THE MOSS FLORA OF MOUNT LUMAKU, SIPITANG, SABAH

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DECLARATION

I hereby declare that the material in this dissertation is my own except for quotations, excerpts, equations, summaries, and references, which have been duly acknowledge.

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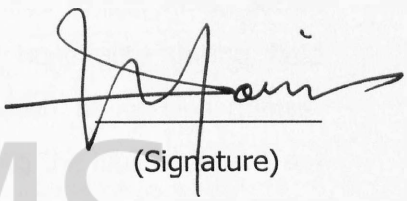

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ABSTRACT

THE MOSS FLORA OF MOUNT LUMAKU, SIPITANG, SABAH

Study on the diversity of mosses was carried out in Mount Lumaku. The objectives of this study were to construct identification keys to genus and species level, to prepare the descriptions, and the checklist of mosses of Mount Lumaku, Sipitang, Sabah. A total of 304 fresh specimens were collected during this study and 52 specimens that were collected in 2003 were also included in this work. A total of 122 species, two subspecies, six varieties, in 60 genera and 27 families of mosses were recorded from Mount Lumaku. This number represents a 21.9 % out of 597 and 17.8 % out of 729 reported taxa from Sabah and Borneo, respectively. The largest family base on taxa is Sematophyllaceae with 19 species and three varieties, followed by Calymperaceae with 11 species, and Dicranaceae with 10 species. Two species are new records to Borneo, namely *Hyophila rosea* R.S. Williams and *Macromitrium salakanum* Müll. Hal., while two species are new records for Sabah, namely *Mitthyridium constrictum* (Sull.) H. Rob. and *Mastopoma subrobustum* Dixon.Two of the moss species are recorded for the second and third time for Sabah, namely *Philonotis calomicra* Broth. and *Holomitrium cylindraceum* (P. Beauv.) Wijk & Margad. Identification keys of genera and species, descriptions of all species, and illustrations of selected species are also presented. In future, more studies should be carried out in other parts of the mountain.

ABSTRAK

Kajian tentang flora lumut jati telah dijalankan di Gunung Lumaku. Objektif kajian ini adalah untuk menyediakan kekunci pengecaman dan keperihalan untuk genus dan spesies yang dijumpai di kawasan ini, dan menyediakan senarai semak lumut jati untuk Gunung Lumaku, Sipitang Sabah. Sejumlah 122 spesies, dua subspesies, dan 6 varieti lumut jati dari 60 genus dan 27 famili telah dilaporkan untuk Gunung Lumaku. Jumlah ini masing-masing mewakili 21.9 % dari 597 dan 17.8 % dari 729 takson lumut jati yang pernah dilaporkan untuk negeri Sabah dan Borneo. Famili yang terbesar berdasarkan bilangan takson ialah Sematophyllaceae dengan 19 spesies dan tiga varieti telah dicatatkan. Diikuti dengan Calymperaceae dengan 11 spesies dan Dicranaceae dengan 10 spesies. Dua spesies dilaporkan sebagai rekod baru untuk Borneo iaitu, Hyophila rosea R.S. Williams, Macromitrium salakanum Müll. Hal., sementara dua spesies dilaporkan sebagai rekod baru bagi negeri Sabah iaitu, Mitthyridium constrictum (Sull.) H. Rob. and Mastopoma subrobustum Dixon. Dua spesies lumut jati telah direkodkan buat kali kedua dan ketiga untuk negeri Sabah iaitu Philonotis calomicra Broth. dan Holomitrium cylindraceum (P. Beauv.) Wijk & Margad. Kekunci pengecaman untuk genus dan spesies, keperihalan untuk semua spesies yang telah dikumpul, dan ilustrasi untuk spesies terpilih juga disediakan di dalam kajian ini. Lebih banyak kajian harus dilakukan di kawasan lain di gunung ini pada masa hadapan.

