp. had a wide distribution in both lowland and upland areas. It is tolerant to fire

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damaged (Saipunkaew *et al*., 2005). In addition, *Chrysothrix* sp. is tolerant to dry areas with high light intensity (Brodo *et al*., 2001). Therefore, they had high chance to establish and occupy substrates such as tree trunk before the other lichens. Foliose lichens increased with increasing forest development (Figure 4.9), especially on *P. cerasoides* in Dong Seng forest.

5.3 Lichen diversity indices

Table 4.4 showed Shannon's diversity index, evenness and species richness of lichens on all host trees species in each study sites. The highest diversity index was found in reforestation plot 1998 (2.50) and followed by those of plot 2000 (2.06), Dong Seng forest (1.77), plot 2002 (1.04), respectively. According to the diversity index, the highest value was occurred when species were equally abundant (Ludwig and Reynolds, 1988). The highest evenness was in reforestation plot 1998 which implies that lichen species in plot 1998 were rather equally distributed. The lowest evenness was in Dong Seng forest which implies that many rare lichen species occurred in Dong Seng forest. Most lichens in Dong Seng forest were found on *P. cerasoides*, more than other tree species, but lichen communities in plot 1998 were found on all trees with high evenness.

Highest lichen diversity (2.80) was found on *P. cerasoides* in Dong Seng forest. This was because *P. cerasoides* in Dong Seng forest had a high number in crustose and foliose lichens, whereas the lowest value (0.25) was on *M. toosendan* in plot 2002 with had fewer in crustose and foliose lichens. Plot 2002 did not have much diversity in both crustose and foliose lichens. The highest species richness was in Dong Seng forest, but this site had lowest evenness, because most lichens there were highly concentrated only on *P. cerasoides* more than other tree species, Dong Seng forest also had the highest species richness; 44 species were found on four trees species in this forest (Table 4.4).

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This implies that recovery of lichen diversity occurs on all trees of reforestation study sites and increased with tree ages; especially *H. dulcis* which had the high lichens diversity among the reforestation plots. In plot 1998, lichens diversity on *H. dulcis* and *S. axillaris* were higher than in the other reforestation plots, because of older tree ages.

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5.4 Similarity of lichen diversity

From cluster analysis of the combined lichen communities on all selected trees across all study sites (Figure 4.11) based on lichen species and percentage cover of lichen, can be divided into two groups; group one composed of plot 1998, 2000 and Dong Seng forest, group two was distinguished by plot 2002. Dendrogram showed that lichen diversities in plot 1998 and plot 2000 were similar to Dong Seng forest. These three areas have similar physical parameters, which influence on lichen growth.

Lichen communities on *H. dulcis* in plot 1998 and 2000 showed the highest similarity of 0.63 (63%). Comparing lichen community in the same year, lichens communities on *H. dulcis* and *S. axillaris* in plot 1998 showed the highest similar with 0.85 (85%). The lowest similarity was found on H. dulcis in plot 2000 and P. cerasoides in 2002 with 0.13 (13%). As the result, lichen community on *H. dulcis* and *S. axillaris* were highly similar might be because of their bark properties. Bark of *H. dulcis* and *S. axillaris* have smooth with similar bark pH (not significantly difference at 95% CI). Armstrong (1990) found that distribution and abundance of epiphytic lichens depended on the age of stands and their bark chemical properties. It is well known that the physical and chemical properties of tree bark influence the composition of lichen species on trees (Barkman, 1958). Hyvärinen, Halonen, and Kauppi (1992) also reported that bark properties and age of forest were considered as factors which more or less had effects on epiphytic lichens' choices of habitats.

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Also, comparing by Sorensen's similarity index of lichen diversity between the oldest plot 1998 and Dong Seng forest were high similar 0.57 (57 %); *Buellia* sp.1, *Diorygma* cf. *epiglaucum, Dirinaria confluens, Graphis* sp.2, *Graphis* sp.4, *Graphis* sp.5, *Graphis* sp.9, *Graphis* sp.10, *Graphis* sp.11, *Graphis* sp.13, *Haematomma puniceum, Lecanora* sp.1, *Lecanora* sp.5, *Malcolmiella* sp.5, *Malcolmiella* sp.2, *Malcolmiella* sp.7, *Pertusaria* sp.1, *Porina* sp.1 . Lichen species might be bioindicators for forest recovery in this study; *Graphis* sp.9, *Haematomma puniceum*, *Malcolmiella* sp.2 and *Hypotrachyna* sp1

5.5 Environmental factors in study sites

Environmental factors in plot 1998 and Dong Seng forest were not significantly different, especially light intensity. This was due to plot 1998 having a closed canopy which was rather similar with Dong Seng forest. Therefore, lichen communities in 1998 and Dong Seng forest were also more similar than other sites.

Considering bark texture, crustose lichens were common on *H. dulcis* and *M. toosendan* which had smooth bark, and foliose lichens were common on *P. cerasoides* which had rough bark. This result is similar to the study of Hale (1952) who found that crustose lichens were common on smooth barks, while foliose lichens were generally found on rough barks. Furthermore, the study of Polyiam and Boonpragob (2001) in Khao Yai National Park which compared vertical lichen communities on two types of bark characterized by their smoothness (persistent) and roughness (crack) also found that foliose lichens were common on the *Dipterocarpus* tree, which had rough bark, but crustose lichens were common on *Ficus* tree, which had smooth bark.

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The effect of bark texture, bark pH and bark dynamic change on lichen communities had influences on number of lichen taxa. In this study, four selected trees showed different ranges of bark pH; *M. toosendan* (pH 5.8-6.4), *H. dulcis* (pH 5.8-6.6), *S. cerasoides* (pH 5.3-6.3) and *P. cerasoides* (pH 5.5-5.9) which had three trend of bark pH; the first trend was more acidic when tree become older; *H. dulcis* and *P. cerasoides*, the second trend was slightly acidic when tree age increasing; *S. axillaris*, and the third trend was slightly acidic but bark pH of tree with different ages were not much different; *M. toosendan*. These properties might be made the difference lichen communities. However, there are several factors which have effect on lichen communities. One should not consider only single factor. The influence of environmental factors could be more important than bark pH. For instance, Kermit and Gauslaa (2001) pointed out that bark pH increased in correlation with tree height; therefore, there was a probability that bark pH was the cause of lichen abundance on forest canopy and mid trunk. Demmig-Adams *et al.* (1990) and Gauslaa and Solhaug (2000) found that lichens which could tolerate high light intensity were also found at canopy level.

5.6 Data analysis of lichen diversity and environmental factors

Trees act as facilitators for epiphytic lichens, as they provide them with a substratum, and with access to light or other ecological factors, such as a specific pH of bark and bark texture. Previous studies of lichens diversity in northern Thailand suggested that lichens can be used for estimating rates of change in a seasonal tropical forest environment (Wolseley and Aguirre-Hudson, 1991). Recovery of lichen diversity might provide information on how lichen species can function as bioindicators of forest recovery.

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Lichen communities and selected tree species had relationships with environmental factors in each study sites (Figure 4.19). Environment factors such as temperature, light intensity, pH of bark, and elevation above sea level, influenced distribution and diversity of lichens. Figure 4.19 demonstrated that light intensity, temperature and bark pH had a positive relationship with *Chrysothrix* sp.1, *Buellia* sp.1 and sterile crust when these factors were high made these lichens with high distribution especially in the youngest reforestation plot (plot 2002). Crustose lichens distribution related with the high elevation especially in plot 1998. *Catinaria* sp.2 distribution in plot 1998, 2000 and Dong Seng forest related with the high relative humidity. Lichens distribution in Dong Seng forest related with the high relative humidity especially foliose lichens and *Catinaria* sp.1. High light intensity can damage to the foliose lichen (Gauslaa *et al*., 2000), Therefore, this study, foliose lichen mostly found in Dong Seng natural forest with low average light intensity and high relative humidity especially two families; Parmeliaceae and Physiaceae. The foliose genera such as *Bulbothrix* occurred more in older plantation plots and also in natural forest. In the Chiang Mai region, Parmeliaceae and Physiaceae were associated with upland sites, where rainfall and relative humidity were also higher than in lowland areas (Saipunkaew *et al.*, 2005).

5.7 Recommendations

The lichen investigation should be determined with consideration of several environmental factors such as light intensity and their substrate properties. It is well known that the physical and chemical properties of tree bark influence the composition of lichen species on trees. The number and composition of lichen species are quite specific to certain tree species, so the diversity of lichen species in forests increases parallel to the diversity of tree species. So, the recovery of lichen diversity might provide informations

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of how lichen species may play vital role as bioindicators of forest recovery in forest restoration. However, some substrate properties such as bark humidity and nutrient content in the bark should be studies since these properties are also important for lichen growth and colonization.

Lichens respond readily to changes in site factors and can be used to monitoring environmental change and conservation for sustainable utilization of large-scale ecosystems efficiently. Studies on distribution, community structure and the environmental influences on lichens, as a model system, were performed intensively in the temperate forests, whereas report from the tropic was less known. Epiphytic lichens are threatening by development and environmental changes.

This study had shown the importance of heterogeneity and diversity of tree species can be maintained rich lichen flora because in this study found that tree species play important role of diversity lichen communities with their distribution and the recovery of lichen diversity increased in plots with longer reforestation age. Extent forest restoration activities could recover the lichen community. In the tropic where floristic diversity is rich, but baseline information of these important information resources are lacking. Conservation programs need more information on each species distribution and their abundance should be study more in long term study.

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CHAPTER 6

CONCLUSION

In the oldest reforestation plot (plot 1998) had higher diversity indices than other reforestation plots (plot 2000 and plot 2002). The result showed that forest restoration plots were covered mostly by crustose lichens and by foliose in Dong Seng Forest. Therefore, lichens diversity were recovery with crustose lichen at the youngest study site (reforestation plot 2002). It can be implied that the youngest study site (reforestation plot 2002) was the first stage of succession in the reforestation area of this study.

This study can be suggested that some lichen genera such as *Chrysothrix* sp. tended to be a pioneer group and might serve as indicators for the primary colonization stages of lichens in the reforestation area because *Chrysothrix* sp. had high percentage cover in the youngest reforestation plot (plot 2002).

From dendrogram of lichen communities belongs with all selected trees in all study sites based on lichen species, percentage cover of lichen and their similarity, lichen diversity in plot 1998 and plot 2000 were recovery nearly with Dong Seng forest.

There was correlation between lichen communities and other environmental factors. Environment factors such as temperature, light intensity, pH of bark, and elevation, had influence on distribution and diversity of lichens. Host tree and their properties act as facilitators for epiphytic lichens, as they provide them with a substratum, and with other ecological factors, such as a specific pH of bark which the different of bark pH of four tree species in this study might be made the different the lichen communities. Bark texture was the most important factor determining lichen communities and distribution. As a result, the smooth bark of *H. dulcis* was suitable for the growth of crustose lichen and their establishment of new thallus in contrast to the foliose lichens on

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the rough of *P. cerasoides* in Dong Seng forest. The family Graphidaceae was the distinct group of crustose lichens with the highest percentage cover and dominated on the smooth bark of the *H. dulcis* especially genus *Graphis* sp. Therefore, Lichens with crustose growth form preferred smooth bark; *H. dulcis* and *M. toosendan* and foliose growth preferred rough bark *S. axillaris* and *P.cerasoides* especially genus *Bulbothrix* sp.

The highest diversity index was found in reforestation plot 1998 (2.50) and followed by those of plot 2000 (2.06), Dong Seng forest (1.77), plot 2002 (1.04), respectively. that the highest lichen diversity value (2.80) was found on *P. cerasoides* in Dong Seng forest. This due to *P. cerasoides* in Dong Seng forest had high number in crustose and foliose lichens, whereas the lowest value (0.25) was on *M. toosendan* in plot 2002 with had less number in crustose and foliose lichens.