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LIST OF ABBREVATIONS

*	New record for Sabah
**	New record for Borneo
BM	British Museum, Great Britain
BORH	Borneensis Herbarium, Universiti Malaysia Sabah
GRO	Groningen Herbarium, Germany
KLU	University of Malaya Herbarium, Kuala Lumpur
L	Leiden Herbarium, Netherlands
NYBG	New York Botanical Garden
SAN	Sabah Forestry Department Herbarium, Sandakan
SFI	Sabah Forestry Industries

CHAPTER 1

INTRODUCTION

1.1 Introduction

Studies of diversity of mosses in Sabah had been conducted by various researchers, among them were Noguchi and Iwatsuki (1972), Iwatsuki and Noguchi (1975), Touw (1978), Frahm *et al.* (1990), Mohamed (1995), and Suleiman and Edwards (2001). These previous studies have been carried out in various localities in Sabah. Previous studies also included collection from Labuan Island or formerly known as Victoria Island (Iwatsuki and Noguchi, 1975). Collection of bryophytes specimens from Labuan Island by a British colonial officer, Hugh Low and his acquaintance, are preserved in New York Botanical Garden (NYBG) in United States of America, and Leiden Herbarium (L) in Netherlands (Frahm *et al.*, 1990). Mountain areas such as Mount Kinabalu, forest reserves, national parks, and state parks are preferred to be studied. Relatively, Sabah is the most botanised part of Borneo, with a record of 599 out of the 729 reported taxa of mosses in this island (Andi and Suleiman, 2005; Mohamed *et al.*, 2006; Suleiman *et al.,* 2006; Suleiman and Akiyama, 2007; Higuchi *et al.*, 2008; Suleiman *et al.*, 2009; Mohamed *et al.*, 2010). Word taxa in this dissertation are referring to species and infraspecific level.

Mount Kinabalu (including Kinabalu Park) is the most important locality for bryological works in Borneo Mohamed (1995). Beside that, Kinabalu Park is identified as the most threatened hot spot of high diversity and endemism in Malesia (Tan and Iwatsuki, 1999). The moss flora of Mount Kinabalu has been studied since the colonial era. Other than Mount Kinabalu, studies of moss diversity on mountainous areas have been carried out for Mount Trus Madi (Suleiman and Edward, 2001), and Crocker Range Park (Suleiman and Akiyama, 2004). However, the study of the moss flora in Sabah was not only concentrated in highlands, but was also covered lowland parts of the state, such as Lower Kinabatangan (Suleiman *et al.*, 2003), Ulu Tungud Forest Reserve (Andi and Suleiman, 2005),

Maliau Basin (Mohamed *et al.*, 2006; Suleiman and Akiyama, 2007) and Golden Hope oil palm plantation, Tawau (Suleiman *et al.*, 2009).

To date, there is no published report on the bryoflora for this area. However, there were several collections of mosses recorded from Mount Lumaku and Sipitang District, namely *Hypnodendron becarii* Hampe., in Groningen Herbarium, Germany (GRO), *H. milnei* subsp. *korthalsii* (Bosch & Sande Lac. ex Paris) Touw, in Leiden Herbarium, Netherlands (L), and *Dicranoloma reflexum* (C. Müll.) Ren., in British Museum and Leiden (Touw, 1971; Klazenga, 1999). Touw (1989) also examined a specimen of *Hypnodendron vitiense* subsp. *vitiense* Mitt. Touw, which was found from Mount Lumaku, in Leiden Herbarium (L).

The surrounding areas of Mount Lumaku have been converted to plantations. Changes in microhabitats have an impact on moss diversity. Thus, the aim of this study is to collect, preserve, and record mosses of the study area. This study will provide baseline data for long-term study of bryoflora in the area, as mosses are known as playing an important role as water reservoir in forest ecosystems. Beside, they also prevent erosion, particularly in steep slopes (Frahm *et al.*, 1990). Data obtained will help decision-makers in designing the conservation plan for ecosystem management.

This study is also filling the gap of information in terms of moss diversity of Crocker Range. Both Kinabalu Park and Crocker Range Park have been studied by bryologists, but there is no study on moss diversity carried out in the southern parts of Crocker Range prior than this. In this study a description of all the mosses of Mount Lumaku is presented together with identification keys to genus and species, and illustrations of selected species.

1.2 Objectives

Objectives of this study are:

1. To construct identification key to species of mosses from Mount Lumaku.
2. To prepare descriptions of mosses from Mount Lumaku.
3. To prepare a checklist of mosses of Mount Lumaku.