By using Sorensen's coefficient shown that similarity between plot 1998 and 2000 was the highest with 0.69 (69 %). The lowest similarity of 0.23 (23%) was between plot 2002 and Dong Seng forest. Plot 1998 was high similarity with Dong Seng forest with 0.57 (57 %); *Buellia* sp.1, *Diorygma* cf. *epiglaucum, Dirinaria confluens, Graphis* sp.2, *Graphis* sp.4, *Graphis* sp.5, *Graphis* sp.9, *Graphis* sp.10, *Graphis* sp.11, *Graphis* sp.13, *Haematomma puniceum, Lecanora* sp.1, *Lecanora* sp5, *Malcolmiella* sp.5, *Malcolmiella* sp.2, *Malcolmiella* sp.7, *Pertusaria* sp.1, *Porina* sp.1 . Thus, 8 years of reforestation made lichen diversity recovery with 57%.

Some lichens are found in older reforestation plots and in natural forest. Therefore, they might be served as bioindicators for forest recovery in this study; *Graphis* sp.9, *Haematomma puniceum*, *Malcolmiella* sp.2 and *Hypotrachyna* sp.1. *Haematomma puniceum* is an indicator for moist forest (Wolseley and Aguirre-Hudson, 1997b)

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Dendrogram showed that lichen diversities in plot 1998 and plot 2000 were similar to Dong Seng forest. This is resulted from different ages of substrate in each area and environmental factors such as light intensity and humidity. It was found that lichen communities on *H. dulcis* in plot 1998 and 2000 showed the highest similarity of 0.63 (63%). Comparing lichen community in the same year, lichens communities on *H. dulcis* and *S. axillaris* in plot 1998 showed the highest similar with 0.85 (85%). The lowest similarity was found on H. dulcis in plot 2000 and P. cerasoides in 2002 with 0.13 (13%). As the result, lichen community on *H. dulcis* and *S. axillaris* were highly similar might be because of their bark properties. The effect of bark texture, bark pH and bark dynamic change on lichen communities had influences on number of lichen taxa.

There was correlation between lichen communities and other environmental factors. The result showed that environment factors such as temperature, light intensity, pH of bark, and elevation above sea level, had influence on distribution and diversity of lichens. Light intensity, temperature and bark pH had relationship with *Chrysothrix* sp.1, *Buellia* sp.1 and sterile crust when these factors were high made these lichens with high distribution especially in the youngest reforestation plot (plot 2002). Crustose lichens distribution related with the high elevation especially in plot 1998. *Catinaria* sp.2 distribution in plot 1998, 2000 and Dong Seng forest related with the high relative humidity. Lichens distribution in Dong Seng forest related with the high relative humidity especially foliose lichens and *Catinaria* sp.1. Therefore, this study, foliose lichen mostly found in Dong Seng natural forest with low average light intensity and high relative humidity especially two families; Parmeliaceae and Physiaceae. The foliose genera such as *Bulbothrix* occurred more in older plantation plots and also in natural forest.

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The important of diversity of host tree species for maintaining high diversity of the epiphytic lichens, which may be applied to other epiphytic flora as well. Therefore, conservation strategy should be focus on preserving host trees diversity.

The recovery of lichen diversity increased in plots with longer reforestation age. Extent forest restoration activities could recover the lichen community. Diversity of tree species and habitats can maintain the diversity of lichens because in this study found that tree species play important role of diversity lichen communities with their distribution. By the insufficient of informations diversity of lichen in tropical forest and reforestation areas in Thailand should be study more in long term study.

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APPENDIX A

LICHEN RECORD FORM

(แบบฟอร์มการสำรวจไลเคน)

Information on the locality of the examined tree

Date: _____ Location: _____

Collector:

_____

General Data

Elevation (Altitude above sea level): _____ mASL

Circumference of tree trunk (GBH) _____cm. (at 1 m. above ground level)

NOTE: ☐ ***Melia toosendan*** **(เลี่ยน)** ☐ ***Hovenia dulcis*** **(หมอนหิน)**

☐ ***Spondias axillaris*** **(มะกัก)** ☐ ***Prunus cerasoides*** **(นางพญาเสือโคร่ง)**

- **Replication number** ☐

☐ Restoration plot in Baan Mae Sa Mai (restoration forest)

YEAR: ☐ 1998 ☐ 2000 ☐ 2002

☐ Dong Sen Forest on Doi Mae Sa (natural forest)

TEXTURE (ผิวเปลือก) ☐ SMOOTH ☐ CRACKED (แตกเป็นร่างแห)

☐ FLAKING (แตกเป็นเกล็ด) ☐ LENTICELLATE (มีช่องอากาศ)

ASPECTS (ทิศที่พบไลเคนมาก) N S E W E/N E/S W/N W/S

NOTE: _____

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Lichen Diversity

- **Site_____ GBH _____**
- **Number of small grid _____Tree Species _____ Tree No_____**

Type of lichen	Lichen Species	Sum of thallus number	% of lichen cover

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NOTE:_____

_____

_____

PHYSICAL PARAMETERS

Date: Location:

_____ _____

Collector: Elevation(mASL):

_____ _____

Light Intensity (Lux)

1	2	3	4	5	6	7	8	9	10

Average Light Intensity (Lux) _____

Temperature (°C)

1	2	3	4	5	6	7	8	9	10

Average Temperature (°C) _____

- Wet Temperature(°C)
  _____
- Dry Temperature (°C)
  _____

Relative Humidity (%) [ ]

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Bark pH Measurement

Date: _____

Collector: _____

Location: _____

Tree No.	*Melia toosendan*	*Hovenia dulcis*	*Spondias axillaris*	*Prunus cerasoides*
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

- **Average bark pH**

Melia toosendan	
Hovenia dulcis	
Spondias axillaris	
Prunus cerasoides	

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APPENDIX B

FREQUENCY OF LICHEN THALLUS AND THEIR PERCENTAGE COVER ON SELECTED TREES

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APPENDIX B

Appendix B1.1 Lichen diversity on *Melia toosendan* in plot 1998

Lichen species plot 1998	***Melia toosendan***																			
	SF T.1	**%C T.1**	**SF T.2**	**%C T.2**	**SF T.3**	**%C T. 3**	**SF T.4**	**%C T.4**	**SF T.5**	**%C T.5**	**SF T.6**	**%C T.6**	**SF T.7**	**%C T.7**	**SF T.8**	**%C T.8**	**SF T.9**	**%C T.9**	**SF T.10**	**%C T.10**
GBH	**92**	**92**	**52**	**52**	**68**	**68**	**45**	**45**	**52**	**52**	**57**	**57**	**63**	**63**	**52**	**52**	**55**	**55**	**47**	**47**
Number of Small units	**296**	**296**	**184**	**184**	**216**	**216**	**144**	**144**	**184**	**184**	**176**	**176**	**200**	**200**	**168**	**168**	**184**	**184**	**160**	**160**
Arthonia sp.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	11
Bacidia sp.1	0	0	0	0	0	0	0	0	0	0	0	0	3	1.5	0	0	0	0	0	0
Buellia sp.1	0	0	13	7.1	0	0	4	2.8	5	2.8	0	0	0	0	0	0	0	0	0	0
Buellia sp.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	6	7	4.4
Buellia sp.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1.3
Chrysothrix sp.	9	3	10	5.4	14	6.5	8	5.6	21	12	21	12	31	16	14	8.3	23	13	11	6.9
Diorygma cf. *epiglaucum*	0	0	0	0	0	0	4	2.8	0	0	0	0	13	6.5	0	0	0	0	0	0
Glyphis scyphuliferum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1.3
Graphis sp.1	4	1.4	0	0	0	0	1	0.7	0	0	0	0	0	0	0	0	0	0	0	0
Graphis sp.2	0	0	0	0	0	0	21	15	0	0	0	0	7	3.5	0	0	0	0	0	0
Graphis sp.3	0	0	0	0	0	0	0	0	2	1.1	0	0	0	0	11	6.5	0	0	14	8.8
Graphis sp.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2.2	0	0
Graphis sp.8	0	0	0	0	4	1.9	11	7.6	3	1.7	0	0	0	0	0	0	0	0	0	0
Graphis sp.9	0	0	0	0	0	0	0	0	0	0	9	5.1	17	8.5	11	6.5	0	0	11	6.9
Graphis sp.13	0	0	0	0	0	0	0	0	0	0	3	1.7	6	3	0	0	0	0	0	0
Haematomma puniceum	0	0	0	0	0	0	0	0	4	2.3	11	6.3	0	0	10	6	2	1.1	8	5
Lecanora sp.1	31	10	3	1.6	8	3.7	9	6.3	6	3.4	0	0	0	0	8	4.8	20	11	8	5

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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Appendix B1.1 (continue)

Lichen species plot 1998	*Melia toosendan*																			
	SF	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**
	T.1	**T.1**	**T.2**	**T.2**	**T.3**	**T. 3**	**T.4**	**T.4**	**T.5**	**T.5**	**T.6**	**T.6**	**T.7**	**T.7**	**T.8**	**T.8**	**T.9**	**T.9**	**T.10**	**T.10**
GBH	**92**	**92**	**52**	**52**	**68**	**68**	**45**	**45**	**52**	**52**	**57**	**57**	**63**	**63**	**52**	**52**	**55**	**55**	**47**	**47**
Number of small units	**296**	**296**	**184**	**184**	**216**	**216**	**144**	**144**	**184**	**184**	**176**	**176**	**200**	**200**	**168**	**168**	**184**	**184**	**160**	**160**
Porina sp.1	0	0	0	0	0	0	6	4.2	11	6.3	0	0	0	0	0	0	0	0	4	2.5
Pyrrhospora russula	5	1.7	19	10	1	0.5	1	0.7	12	6.8	0	0	0	0	35	18	4	2.2	9	5.6
Sterile crust	42	14	31	17	32	15	37	36	32	18	11	6.3	52	26	47	23	52	28	42	26

Appendix B1.2 Lichen diversity on *Hovenia dulcis* in plot 1998

Lichen species plot 1998	*Hovenia dulcis*																			
	SF	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**
	T.1	**T.1**	**T.2**	**T.2**	**T.3**	**T. 3**	**T.4**	**T.4**	**T.5**	**T.5**	**T.6**	**T.6**	**T.7**	**T.7**	**T.8**	**T.8**	**T.9**	**T.9**	**T.10**	**T.10**
GBH	**27**	**25**	**33**	**33**	**24**	**24**	**24**	**24**	**27**	**27**	**29**	**29**	**23**	**23**	**19**	**19**	**21**	**21**	**26**	**26**
Number of small units	**88**	**88**	**112**	**112**	**80**	**80**	**80**	**80**	**88**	**88**	**96**	**96**	**80**	**80**	**56**	**56**	**72**	**72**	**88**	**88**
Arthonia sp.1	0	0	0	0	0	0	0	0	0	0	6	6.3	0	0	0	0	0	0	0	0
Bacidia sp.3	0	0	1	1.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buellia sp.3	5	5.68	2	2.5	0	0	4	5	2	2.5	0	0	0	0	0	0	0	0	1	1.1
Catinaria sp.2	3	3.40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2.3
Chrysothrix sp.	11	12.5	11	14	12	11	11	14	12	14	0	0	0	0	6	11	8	11	11	13
Diorygma cf. *epiglaucum*	4	4.55	0	0	0	0	0	0	0	0	0	0	5	6.3	0	0	0	0	8	9.1
Glyphis cf.*cicanoricosa*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2.8	0	0
Glyphis scyphuliferum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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Appendix B1.2 (continue)

Lichen species plot 1998	*Hovenia dulcis*																			
	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C
	T.1	T.1	T.2	T.2	T.3	T. 3	T.4	T.4	T.5	T.5	T.6	T.6	T.7	T.7	T.8	T.8	T.9	T.9	T.10	T.10
GBH	**27**	**25**	**33**	**33**	**24**	**24**	**24**	**24**	**27**	**27**	**29**	**29**	**23**	**23**	**19**	**19**	**21**	**21**	**26**	**26**
Number of small units	**88**	**88**	**112**	**112**	**80**	**80**	**80**	**80**	**88**	**88**	**96**	**96**	**80**	**80**	**56**	**56**	**72**	**72**	**88**	**88**
Graphis sp.1	1	1.14	4	5	3	2.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Graphis sp.2	0	0	0	0	0	0	3	3.8	0	0	0	0	0	0	4	7.1	0	0	0	0
Graphis sp.3	3	3.40	3	3.8	3	2.7	2	2.5	7	8.8	0	0	2	2.5	11	20	7	9.7	5	5.7
Graphis sp.4	0	0	0	0	0	0	0	0	0	0	11	11	2	2.5	0	0	0	0	0	0
Graphis sp.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	15	4	4.5
Graphis sp.8	0	0	4	5	0	0	0	0	3	3.4	0	0	0	0	0	0	11	15	4	4.5
Graphis sp.9	4	4.55	8	10	4	3.6	15	19	7	8.8	0	0	0	0	0	0	21	29	3	3.4
Graphis sp.11	0	0	0	0	0	0	0	0	0	0	0	0	5	6.3	0	0	0	0	0	0
Haematomma puniceum	0	0	1	1.3	0	0	0	0	0	0	11	11	5	6.3	2	3.6	4	5.6	7	8
Lecanora sp.1	6	6.81	8	10	11	9.8	11	14	5	6.3	0	0	0	0	0	0	6	8.3	4	4.5