1.3 Scope of Study

This study has covered two localities on Mount Lumaku, namely Muaya Education Centre or Muaya Waterfall (site 1) and summit region of Mount Lumaku (site 2), which was accessed via Sabah Forest Industries (SFI) Mendulong Station. The elevations covered were at 700-1200 m and 1600-1750 m above sea level respectively. The specimen collections were made on the terrestrial level and did not cover the canopy habitat of mosses. However, the habitats of fallen twigs or fallen branches from canopy were also studied.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Classification of Musci

Musci or mosses are classified under the Division Bryophyta (Schofield, 1985). The other two classes in bryophyta are Hepaticae or liverworts and Anthocerotae or hornworts (Schofield, 1985). Mosses can be distinguished from other bryophytes form its extensive protonema, multicellular rhizoids, leafy gametophores, and generally arranged in three rows leaves (Schofield, 1985). Their extensive range of morphologies is a product of alternation of haploid and diploid generations (Newton *et al.*, 2009).

Traditionally, mosses can be separated based on their growth forms, which are acrocarpus and pleurocarpus. Acrocarpus mosses usually have upright primary stems with sporophyte grows on the terminal side. Meanwhile, pleurocarpus mosses usually have creeping primary stems and branched, with sporophytes grows from branches (Frahm *et al.*, 1990). Acropcarpus mosses are considered as more primitive compared to pleurocarpus and can be predominantly found on terrestrial habitats (Buck and Goffinet, 2000). In temperate region, pleurocarpus are dominant on terrestrial habitats such as soil, meanwhile in tropics they are successful epiphytes, and often found on tree trunk (Buck and Goffinet, 2000). Studies using molecular data revealed the relationships of pleurocarpus mosses in details compare to using morphological data (Newton *et al.*, 2009). The molecular gene sequence data proposed, patterns of diversification of pleurocarpus mosses took place in the same time frame of diversification of early angiosperms (Newton *et al.*, 2007).

Manuel (1980), classified mosses into 19 orders from four subclasses;Tetraphididae, Polytrichidae, Buxbaumidae, and Bryoidae, and three classes, namely Sphagnopsida, Andreaeopsida, and Bryopsida. Bryopsida is the

largest class among three, with over 600 genera (Manuel, 1980). He divided them essentially base on their differences in the morphology of sporophytes. Further classifications into orders, families, genera is made base on the nature, morphology of peristomes, and characteristics of gametophores. Schofield (1985) separated mosses into seven subclasses, namely Andreaeidae, Sphagnidae, Tetraphidae, Polytrichicae, Buxbaumidae, Bryidae, and Archididae. He also approximated there are 10,000 species of mosses out of about 700 genera. The classification is made base on the morphology of sporophytes especially the characteristics of sporangium.

Buck and Goffinet (2000) took the classification of mosses to a new phase when they acknowledged the roles of molecular data in their work. However, the molecular information of mosses is still inadequate, thus morphology is still influential in mosses classification, for example, genus *Takakia* was grouped with liverworts and only recognized as moss when its sporophytes were ultimately described (Buck and Goffinet, 2000; Newton *et al.*, 2009). The decision to recognized *Takakia* as moss was then well supported by evidence from molecular studies. Studies that utilized DNA and molecular data suggested genus *Sphagnum* and *Takakia* are monophyletics (Cox *et al.*, 2004; Newton *et al.*, 2007; Newton *et al.*, 2009).

Buck and Goffinet (2000) classified mosses into six classes, namely Takakopsida, Sphagnopsida, Andreaeopsida, Andreaeobryopsida, Polytrichopsida, and Bryopsida. They are in agreement with Manuel (1980) as they considered Bryopsida as the largest class of mosses base on number of taxa. Meanwhile, Newton *et al.* (2009) estimated there are 13,000 species of living mosses. They divided mosses into 59 families from eight classes and considered 90% of extant species are belong to two subclasses, which are Dicranidae and Bryidae. The classification and evolutionary history of mosses proposed by Newton *et al.* (2009) are still relied on morpohological data such as the structure or peristome and growths form to produce their classification.

2.2 History of Moss Flora Study in Sabah and Borneo

Sabah is one of the most important sites for bryoflora studies in Borneo. The earlier efforts to collect bryophytes in Sabah focused on highlands due to the greater diversity as compared to lowland areas. Bryophyte collections in Sabah were made as early as 1845 by the British colonial officer Hugh Low (Frahm *et al.*, 1990). Low brought some bryophyte specimens along with flowering plant collections from Mount Kinabalu (Frahm *et al.*, 1990). Meanwhile, in between 1844 to 1870 Dozy and Molkenboer reported on some mosses from Borneo, among them were; *Brachymenium nepalense* Hook., *Acroporium microcladum* (Dozy & Molk.) B. C. Tan, *Acroporium secundum* (Reinw. & Hornsch.) M. Fleisch., and *Macromitrium fuscescens* Schwägr (Suleiman *et al.*, 2006). Another British plant collector, Frederick W. Burbridge, from Kew Garden, and several colleagues collected some bryophyte specimens from Mount Kinabalu in the period from 1877 to 1878 (Frahm *et al.*, 1990). Their collections are kept in New York Botanical Garden (NYBG) and Leiden (L.) (Frahm *et al.*, 1990). In 1931, Holttum made a systematic collection of mosses from the Mount Kinabalu, and his collections were examined and documented by Dixon in 1935.