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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Appendix B1.3 Lichen diversity on *Spondias axillaris* in plot 1998

Lichen species plot 1998	*Spondias axillaris*																			
	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C
	T.1	T.1	T.2	T.2	T.3	T. 3	T.4	T.4	T.5	T.5	T.6	T.6	T.7	T.7	T.8	T.8	T.9	T.9	T.10	T.10
GBH	**39**	**39**	**34**	**34**	**51**	**51**	**53**	**53**	**57**	**57**	**83**	**83**	**84**	**84**	**41**	**41**	**63**	**63**	**64**	**64**
Number of small units	**88**	**88**	**112**	**112**	**168**	**168**	**176**	**176**	**184**	**184**	**264**	**264**	**240**	**240**	**96**	**96**	**208**	**208**	**192**	**192**
Bacidia sp.3	0	0	2	1.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2.1
Buellia sp.1	0	0	4	3.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buellia sp.2	0	0	0	0	3	1.8	0	0	7	3.8	5	1.9	0	0	0	0	0	0	5	2.6
Chrysothrix sp.	13	15	11	9.8	9	5.4	23	13	5	2.7	7	2.7	21	8.8	15	16	7	3.4	7	3.6
Diorygma cf. *epiglaucum*	0	0	0	0	0	0	0	0	13	7.1	0	0	0	0	0	0	0	0	0	0
Graphis sp.1	5	5.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Graphis sp.3	3	3.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Graphis sp.4	0	0	0	0	0	0	0	0	0	0	11	4.2	0	0	0	0	0	0	0	0
Graphis sp.8	5	5.7	0	0	0	0	0	0	0	0	0	0	0	0	3	3.1	0	0	0	0
Graphis sp.9	10	11	7	6.3	0	0	0	0	0	0	11	4.2	16	6.7	2	2.1	5	2.4	0	0
Graphis sp.11	9	10	0	0	0	0	6	3.4	0	0	16	6.1	0	0	0	0	0	0	6	3.1
Graphis sp.13	4	4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecanora sp.1	7	8	3	2.7	3	1.8	0	0	5	2.7	7	2.7	0	0	1	1	11	5.3	7	3.6
Malcolmiella sp.2	0	0	0	0	0	0	4	2.3	0	0	0	0	0	0	0	0	0	0	0	0
Malcolmiella sp.5	0	0	0	0	0	0	0	0	0	0	2	0.8	0	0	0	0	0	0	0	0
Pyrrhospora russula	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1.4	0	0
Sterile crust	7	8	29	26	10	6	28	16	21	11	37	14	32	13	21	22	31	15	31	16

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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Appendix B1.4 Lichen diversity on *Prunus cerasoides* in plot 1998

Lichen species plot 1998	*Prunus cerasoides*																			
	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C
	T.1	T.1	T.2	T.2	T.3	T. 3	T.4	T.4	T.5	T.5	T.6	T.6	T.7	T.7	T.8	T.8	T.9	T.9	T.10	T.10
GBH	**31**	**31**	**40**	**40**	**30**	**30**	**29**	**29**	**40**	**40**	**40**	**40**	**37**	**37**	**50**	**50**	**40**	**40**	**26**	**26**
Number of small units	**112**	**112**	**88**	**88**	**104**	**104**	**112**	**112**	**128**	**128**	**144**	**144**	**120**	**120**	**120**	**120**	**136**	**136**	**88**	**88**
Arthopyrenia sp.1	11	7.6	0	0	9	7.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bacidia sp1.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3.3	0	0	0	0
Bacidia sp.2	0	0	0	0	3	2.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buellia sp.1	6	5.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buellia sp.2	0	0	0	0	8	7.7	11	9.8	5	3.9	15	10	0	0	0	0	0	0	0	0
Bulbothrix sp.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1.7	0	0	0	0
Byssoloma sp.1	0	0	0	0	0	0	0	0	0	0	2	1.4	0	0	0	0	0	0	0	0
Catinaria sp2	2	1.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1.1
Chrysothrix sp.	15	13	3	3.4	12	12	7	6.3	2	1.6	6	4.2	5	4.2	3	2.5	4	2.9	6	6.8
Diorygma cf. *epiglaucum*	0	0	4	4.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dirinaria confluens	0	0	0	0	0	0	0	0	0	0	3	2.1	0	0	2	1.7	3	2.2	3	3.4
Graphis sp.2	0	0	2	2.3	0	0	0	0	0	0	16	11	7	5.8	4	3.3	0	0	0	0
Graphis sp.4	0	0	0	0	4	3.8	0	0	0	0	1	0.7	0	0	0	0	0	0	3	3.4
Graphis sp.7	4	3.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Graphis sp.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3.4
Graphis sp.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2.3
Graphis sp.11	0	0	0	0	0	0	0	0	3	2.3	0	0	0	0	0	0	0	0	0	0
Graphis sp.10	0	0	0	0	0	0	0	0	3	2.3	0	0	0	0	0	0	0	0	0	0

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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Appendix B1.4 (continue)

Lichen species plot 1998	***Prunus*** *cerasoides*																			
	SF	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**
	T.1	**T.1**	**T.2**	**T.2**	**T.3**	**T. 3**	**T.4**	**T.4**	**T.5**	**T.5**	**T.6**	**T.6**	**T.7**	**T.7**	**T.8**	**T.8**	**T.9**	**T.9**	**T.10**	**T.10**
GBH	**31**	**31**	**40**	**40**	**30**	**30**	**29**	**29**	**40**	**40**	**40**	**40**	**37**	**37**	**50**	**50**	**40**	**40**	**26**	**26**
Number of small units	**112**	**112**	**88**	**88**	**104**	**104**	**112**	**112**	**128**	**128**	**144**	**144**	**120**	**120**	**120**	**120**	**136**	**136**	**88**	**88**
Lecanora sp.1	0	0	2	2.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malcolmiella sp3.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.7	0	0
Parmotrema tinctorum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.7	0	0
Pertusaria sp.1	1	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pyrrhospora russula	0	0	0	0	0	0	0	0	0	0	1	0.7	0	0	0	0	0	0	1	1.1
Sterile crust	10	8.9	11	13	11	11	17	15	11	8.6	11	7.6	2	1.7	17	14	11	8.1	7	8

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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Appendix B2.1 Lichen diversity on *Melia toosendan* in plot 2000

Lichen species plot 2000	*Melia toosendan*																			
	SF	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**
	T.1	**T.1**	**T.2**	**T.2**	**T.3**	**T. 3**	**T.4**	**T.4**	**T.5**	**T.5**	**T.6**	**T.6**	**T.7**	**T.7**	**T.8**	**T.8**	**T.9**	**T.9**	**T.10**	**T.10**
GBH	**64**	**64**	**16**	**16**	**23**	**23**	**18**	**18**	**15**	**15**	**42**	**42**	**52**	**52**	**42**	**42**	**37**	**37**	**41**	**41**
Number of small units	**208**	**208**	**56**	**56**	**80**	**80**	**72**	**72**	**48**	**48**	**136**	**136**	**160**	**160**	**136**	**136**	**120**	**120**	**128**	**128**
Bacidia sp.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1.5	0	0	0	0
Buellia sp.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	3.7	0	0	0	0
Bulbothrix sp.1	0	0	0	0	0	0	0	0	1	2.1	0	0	0	0	3	2.2	0	0	3	2.3
Chrysothrix sp.	0	0	4	7.1	4	5	6	11	9	19	22	16	23	14	0	0	15	13	18	14
Diorygma sp.1	0	0	0	0	0	0	0	0	2	4.2	0	0	0	0	0	0	0	0	0	0
Graphis sp.1	0	0	0	0	0	0	0	0	2	4.2	0	0	0	0	0	0	11	9.2	7	5.5
Graphis sp.5	0	0	0	0	0	0	3	5.4	0	0	0	0	0	0	0	0	0	0	0	0
Graphis sp.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1.5	0	0	0	0
Graphis sp.9	12	5.8	0	0	9	11	2	3.6	0	0	0	0	0	0	13	9.6	9	7.5	0	0
Graphis sp.11	0	0	15	27	5	6.3	11	20	4	8.3	0	0	0	0	3	2.2	0	0	0	0
Lecanora sp.1	0	0	0	0	0	0	0	0	1	2.1	0	0	0	0	2	1.5	0	0	0	0
Lecanora sp.2	0	0	0	0	0	0	0	0	0	0	0	0	5	3.1	7	5.1	2	1.7	0	0
Parmotrema sp.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1.5	0	0	0	0
Pyrrhospora russula	0	0	1	1.8	1	1.3	2	3.6	1	2.1	1	0.7	0	0	3	2.2	0	0	0	0
Sterile crust	23	11	17	30	20	25	7	13	4	8.3	40	29	15	9.4	10	7.4	36	30	30	23

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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Appendix B2.2 Lichen diversity on *Hovenia dulcis* in plot 2000

lichen species plot 2000	*Hovenia dulcis*																			
	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C
	T.1	T.1	T.2	T.2	T.3	T. 3	T.4	T.4	T.5	T.5	T.6	T.6	T.7	T.7	T.8	T.8	T.9	T.9	T.10	T.10
GBH	**14**	**14**	**29**	**29**	**27**	**27**	**14**	**14**	**9**	**9**	**15**	**15**	**14**	**14**	**9**	**9**	**16**	**16**	**19**	**19**
Number of small units	**48**	**48**	**96**	**96**	**88**	**88**	**48**	**48**	**32**	**32**	**48**	**48**	**48**	**48**	**32**	**32**	**56**	**56**	**64**	**64**
Arthonia sp.1	0	0	0	0	0	0	0	0	0	0	0	0	1	2.1	0	0	2	3.6	0	0
Arthothelium sp.1	0	0	0	0	9	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buellia sp.2	0	0	0	0	3	3.4	0	0	0	0	6	13	2	4.2	0	0	18	32	0	0
Buellia sp.3	0	0	0	0	3	3.4	0	0	0	0	0	0	0	0	1	3.1	0	0	1	1.6
Bulbothrix sp.1	0	0	0	0	1	1.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Byssoloma cf. *sudiscordans*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1.6
Catinaria sp2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	7.8
Chrysothrix sp.	0	0	0	0	0	0	2	5.2	8	16	12	25	16	33	15	47	11	20	12	19
Diorygma cf. *epiglaucum*	0	0	0	0	1	1.1	1	2.1	0	0	0	0	0	0	0	0	2	3.6	0	0
Dirinaria confluens	0	0	0	0	1	1.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Graphis sp.1	1	2.1	1	1	1	1.1	0	0	0	0	0	0	0	0	3	9.4	3	5.4	0	0
Graphis sp.2	0	0	0	0	0	0	0	0	0	0	2	4.2	0	0	3	9.4	0	0	0	0
Graphis sp.3	0	0	0	0	0	0	0	0	0	0	0	0	2	4.2	0	0	0	0	0	0
Graphis sp.4	0	0	0	0	0	0	0	0	0	0	1	2.1	0	0	0	0	0	0	0	0
Graphis sp.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5.4	0	0
Graphis sp.11	0	0	11	11	0	0	0	0	5	16	0	0	2	4.2	4	13	11	20	17	27
Graphis sp.13	0	0	0	0	12	14	0	0	0	0	3	6.3	0	0	0	0	0	0	0	0

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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Appendix B2.2 (Continued)

lichen species	*Hovenia dulcis*																			
plot 2000	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C
	T.1	T.1	T.2	T.2	T.3	T. 3	T.4	T.4	T.5	T.5	T.6	T.6	T.7	T.7	T.8	T.8	T.9	T.9	T.10	T.10
GBH	**14**	**14**	**29**	**29**	**27**	**27**	**14**	**14**	**9**	**9**	**15**	**15**	**14**	**14**	**9**	**9**	**16**	**16**	**19**	**19**
Number of small units	**48**	**48**	**96**	**96**	**88**	**88**	**48**	**48**	**32**	**32**	**48**	**48**	**48**	**48**	**32**	**32**	**56**	**56**	**64**	**64**
Graphis sp.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3.1
Graphis sp.9	0	0	0	0	3	3.4	2	5.2	1	3.8	5	10	0	0	2	6.3	4	7.1	0	0
Haematomma puniceum	0	0	4	4.2	8	9.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecanora sp.1	0	0	0	0	20	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecanora sp.2	0	0	0	0	3	3.4	0	0	3	9.4	0	0	0	0	0	0	10	18	0	0
Lecanora sp.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malcolmiella sp.2	0	0	1	1	0	0	0	0	2	6.3	0	0	0	0	0	0	0	0	0	0
Malcolmiella sp.3	0	0	0	0	0	0	0	0	0	0	6	13	0	0	3	9.4	0	0	0	0
Malcolmiella sp.6	0	0	7	7.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ochrolechia sp.1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parmotrema sp.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parmotrema tinctorum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3.1
Pertusaria sp.1	0	0	0	0	0	0	0	0	0	0	4	8.3	0	0	2	6.3	7	13	11	17
Pyrrhospora russula	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4.7
Sterile crust	3	6.3	19	20	21	24	10	21	17	53	6	13	11	23	13	41	21	38	33	52

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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Appendix B2.3 Lichen diversity on *Spondias axillaris* in plot 2000

lichen species plot 2000	*Spondias axillaris*																			
	SF	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**
	T.1	**T.1**	**T.2**	**T.2**	**T.3**	**T. 3**	**T.4**	**T.4**	**T.5**	**T.5**	**T.6**	**T.6**	**T.7**	**T.7**	**T.8**	**T.8**	**T.9**	**T.9**	**T.10**	**T.10**
GBH	**24**	**24**	**24**	**24**	**22**	**22**	**34**	**34**	**30**	**30**	**12**	**12**	**22**	**22**	**33**	**33**	**26**	**26**	**16**	**16**
Number of small units	**72**	**72**	**72**	**72**	**64**	**64**	**112**	**112**	**96**	**96**	**40**	**40**	**64**	**64**	**112**	**112**	**96**	**96**	**56**	**56**
Buellia sp.2	0	0	2	2.8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buellia sp.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3.1	0	0
Bulbothrix sp.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5.2	0	0
Byssoloma cf. *sudiscordans*	1	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chrysothrix sp.	15	21	18	25	20	31	39	35	1	1	0	0	0	0	24	21	0	0	0	0
Graphis sp.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1.8	0	0	2	3.6
Graphis sp.11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	30	0	0
Malcolmiella sp.3	0	0	0	0	1	1.6	4	3.6	0	0	0	0	0	0	0	0	0	0	0	0
Sterile crust	31	43	14	19	0	0	0	0	32	33	15	38	15	23	31	28	20	21	8	14

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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Appendix B2.4 Lichen diversity on *Prunus cerasoides* in plot 2000

lichen species plot 2000	*Prunus cerasoides*																			
	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C
	T.1	T.1	T.2	T.2	T.3	T. 3	T.4	T.4	T.5	T.5	T.6	T.6	T.7	T.7	T.8	T.8	T.9	T.9	T.10	T.10
GBH	**17**	**17**	**29**	**29**	**20**	**20**	**18**	**18**	**23**	**23**	**32**	**32**	**24**	**24**	**14**	**14**	**16**	**16**	**17**	**17**
Number of small units	**56**	**56**	**112**	**112**	**72**	**72**	**64**	**64**	**72**	**72**	**96**	**96**	**72**	**72**	**40**	**40**	**48**	**48**	**56**	**56**
Buellia sp.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	34
Bulbothrix sp.1	0	0	0	0	0	0	0	0	0	0	1	1.1	0	0	0	0	0	0	0	0
Chrysothrix sp.	1	1.8	2	1.8	1	1.4	3	4.7	3	4.2	16	17	0	0	11	28	2	4.2	3	5.4
Graphis sp.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5	11	23	0	0
Graphis sp.9	0	0	0	0	0	0	0	0	0	0	16	17	0	0	0	0	0	0	0	0
Lecanora sp.1	0	0	0	0	0	0	0	0	0	0	6	6.3	0	0	0	0	0	0	0	0
Sterile crust	11	20	11	9.8	3	4.2	0	0	3	4.2	5	5.2	10	14	0	0	0	0	26	46

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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Appendix B3.1 Lichen diversity on *Melia toosendan* in plot 2002

lichen species plot 2002	*Melia toosendan*																			
	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C
	T.1	T.1	T.2	T.2	T.3	T. 3	T.4	T.4	T.5	T.5	T.6	T.6	T.7	T.7	T.8	T.8	T.9	T.9	T.10	T.10
GBH	**32**	**32**	**29**	**29**	**29**	**29**	**25**	**25**	**47**	**47**	**28**	**28**	**32**	**32**	**29**	**29**	**50**	**50**	**42**	**42**
Number of small units	**96**	**96**	**96**	**96**	**80**	**80**	**80**	**80**	**48**	**48**	**96**	**96**	**112**	**112**	**104**	**104**	**160**	**160**	**136**	**136**
Bulbothrix sp.1	3	3.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.7
Chrysothrix sp.	78	81	83	86	70	88	60	75	10	6.9	67	70	86	77	77	74	91	57	72	53
Graphis sp.11	0	0	5	5.2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malcolmiella sp.6	8	8.3	0	0	0	0	0	0	0	0	0	0	0	0	9	8.7	8	5	4	2.9
Sterile crust	62	64	44	46	34	54	48	60	33	23	28	29	17	15	41	39	66	41	54	40

Appendix B3.2 Lichen diversity on *Hovenia dulcis* in plot 2002

Lichen species plot 2002	*Hovenia dulcis*																			
	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C
	T.1	T.1	T.2	T.2	T.3	T. 3	T.4	T.4	T.5	T.5	T.6	T.6	T.7	T.7	T.8	T.8	T.9	T.9	T.10	T.10
GBH	**19**	**19**	**11**	**11**	**13**	**13**	**19**	**19**	**26**	**26**	**23**	**23**	**27**	**27**	**22**	**22**	**24**	**24**	**25**	**25**
Number of small units	**64**	**64**	**40**	**40**	**48**	**48**	**64**	**64**	**88**	**88**	**72**	**72**	**88**	**88**	**80**	**80**	**72**	**72**	**80**	**80**
Arthonia sp.1	0	0	0	0	3	6.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Buellia sp.1	0	0	0	0	1	2.1	9	14	1	1.1	0	0	2	2.3	5	6.3	20	28	6	7.5
Chrysothrix sp.	42	66	23	58	8	17	48	75	65	74	18	25	81	93	67	84	35	49	33	41
Graphis sp.3	0	0	0	0	4	8.3	2	3.1	0	0	0	0	1	1.1	2	2.5	4	5.6	0	0
Malcolmiella sp.6	0	0	0	0	0	0	18	28	0	0	0	0	10	11	0	0	1	1.4	0	0
Sterile crust	40	63	32	80	14	29	37	58	76	86	32	44	54	61	2	2.5	11	15	59	74

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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Appendix B3.3 Lichen diversity on *Spondias axillaris* in plot 2002

Lichen species plot 2002	*Spondias axillaris*																			
	SF	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**
	T.1	**T.1**	**T.2**	**T.2**	**T.3**	**T. 3**	**T.4**	**T.4**	**T.5**	**T.5**	**T.6**	**T.6**	**T.7**	**T.7**	**T.8**	**T.8**	**T.9**	**T.9**	**T.10**	**T.10**
GBH	**28**	**28**	**28**	**28**	**25**	**25**	**17**	**17**	**21**	**21**	**34**	**34**	**25**	**25**	**32**	**32**	**32**	**32**	**32**	**32**
Number of Small units	**88**	**88**	**72**	**72**	**88**	**88**	**56**	**56**	**64**	**64**	**112**	**112**	**72**	**72**	**104**	**104**	**104**	**104**	**104**	**104**
Buellia sp.1	0	0	2	2.8	6	6.8	6	11	0	0	0	0	10	14	1	1.1	41	39	12	12
Bulbothrix sp.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1.1	0	0	0	0
Chrysothrix sp.	44	50	37	51	41	47	14	25	1	1.6	30	27	10	14	43	49	77	74	13	13
Graphis sp.3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2.3	0	0	0	0
Malcolmiella sp.6	0	0	6	8.3	48	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sterile crust	20	23	32	44	10	11	20	36	6	9.4	13	12	24	33	52	59	9	8.7	31	30

Appendix B3.4 Lichen diversity on *Prunus cerasoides* in plot 2002

Lichen species plot 2002	*Prunus cerasoides*																			
	SF	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**
	T.1	**T.1**	**T.2**	**T.2**	**T.3**	**T. 3**	**T.4**	**T.4**	**T.5**	**T.5**	**T.6**	**T.6**	**T.7**	**T.7**	**T.8**	**T.8**	**T.9**	**T.9**	**T.10**	**T.10**
GBH	**17**	**17**	**19**	**19**	**12**	**12**	**16**	**16**	**22**	**22**	**18**	**18**	**19**	**19**	**29**	**29**	**26**	**26**	**18**	**18**
Number of Small units	**64**	**64**	**64**	**64**	**56**	**56**	**56**	**56**	**64**	**64**	**64**	**64**	**64**	**64**	**72**	**72**	**88**	**88**	**56**	**56**
Buellia sp.1	0	0	0	0	13	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chrysothrix sp.	3	4.7	5	7.8	0	0	0	0	0	0	0	0	0	0	1	1.4	0	0	3	5.6
Sterile crust	3	4.7	8	13	32	57	31	55	4	6.3	4	6.3	0	0	10	14	0	0	5	8.9

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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Appendix B4.1 Lichen Diversity on *Melia toosendan* in Dong Seng Forest

lichen species Dong Seng forest	*Melia toosendan*											
	SF	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**
	T.1	**T.1**	**T.2**	**T.2**	**T.3**	**T. 3**	**T.4**	**T.4**	**T.5**	**T.5**	**T.6**	**T.6**
GBH	**136**	**136**	**40**	**40**	**118**	**118**	**127**	**127**	**69**	**69**	**186**	**186**
Number of Small units	**520**	**520**	**160**	**160**	**472**	**472**	**502**	**502**	**272**	**272**	**744**	**744**
Buellia sp.1	0	0	0	0	0	0	3	0.6	0	0	0	0
Diorygma cf. *epiglaucum*	12	2.3	5	3.1	0	0	3	0.6	0	0	0	0
Diorygma cf. *poitaei*	0	0	0	0	0	0	0	0	0	0	15	2
Diorygma sp.1	0	0	0	0	0	0	6	1.2	0	0	0	0
Dirinaria confluens	0	0	3	1.9	4	0.8	0	0	0	0	0	0
Graphis sp.2	0	0	0	0	9	1.9	0	0	0	0	0	0
Graphis sp.4	0	0	0	0	3	0.6	0	0	0	0	11	1.5
Graphis sp.5	0	0	4	2.5	0	0	0	0	0	0	0	0
Graphis sp.6	5	1	0	0	2	0.4	0	0	7	2.6	0	0
Graphis sp.9	19	3.7	2	0.6	0	0	0	0	6	2.2	0	0
Graphis sp.10	0	0	0	0	7	1.5	0	0	0	0	0	0
Graphis sp.11	11	1.9	2	0.6	0	0	5	1	0	0	16	2.2
Lecanora sp.1	0	0	0	0	0	0	9	1.8	7	2.6	0	0
Lecanora sp.5	0	0	0	0	8	1.7	12	2.4	0	0	0	0
Malcolmiella sp2.	0	0	0	0	0	0	0	0	9	3.3	0	0
Parmotrema sp.1	0	0	0	0	0	0	1	0.2	0	0	0	0
Pertusaria sp.1	7	1.3	0	0	0	0	0	0	0	0	0	0
Pyxine cf. *reticulata*	0	0	0	0	0	0	2	0.4	0	0	0	0
Sterile crust	6	1.2	5	3.1	12	2.5	15	3	11	4	26	3.5

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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Appendix B4.2 Lichen diversity on *Hovenia dulcis* in Dong Seng Forest

lichen species Dong Seng forest	*Hovenia dulcis*																			
	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C
	T.1	T.1	T.2	T.2	T.3	T. 3	T.4	T.4	T.5	T.5	T.6	T.6	T.7	T.7	T.8	T.8	T.9	T.9	T.10	T.10
GBH	**82**	**82**	**70**	**70**	**72**	**72**	**92**	**92**	**90**	**90**	**93**	**93**	**69**	**69**	**90**	**90**	**92**	**92**	**98**	**98**
Number of Small units	**328**	**328**	**280**	**280**	**288**	**288**	**368**	**368**	**360**	**360**	**368**	**368**	**304**	**304**	**360**	**360**	**368**	**368**	**404**	**404**
Buellia sp.1	0	0	0	0	0	0	8	2.2	6	1.7	6	1.6	8	2.6	0	0	0	0	0	0
Graphis sp.3	0	0	0	0	0	0	0	0	0	0	0	0	5	1.6	0	0	0	0	0	0
Graphis sp.9	0	0	2	0.7	7	2.4	0	0	0	0	3	0.8	0	0	0	0	0	0	0	0
Graphis sp.11	0	0	6	2.1	0	0	13	3.5	0	0	2	0.5	0	0	0	0	0	0	0	0
Lecanora sp.5	10	3	2	0.7	3	1	3	0.8	0	0	0	0	0	0	7	1.9	14	3.8	0	0
Malcolmiella sp2.	12	3.7	0	0	11	3.8	16	4.3	11	3.1	0	0	11	4	8	2.2	0	0	0	0
Malcolmiella sp4.	0	0	2	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Malcolmiella sp5.	0	0	0	0	0	0	6	1.6	0	0	0	0	0	0	0	0	0	0	0	
Malcolmiella sp7.	0	0	0	0	0	0	0	0	3	0.8	0	0	0	0	0	0	0	0	0	0
Pertusaria sp.1	0	0	0	0	0	0	0	0	0	0	8	2.2	0	0	0	0	0	0	0	0
Phaeographis sp.1	0	0	0	0	0	0	0	0	0	0	7	1.9	0	0	0	0	0	0	0	0
Pyrenula sp.1	0	0	0	0	0	0	0	0	0	0	0	0	6	2.0	4	1.1	0	0	0	0
Pyrenula sp.2	0	0	0	0	0	0	0	0	0	0	0	0	11	3.6	0	0	0	0	0	0
Pyrenula sp.3	0	0	0	0	0	0	0	0	0	0	0	0	9	3.0	0	0	0	0	0	0
Sterile crust	0	0	0	0	14	4.9	20	5.4	17	7.7	23	6.3	13	4.3	16	4.4	20	5.4	28	6.9

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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Appendix B4.3 Lichen Diversity on *Spondias axillaris* in Dong Seng Forest

lichen species Dong Seng forest	*Spondias axillaris*							
	SF	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**
	T.1	**T.1**	**T.2**	**T.2**	**T.3**	**T. 3**	**T.4**	**T.4**
GBH	**102**	**102**	**107**	**107**	**116**	**116**	**163**	**163**
Number of Small units	**320**	**320**	**336**	**336**	**360**	**360**	**648**	**648**
Buellia sp.1	4	1.3	0	0	6	1.7	21	3.2
Graphis sp.11	0	0	0	0	2	0.6	0	0.0
Graphis sp.12	0	0	0	0	2	0.6	0	0
Graphis sp.13	0	0	0	0	0	0	14	2.2
Malcolmiella sp1.	0	0	0	0	4	1.1	0	0
Porina sp.1	3	0.9	11	3.3	0	0	0	0
Pyrenula sp.1	0	0	0	0	0	0	8	1.2
Pyrenula sp.2	0	0	0	0	0	0	12	1.9
Sterile crust	12	3.8	13	3.9	12	3.3	16	2.5

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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Appendix B4.4 Lichen Diversity on *Prunus cerasoides* in Dong Seng Forest

Lichen species Dong Seng forest	*Prunus cerasoides*																			
	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C	SF	%C
	T.1	T.1	T.2	T.2	T.3	T. 3	T.4	T.4	T.5	T.5	T.6	T.6	T.7	T.7	T.8	T.8	T.9	T.9	T.10	T.10
GBH	**45**	**45**	**38**	**38**	**39**	**39**	**43**	**43**	**57**	**57**	**34**	**34**	**72**	**72**	**50**	**50**	**90**	**90**	**27**	**27**
Number of Small units	**144**	**144**	**120**	**120**	**128**	**128**	**176**	**176**	**224**	**224**	**104**	**104**	**288**	**288**	**200**	**200**	**328**	**328**	**314**	**314**
Buellia sp.1	0	0	1	0.8	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Bulbothrix cf. *meizospora*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.3
Bulbothrix cf. *setschawensis*	0	0	2	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bulbothrix isidiza	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0
Bulbothrix sp.1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Bulbothrix tabacina	0	0	1	0.8	0	0	3	1.7	2	0.9	0	0	0	0	0	0	0	0	0	0
Canoparmelia sp.1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	4	2	0	0	1	0.3
Catinaria sp.1	2	1.4	0	0	0	0	1	0.6	0	0	1	1	0	0	0	0	0	0	0	0
Catinaria sp.2	1	0.7	7	5.8	2	1.6	0	0	0	0	0	0	0	0	1	0.5	0	0	0	0
Dirinaria confluens	0	0	0	0	0	0	0	0	2	0.9	0	0	0	0	0	0	0	0	0	0
Graphis sp.3	5	3.5	0	0	1	0.8	0	0	0	0	2	1.9	0	0	0	0	0	0	0	0
Graphis sp.9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0.3	0	0
Haematomma puniceum	0	0	0	0	4	3.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Heterodermia cf. *diademata*	3	2.1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hypotrachyna sp.1	0	0	3	2.5	0	0	0	0	0	0	0	0	0	0	0	0	1	0.3	0	0
Lecanora sp.1	0	0	1	0.8	2	1.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lecanora sp.3	0	0	0	0	0	0	0	0	0	0	0	0	5	1.7	0	0	0	0	0	0

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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Appendix B4.4 (Continued)

Lichen species	*Prunus cerasoides*																			
Dong Seng forest	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**	**SF**	**%C**
	T.1	**T.1**	**T.2**	**T.2**	**T.3**	**T. 3**	**T.4**	**T.4**	**T.5**	**T.5**	**T.6**	**T.6**	**T.7**	**T.7**	**T.8**	**T.8**	**T.9**	**T.9**	**T.10**	**T.10**
GBH	**45**	**45**	**38**	**38**	**39**	**39**	**43**	**43**	**57**	**57**	**34**	**34**	**72**	**72**	**50**	**50**	**90**	**90**	**27**	**27**
Number of Small units	**144**	**144**	**120**	**120**	**128**	**128**	**176**	**176**	**224**	**224**	**104**	**104**	**288**	**288**	**200**	**200**	**328**	**328**	**314**	**314**
Parmelinella sp.1	1	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parmelinopsis sp.1	2	1.4	0	0	0	0	2	1.1	0	0	0	0	0	0	0	0	0	0	0	0
Parmotrema sp.1	1	0.7	2	1.7	2	1.6	0	0	0	0	0	0	0	0	2	1	0	0	1	0.3
Porina sp.2	0	0	0	0	0	0	1	0.6	0	0	0	0	0	0	0	0	0	0	0	0
Rimelia sp.1	0	0	2	1.7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sterile crust	0	0	3	2.5	1	0.8	3	1.7	3	1.3	1	1	2	0.7	2	1	2	0.6	0	0

Note: GBH = Girth at breast height (cm), SF = Sum of lichens thallus frequency, %C = Percentage cover of lichens

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APPENDIX C

LIST OF LICHENS SIMILARITY

Table C.1 Sorensen's coefficient of lichen diversity on same tree species between study Sites

Selected tree species	Study sites and percentage of similarity	Similar lichen species
Melia toosendan Sieb & Zucc.	S1 and S2 (**30%**)	*Bulbothrix* sp.1, *Graphis* sp.11
	S1 and S3 (**21%**)	*Chrysothrix* sp.
	S1 and S4 (**43%**)	*Graphis* sp.11
	S2 and S3 (**44 %**)	*Buellia* sp.2, *Chrysothrix* sp., *Graphis* sp.1, *Graphis* sp.8, *Graphis* sp.9, *Lecanora* sp.1, *Pyrrhospora russula*
	S2 and S4 (**50%**)	*Diorygma* sp.1, *Graphis* sp.5, *Graphis* sp.9, *Graphis* sp.11, *Lecanora* sp.1, *Parmotrema* sp.1
	S3 and S4 (**41%**)	*Buellia* sp.1, *Diorygma* cf. *epiglaucum*, *Graphis* sp.2, *Graphis* sp.4, *Lecanora* sp.1
Hovenia dulcis Thunb.	S1 and S2 (**23%**)	*Arthonia* sp.1, *Chrysothrix* sp., *Graphis* sp.3, *Malcolmiella* sp.6
	S1 and S3 (**35%**)	*Arthonia* sp.1, *Buellia* sp.1, *Chrysothrix* sp., *Graphis* sp.3, *Malcolmiella* sp.6
	S1 and S4 (**30%**)	*Buellia* sp.1, *Graphis* sp.3
	S2 and S3 (**63%**) **	*Arthonia* sp.1, *Chrysothrix* sp., *Diorygma* cf. *epiglaucum*, *Graphis* sp.1, *Graphis* sp.2, *Graphis* sp.3, *Graphis* sp.4 *Graphis* sp.8, *Graphis* sp.9, *Graphis* sp.11, *Haematomma puniceum*, *Lecanora* sp.1, *Lecanora* sp.5, *Malcolmiella* sp.2, *Pyrrhospora russula*
	S2 and S4 (**28%**)	*Graphis* sp.11, *Graphis* sp.3, *Graphis* sp.9, *Lecanora* sp.5, *Malcolmiella* sp.2, *Pertusaria* sp.1

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Table C.1 (continue)

Selected tree species	Study sites and percentage of similarity	Similar lichen species
Hovenia dulcis Thunb.	S3 and S4 (**38%**)	*Buellia* sp.1, *Graphis* sp .3, *Graphis* sp.9, *Graphis* sp.5, *Graphis* sp.11, *Malcolmiella* sp.2, *Malcolmiella* sp.5, *Malcolmiella* sp.7
Spondias axillaris Roxb.	S1 and S2 (**38%**)	*Bulbothrix* sp1, *Chrysothrix* sp.
	S1 and S3 (**30%**)	*Buellia* sp.1, *Chrysothrix* sp., *Graphis* sp.3, *Malcolmiellasp*.6
	S1 and S4 (**63%**) **	*Buellia* sp.1
	S2 and S3 (**34 %**)	*Buellia* sp.2, *Buellia* sp.3, *Chrysothrix* sp., *Graphis* sp.9, *Graphis* sp.11
	S2 and S4 (**38%**)	*Graphis* sp.11
	S3 and S4 (**42%**)	*Buellia* sp.1, *Graphis* sp.11, *Graphis* sp.13, *Porina* sp.1
Prunus cerasoides D. Don	S1 and S2 (**60%**)	*Buellia* sp.1, *Chrysothrix* sp.
	S1 and S3 (**23%**)	*Buellia* sp.1 *Chrysothrix* sp.
	S1 and S4 (**15%**)	*Buellia* sp.1
	S2 and S3 (**40%**)	*Buellia* sp.1, *Bulbothrix* sp.1, *Chrysothrix* sp., *Graphis* sp.2, *Graphis* sp.9, *Lecanora* sp.1
	S2 and S4 (**33%**)	*Buellia* sp.1, *Bulbothrix tabacina*, *Graphis* sp.9, *Lecanora* sp.1
	S3 and S4 (**30%**)	*Buellia* sp.1 *Catinaria* sp.2, *Dirinaria confluens*, *Graphis* sp.9, *Lecanora* sp.1, *Pertusaria* sp.1

Note: S1 = Reforestation plot 2002, S2 = Reforestation plot 2000,

S3 = Reforestation plot 1998, S4 = Dong Seng Forest

** = the highest similarity

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Table C.2 Sorensen's coefficient of lichen diversity between tree species in each study sites

Study sites	Host tree species and percentage of similarity	Similar lichen species
S1	Mt and Hd **(67%)**	*Chrysothrix* sp., *Malcolmiella* sp.6
	Mt and Sa **(77%)**	*Chrysothrix* sp., *Bulbothrix* sp.1, *Malcolmiellasp*.6
	Mt and Pc **(67%)**	*Chrysothrix* sp.
	Hd and Sa **(77%)**	*Buellia* sp.1, *Chrysothrix* sp., *Graphis* sp.3, *Malcolmiellasp*.6
	Hd and Pc **(67%)**	*Buellia* sp.1, *Chrysothrix* sp.
	Sa and Pc **(60%)**	*Buellia* sp.1, *Chrysothrix* sp.
S2	Mt and Hd **(51%)**	*Buellia* sp.2, *Bulbothrix* sp.1, *Graphis* sp.11, *Graphis* sp.9
	Mt and Sa **(44%)**	*Bulbothrix* sp.1, *Chrysothrix* sp., *Graphis* sp.2, Graphis sp.9, *Lecanora* sp.1
	Mt and Pc **(38%)**	*Bulbothrix* sp.1, *Chrysothrix* sp., *Graphis* sp.9
	Hd and Sa **(42%)**	*Chrysothrix* sp., *Malcolmiella* sp.6
	Hd and Pc **(28%)**	*Chrysothrix* sp., *Bulbothrix* sp.1, *Malcolmiella* sp.6
	Sa and Pc **(38%)**	*Bulbothrix* sp.1, *Chrysothrix* sp., *Graphis* sp.9
S3	Mt and Hd **(72%)**	*Arthonia* sp.1, *Buellia* sp.1, *Buellia* sp.3, *Catinaria* sp2, *Chrysothrix* sp., *Diorygma* cf. *epiglaucum, Glyphis scyphuliferum, Graphis* sp.1, *Graphis* sp.2, *Graphis* sp.3, *Graphis* sp.4, *Graphis* sp.9, *Haematomma puniceum, Lecanora* sp.1, *Lecanora* sp.4, *Porina* sp.1, *Pyrrhospora russula*
	Mt and Sa **(79%)**	*Bacidia* sp.1, *Buellia* sp.1, *Buellia* sp.2, *Buellia* sp.3, *Chrysothrix* sp., *Diorygma* cf. *epiglaucum, Graphis* sp.1, *Graphis* sp.2, *Graphis* sp.3, *Graphis* sp.4, *Graphis* sp.8, *Graphis* sp.9, *Graphis* sp.13, *Haematomma puniceum, Lecanora* sp.1, *Lecanora* sp.4, *Porina* sp.1, *Pyrrhospora russula*
	Mt and Pc **(58%)**	*Bacidia* sp.1, *Buellia* sp.1, *Buellia* sp.2, *Catinaria* sp2, *Chrysothrix* sp., *Diorygma* cf. *epiglaucum, Graphis* sp.2, *Graphis* sp.4, *Graphis* sp.8, *Graphis* sp.9, Lecanora sp.1, *Pyrrhospora russula*

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Table C.2 (continue)

Study sites	Host tree species and percentage of similarity	Similar lichen species
S3	Hd and Sa **(85%) ****	*Buellia* sp.2, *Bulbothrix* sp.1, *Chrysothrix* sp., *Graphis* sp.1, *Graphis* sp.5, *Graphis* sp.8, *Graphis* sp.9, *Graphis* sp.11, *Lecanora* sp.1, *Lecanora* sp.2, *Parmotrema* sp.1, *Pyrrhospora russula*
	Hd and Pc **(51%)**	*Buellia* sp.2, *Chrysothrix* sp., *Graphis* sp.9, *Graphis* sp.11
	Sa and Pc **(57%)**	*Bulbothrix* sp.1, *Chrysothrix* sp., *Graphis* sp.9, *Lecanora* sp.1
S4	Mt and Hd **(39%)**	*Buellia* sp.1, *Graphis* sp.11, *Graphis* sp.9, *Lecanora* sp.5, *Malcolmiella* sp.2, *Pertusaria* sp.1
	Mt and Sa **(35%)**	*Buellia* sp.1, *Graphis* sp.11
	Mt and Pc **(31%)**	*Buellia* sp.1, *Dirinaria confluens*, *Graphis* sp.9, *Lecanora* sp.1, *Parmotrema* sp.1, *Pertusaria* sp.1
	Hd and Sa **(46%)**	*Buellia* sp.1, *Graphis* sp.11, *Pyrenula* sp.1, *Pyrenula* sp.2
	Hd and Pc **(22%)**	*Buellia* sp.1,
	Sa and Pc **(23%)**	*Buellia* sp.1, *Graphis* sp.3, *Graphis* sp.9,

Note: Mt = *Melia toosendan* Sieb and Zucc, Hd = *Hovenia dulcis* Thunb.

Sa = *Spondias axillaris* Roxb, Pc = *Prunus cerasoides* D. Don

** = the highest similarity

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Table C.3 Sorensen's coefficient of lichen diversity on all selected tree species between each study sites

Study sites and percentage of similarity	Similar lichen species
S1 and S2 (30%)	*Chrysothrix* sp., *Arthonia* sp1, *Buellia* sp.1, *Bulbothrix* sp.1, *Graphis* sp.11, *Graphis* sp.3, *Malcolmiella* sp.6
S1 and S3 (30%)	*Buellia* sp.1, *Bulbothrix* sp.1, *Graphis* sp.11, *Malcolmiella* sp.6, *Chrysothrix* sp.
S1 and S4 (23%)	*Buellia* sp.1, *Graphis* sp.11, *Graphis* sp.3
S2 and S3 (69%) **	*Arthonia* sp.1 , *Buellia* sp.1, *Buellia* sp.3, *Bulbothrix* sp.1, *Catinaria* sp.2, *Chrysothrix* sp., *Diorygma* cf. *epiglaucum, Dirinaria confluens, Graphis* sp.1, *Graphis* sp.2, *Graphis* sp.4, *Graphis* sp.5, *Graphis* sp.8, *Graphis* sp.9, *Graphis* sp.11, *Graphis* sp.13, *Haematomma puniceum, Lecanora* sp.1, *Lecanora* sp5, *Malcolmiella* sp.2, *Malcolmiella* sp.6, *Pyrrhospora russula,*
S2 and S4 (52%)	*Buellia* sp.1, *Bulbothrix tabacina*, *Diorygma* cf. *epiglaucum, Diorygma* sp.1, *Dirinaria confluens*, *Graphis* sp.2, *Graphis* sp.3, *Graphis* sp.4, *Graphis* sp.5, *Graphis* sp.9, *Graphis* sp.11, *Graphis* sp.13, *Haematomma puniceum, Lecanora* sp.1, *Lecanora* sp.5, *Malcolmiella* sp.2, *Parmotrema* sp.1, *Pertusaria* sp.1
S3 and S4 (57%)	*Buellia* sp.1, *Diorygma* cf. *epiglaucum, Dirinaria confluens, Graphis* sp.2, *Graphis* sp.4, *Graphis* sp.5, *Graphis* sp.9, *Graphis* sp.10, *Graphis* sp.11, *Graphis* sp.13, *Haematomma puniceum, Lecanora* sp.1, *Lecanora* sp5, *Malcolmiella* sp.5, *Malcolmiella* sp.2, *Malcolmiella* sp.7, *Pertusaria* sp.1, *Porina* sp.1

Note: S1 = Reforestation plot 2002, S2 = Reforestation plot 2000, S3 = Reforestation plot 1998, S4 = Dong Seng Forest

** = the highest similarity

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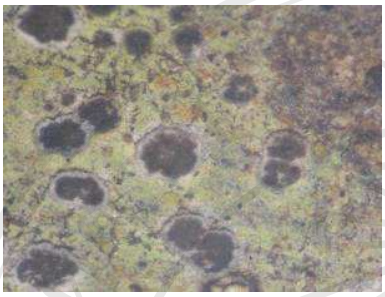
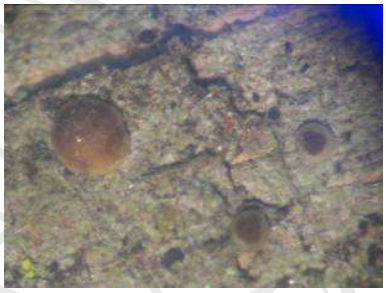
APPENDIX D

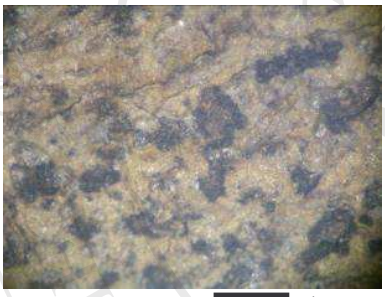
PICTURES OF LICHENS



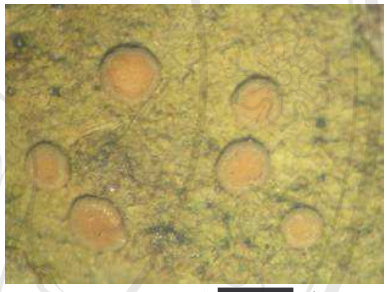
Arthonia sp.1



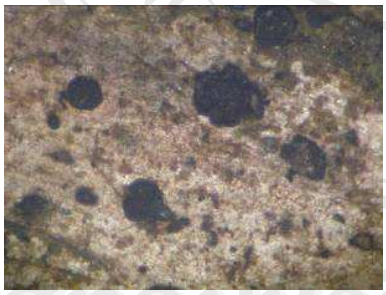
Bacidia sp.2



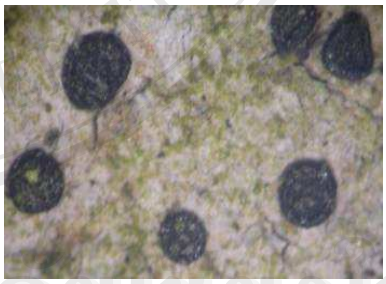
Arthothelium sp.1



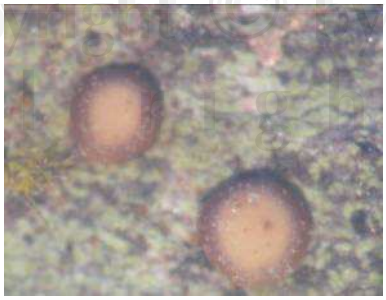
Bacidia sp.3



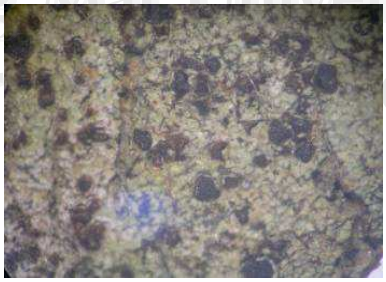
Arthopyrenia sp.1



Buellia sp. 1



Bacidia sp.1



Buellia sp.2

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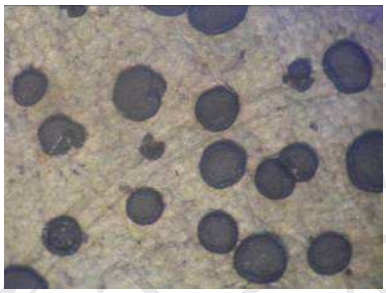
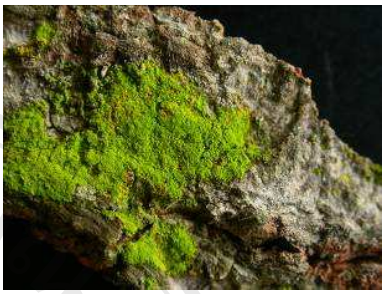


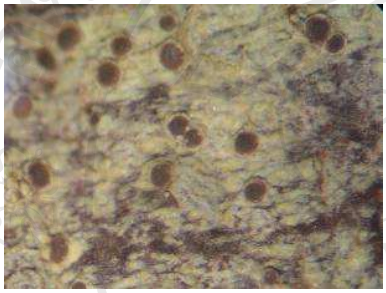
1 mm

Buellia sp.3



1 mm

Chrysothrix sp.



1 mm

Catinaria sp.1

1 mm

Diorygma cf. *poitaei*

1 mm

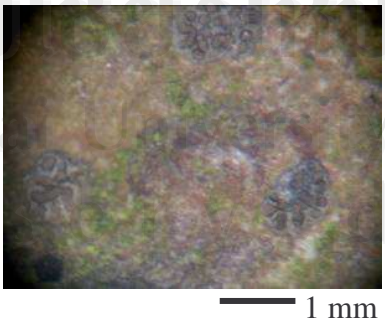
Catinaria sp.2

1 mm

Diorygma cf. *epiglaucum*

1 mm

Byssoloma cf. *subdiscordans*



1 mm

Glyphis cf. *cicaticosa*

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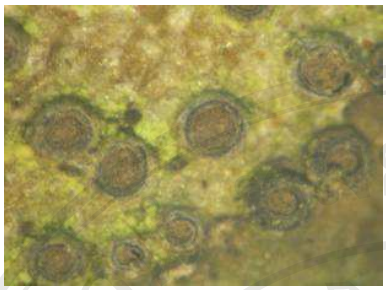

1 mm

Glyphis scyphuliferum

1 mm

Graphis sp.4

1 mm

Graphis sp.1

1 mm

Graphis sp.5

1 mm

Graphis sp.2

1 mm

Graphis sp.6

1 mm

Graphis sp.3

1 mm

Graphis sp.7

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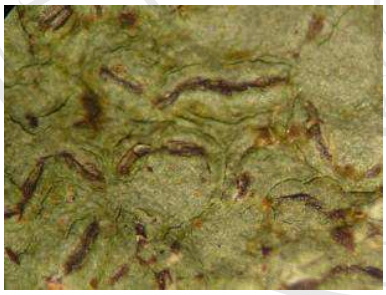
Graphis sp.8

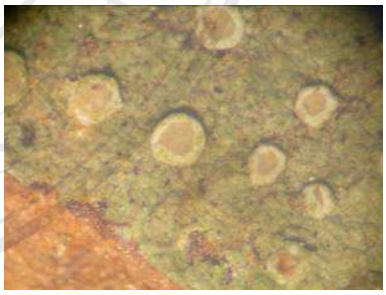
Graphis sp.12

Graphis sp.9

Graphis sp.13

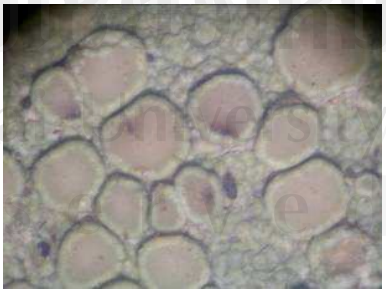


Graphis sp.10



Lecanora sp.1

Graphis sp.11



Lecanora sp.2

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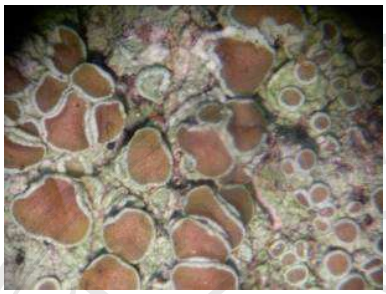
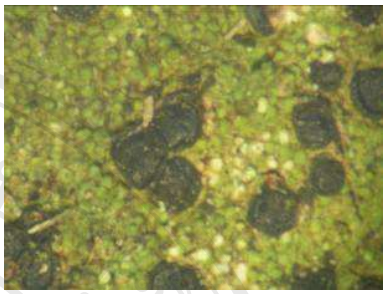


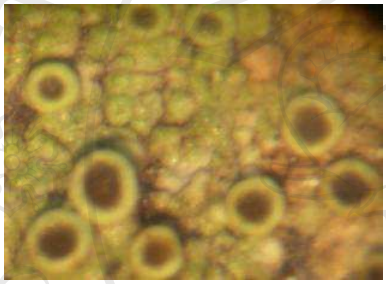
1 mm

Lecanora sp.3



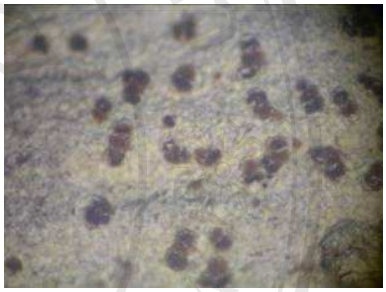
1 mm

Malcolmiella sp.2



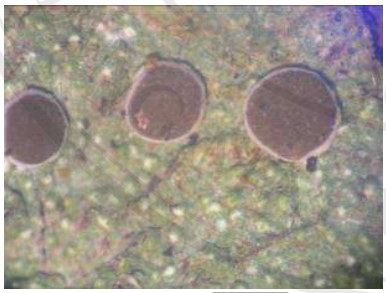
1 mm

Lecanora sp.4



1 mm

Malcolmiella sp.3

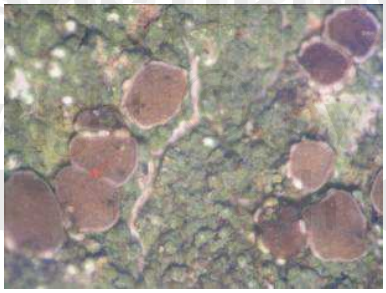


1 mm

Lecanora sp.5

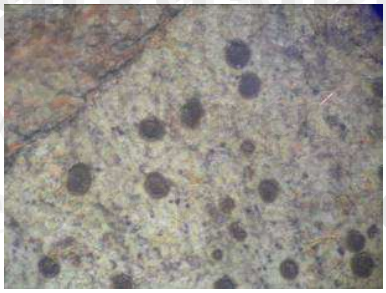
1 mm

Malcolmiella sp.4



1 mm

Malcolmiella sp.1



1 mm

Malcolmiella sp.5

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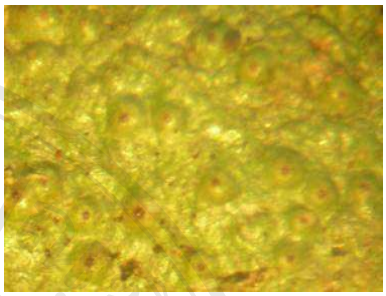
1 mm

Malcolmiella sp. 6

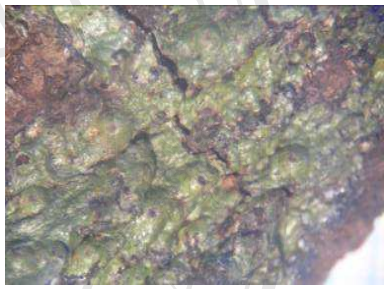


1 mm

Porina sp.1

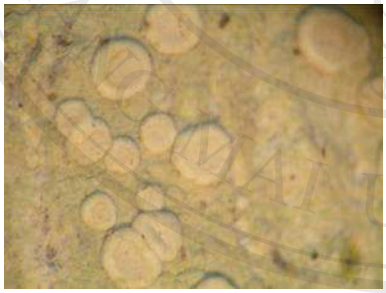
1 mm

Malcolmiella sp. 7



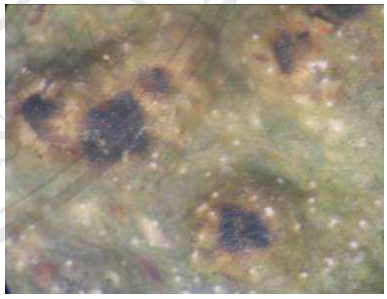
1 mm

Porina sp.2



1 mm

Ochrolechia sp.1

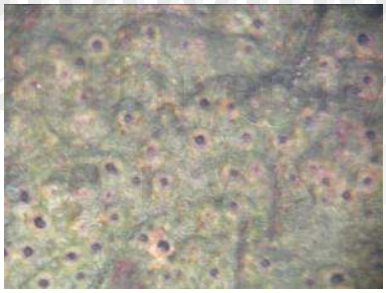


1 mm

Phaeographis sp.

1 mm

Pertusaria sp.1



1 mm

Pyrenula sp.1

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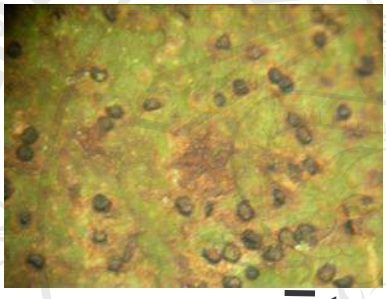
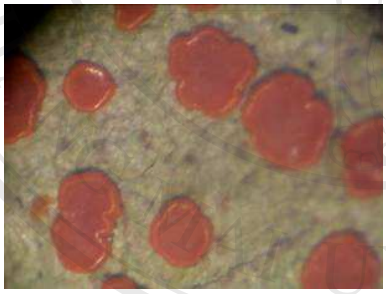
Pyrenula sp.2

Bulbothrix tabacina



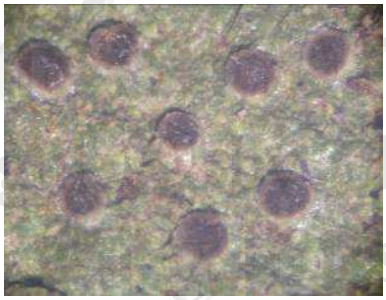
Pyrenula sp.3

Bulbothrix cf. *meizospora*

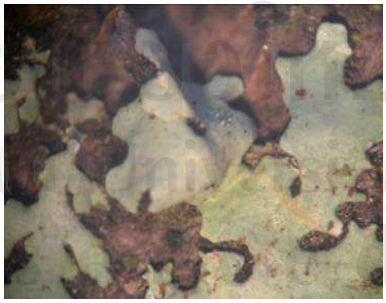


Pyrrospora russula

Bulbothrix cf. *setschawensis*



Rinodina sp.1



Bulbothrix isidiza

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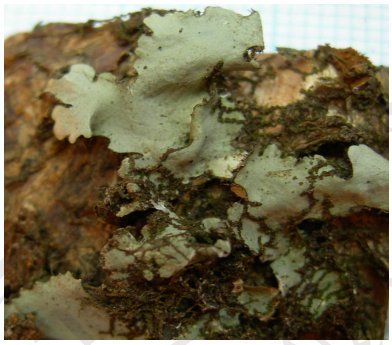
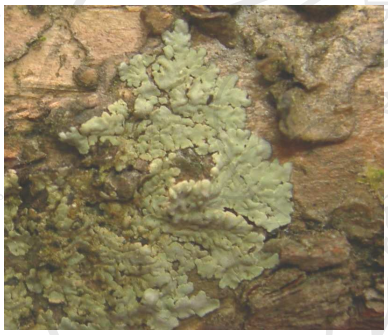


1 mm

Canoparmelia sp.1

1 mm

Pyxine retirugella



1 mm

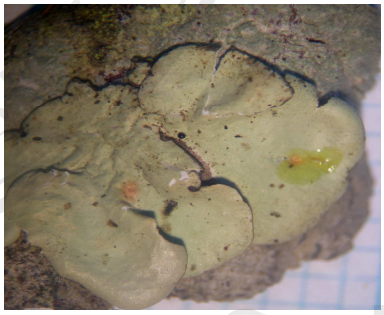
Dirinaria confluens

1 mm

Heterodermia cf. *diademata*

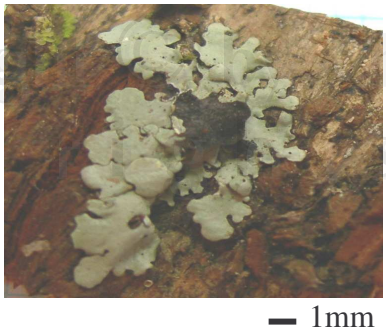
1 mm

Rimelia sp.1



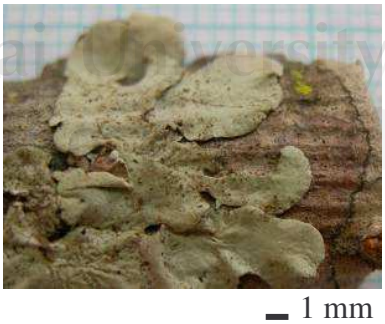
1mm

Parmotrema tinctorum



1mm

Parmelinopsis sp.1



1 mm

Parmotrema sp.1

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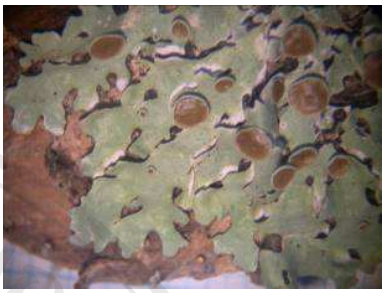
1 mm

Hypotrachyna sp.1

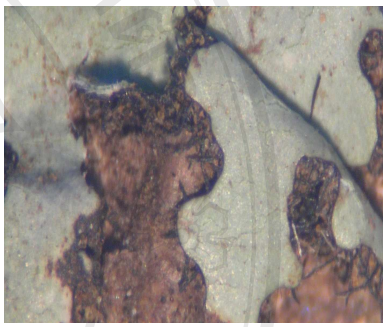


1 mm

Hypotrachyna sp.2

1 mm

Bulbothrix sp.1



1 mm

Parmelinella sp.1

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APPENDIX E

Tree Specie Descriptions for this study

***Hovenia dulcis* Thunb. (Rhamnaceae) (หมอนหิน) (Gilman and Watson, 1993)**

A large, briefly deciduous tree. Common name is Japanese Raisin Tree. **Size** 12 to 30 m tall, in height with a spread about 2/3rds of the height. Grows at a medium rate, about 2 feet per year. **Leaf** Upright-oval to rounded shape, 11-14 x 5-9 cm, alternate, simple**,** serrate, pinnate; reticulate with many smaller lateral branches, glossy green in summer. Fall color is a mixture of yellow. **Flower** is a 1.5 -2.5 cm diameter cyme consisting of many small 2.5 mm diameter greenish white flowers occurring in March to May. Slightly fragrant. **Fruit** is a reddish-brown drupe, about 7-8.5 x 6-7.5 mm in diameter about the size of a raisin, hence the name. **Seed** 5-6 x 5-6 mm red-black seed capsules are edible; have strong sweet fragrance; August to February; bird-dispersed, particularly by pigeons (Hitchcock and Elliott, 1999). They are sweet, and can be eaten. **Bark** Smooth, gray on young trees. On older trees it is a light gray, slightly furrowed, peeling in strips which reveals darker brown tones underneath.

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***Melia toosendan* Sieb. & Zucc. (Meliaceae) (เกรียน, เลี่ยนดอกม่วง) (Gardner *et al*., 2000)**

A medium-sized, briefly deciduous tree, pioneer tree. **Size** ~ 25 m with very open crown and widely spreading branches with moderate growth rate. **Bark** pale gray or brown with narrow fissures, inner bark cream. **Leaf** bipinnate or tripinnate, clustered near end of twigs, 4-5 pairs of side stalks with 2-5 pairs of opposite leaflets, 3-7 x 1.2 -2 cm,

ovate with narrow tips, margin usually with scattered irregular teeth. Mature leaflets smooth, sometimes with whitish powder below (glaucous). Leaflet stalks 0.2 -0.4 cm **Flower** 2.5 – 3 cm, white with violet centre, in large open branched clusters grouped near end of twigs. 5-6 small curved backwards. Stamen tube violet, cylindrical, as long as petals, 8-10 anthers attach just below rim between teeth. Single slender style as long as stamen tube with unlobed stigma; January to March. **Fruit** 1.6 – 2 cm, green, thinly-fleshy, 6-8 lobes each with s single small stone; October to March; animal-dispersed.

Prunus cerasoides **D. Don (Rosaceae) (นางพญาเสือโคร่ง) (Gardner *et al*., 2000)**

Deciduous tree and has been identified as an excellent 'framework tree species' for restoring evergreen forest in seasonally dry tropical forestlands (Elliott, 2000). **Size** is 18 m. with moderate to high growth rate. Common name is Himalayan flowering cherry. **Bark** red-brown, shiny, peeling in horizontal strips with large tan lenticels. **Leaf** 5-12 x 3-5 cm, narrowly ovate with tapering tip and blunt or rounded base, sharply toothed, with 2-4 orange glands on margin near base of leaf or at top of stalk. Stalks 0.8 -1.5 cm, slender with large, deeply divided stipules, soon falling. **Flower** 1 -2.5 cm, bright pink or rarely white, in clusters with or without a common stalk, often 3 – flowered, individual stalks slender, 0.7-2 cm, no hairs, behind young leaves. Calyx pink, with triangular lobes, smooth. Overy without hairs; December to January. **Fruit** 1-1.5 cm, ellipsoid (ovoid), pink or bright red and shiny, thinly fleshy, with single bony, wrinkled stone (pyrene); March to May; dispersed by birds, squirrels and other small mammals.

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Spondias axillaris **Roxb (Anacardiaceae) (มะกัก, มะมื่อ, มะกอกหนัง)**
(Gardner *et al*., 2000)

A medium-sized, briefly deciduous tree. **Size** ~ 30 m **Bark** dark grey or red-brown, cracked and peeling in vertical flakes, inner barks red. **Leaf** odd-pinnate, 3(5)-13 pairs of opposite leaflets, 7-13 x 3-5 cm, upper ones largest, narrowly ovate or lanceolate with tapering tips and oblique base, young leaves with scattered teeth, mature leaves of ten without teeth. 8 -16 pairs of side vein, often with tufts of hairs in axils, no marginal vein. Side leaflet stalks 0.7 – 1.3 cm, end one 1.5 -4 cm. **Flower** 0.4 – 0.5 cm, dark red, males in large branched clusters at end of twigs and upper leaf axils, bisexuals in small groups of 2-3 flowers in leaf axils. Calyx < 2 mm, 5 lobed, dark red-purple, smooth outside, glandular –hairy inside. 5 petals, pointed, smooth and overlapping. 10 stamens alternating with disc lobes, bisexuals with 5 very short styles near top of large, globular ovary; January to March. **Fruit** 2-3 cm, green or yellow, ovoid with 5 depressions at top, single large stone with up to 5 holes at top and the same number of seeds; June to August; animal-dispersed.

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APPENDIX F

STATISTICAL ANALYSIS TABLES

Table F1. One-way analysis of variances (ANOVA) of average temperature (°C) in all study sites during January to June 2006 (n=6)

ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	32.458	3	10.819	13.114	.000
Within Groups	16.500	20	.825		
Total	48.958	23			

Duncan		Subset for alpha = .05	
	N	1	2
DSF on DMS	6	24.3333 [a]	
plot 1998	6	24.8333 [a]	
plot 2000	6		26.5000 [b]
plot 2002	6		27.1667 [b]
Sig.		.352	.218

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 6.000.

Table F2. One-way analysis of variances (ANOVA) of average light intensity (lux) in all study sites during January to June 2006 (n=6)

ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	71124411.669	3	23708137.223	66.048	.000
Within Groups	7179068.004	20	358953.400		
Total	78303479.673	23			

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Table F2. (Continue)

Duncan		Subset for alpha = .05		
	N	1	2	3
DSF on DMS	6	1140.7750 [a]		
plot 1998	6	1298.2050 [a]		
plot 2000	6		3410.7417 [b]	
plot 2002	6			5344.1417 [c]
Sig.		.654	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 6.000.

Table F3. One-way analysis of variances (ANOVA) of Relative Humidity (%) in all study sites during January to June 2006 (n=6)

ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	637.833	3	212.611	1.561	.230 [NS]
Within Groups	2724.000	20	136.200		
Total	3361.833	23			

Note: NS = Not Significant

Table F4. One-way analysis of variances (ANOVA) for average bark pH of *Melia toosenden*

ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.150	3	.383	6.446	.002
Within Groups	1.903	32	.059		
Total	3.053	35			

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Table F4. (Continue)

Duncan		Subset for alpha = .05		
	N	1	2	3
1998	10	5.9600 [a]		
2002	10	6.1540 [ab]	6.1540 [ab]	
2000	10		6.3520 [bc]	6.3520 [bc]
DSF on DMS	6			6.4317 [c]
Sig.		.109	.103	.504

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 8.571.
b The group sizes are unequal. The harmonic mean of the group sizes is used.

Table F5. One-way analysis of variances (ANOVA) for average bark pH of *Hovenia dulcis*

ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.808	3	.936	13.854	.000
Within Groups	2.432	36	.068		
Total	5.240	39			

Duncan		Subset for alpha = .05		
	N	1	2	3
DSF on DMS	10	5.9000 [a]		
1998	10		6.1520 [b]	
2000	10		6.321 [b]	
2002	10			6.6290 [c]
Sig.		1.000	.155	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 10.000.

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Table F6. One-way analysis of variances (ANOVA) for average bark pH of *Spondias Axillaris*

ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.867	3	1.289	12.859	.000
Within Groups	3.608	36	.100		
Total	7.475	39			

Duncan	N	Subset for alpha = .05	
		1	2
DSF on DMS	10	5.5390 [a]	
1998	10	5.6530 [a]	
2002	10		6.0840 [b]
2000	10		6.3020 [b]
Sig.		.426	.132

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 10.000.

Table F7. One-way analysis of variances (ANOVA) for average of bark pH: *Prunus cerasoides*

ANOVA	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.013	3	.004	.043	.988 [NS]
Within Groups	2.926	30	.098		
Total	2.939	33			

Note: NS = Not Significant

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Table F8. T- Test compare average bark pH of each tree species in four study sites

One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
MELIA	4	6.1675	.2524	.1262
HOVENIA	4	6.1825	.3460	.1730
SPONDIAS	4	5.8800	.3947	.1974
PRUNUS	4	5.7500	.2124	.1062

One-Sample Test

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
MELIA	48.876	3	.000	6.1675	5.7659	6.5691
HOVENIA	35.741	3	.000	6.1825	5.6320	6.7330
SPONDIAS	29.794	3	.000	5.8800	5.2519	6.5081
PRUNUS	54.131	3	.000	5.7500	5.4120	6.0880

Table F9. Pair-Test compares average bark pH of each tree species in four study sites

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	MELIA - HOVENIA	-1.50E-02	.4856	.2428	-.7877	.7577	-.062	3	.955
Pair 2	MELIA - SPONDIAS	.2875	.2521	.1261	-.1137	.6887	2.281	3	.107
Pair 3	MELIA - PRUNUS	.4175	.3525	.1762	-.1433	.9783	2.369	3	.099
Pair 4	HOVENIA - SPONDIA	.3025	.4323	.2162	-.3854	.9904	1.399	3	.256
Pair 5	HOVENIA - PRUNUS	.4325	.1795	8.976E-02	.1469	.7181	4.819	3	.017
Pair 6	SPONDIAS - PRUNU	.1300	.3419	.1709	-.4140	.6740	.761	3	.502

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Table F9. (Continue)

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	MELIA	6.1675	4	.2524	.1262
	HOVENIA	6.1825	4	.3460	.1730
Pair 2	MELIA	6.1675	4	.2524	.1262
	SPONDIAS	5.8800	4	.3947	.1974
Pair 3	MELIA	6.1675	4	.2524	.1262
	PRUNUS	5.7500	4	.2124	.1062
Pair 4	HOVENIA	6.1825	4	.3460	.1730
	SPONDIAS	5.8800	4	.3947	.1974
Pair 5	HOVENIA	6.1825	4	.3460	.1730
	PRUNUS	5.7500	4	.2124	.1062
Pair 6	SPONDIAS	5.8800	4	.3947	.1974
	PRUNUS	5.7500	4	.2124	.1062

Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	MELIA & HOVENIA	4	-.300	.700
Pair 2	MELIA & SPONDIAS	4	.783	.217
Pair 3	MELIA & PRUNUS	4	-.144	.856
Pair 4	HOVENIA & SPONDIAS	4	.324	.676
Pair 5	HOVENIA & PRUNUS	4	.902	.098
Pair 6	SPONDIAS & PRUNUS	4	.501	.499

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