Studies by a Japanese team in 1972 and 1975 have recorded a total of 155 species of mosses, three subspecies and three varieties from 69 genera and 26 families for Sabah (Iwatsuki and Noguchi, 1975; Noguchi and Iwatsuki, 1972). The studies have also discovered 15 species and one genus that were new to science. Touw (1978) had listed 649 taxa of mosses from Borneo and a total of 477 taxa are reported from Sabah. Recently, Suleiman *et al.* (2006) updated the checklist of mosses reported from Borneo. The most recent numbers of moss taxa in Sabah is 597, meanwhile for Borneo is 729 (Andi & Suleiman, 2005; Mohamed *et al.*, 2006; Suleiman *et al.*, 2006; Suleiman and Akiyama, 2007; Higuchi *et al.*, 2008; Suleiman *et al.*, 2009; Mohamed *et al.*, 2010).

Touw (1978) recorded 323 species from Kinabalu out of 649 taxa of mosses reported from Borneo. A comprehensive checklist of bryophytes in the Kinabalu Park was published by Frahm *et al.* (1990). It consists of 358 taxa from 136 genera and 46 families of mosses. Meanwhile, Mohamed (1995) has listed a total of 106

species of mosses belonging 65 genera and 25 families from Sayap-Kinabalu Park. The study has also recorded ten species that were new to Borneo, 11 species were new to Sabah, and 17 species were new to Kinabalu. Akiyama *et al.* (2001) recorded a total of 203 species from 111 genera and 40 families of mosses from Kinabalu Park, Sabah. The study has also found 25 species which were new records for Kinabalu Park and 17 species which are new records for Borneo. Recently, Higuchi *et al.* (2008) studied the mosses flora of Mount Kinabalu and listed a total of 97 species from 43 genera and 18 families. The inventory also found new additions to the moss flora of Borneo Island, namely *Ditrichum heteromallum* (Hedw.) Britt., *Fissidens braunii* (Müll.Hal.) Dozy & Molk., and *Syrrhopodon tjibodensis* M. Fleisch.

Study of moss flora in Sabah also extended to various parts of the state, including lowland areas. Suleiman and Edwards (2002) have listed a total of 153 taxa of mosses for Mount Trus Madi. The study also noted 11 taxa which are new records for Borneo and five taxa are new records for Sabah. A study of moss flora of Crocker Range Park has recorded a total of 126 species from 74 genera and 27 families (Suleiman and Akiyama, 2004). However, the survey only focused on Ulu Kimanis area, on the northwestern and southwestern slope of central part of Crocker Range Park, and Alab Pass (Suleiman and Akiyama, 2004). The park encompasses a very large area and has wide range of habitats. Therefore, further study in this area will increase the number of species found.

In 2003, a total of 47 species of mosses from 24 genera and 12 families were listed for Lower Kinabatangan (Suleiman *et al.*, 2003). The study has recorded *Fissidens virens* Thwait. & Mitt. as new addition to the moss flora of Sabah. Andi and Suleiman (2005) listed a total of 70 species and five varieties of mosses in 31 genera and 18 families from Ulu Tungud Forest Reserve. A study on bryoflora from Eucalyptus Camp, which is located at the north western part of Maliau Basin, was done by Mohamed *et al.* (2006). The expedition contributed a total of 108 moss taxa, with one taxon as new addition to moss flora of Borneo. Another collection was made in southern part of Maliau Basin Conservation Area, Sabah and has recorded 86 taxa of mosses from 40 genera and 15 families (Suleiman and

Akiyama, 2007). The study also documented *Clastobryum cuculligerum* (Sande Lac.) Tixier and *Syrrhopodon parasiticus* (Brid.) Besch. as new addition to moss flora of Borneo. Meanwhile, *Leucobryum bowringii* Mitt., *Syrrhopodon sarawakensis* (Dixon) W.D.Reese and *Trismegistia korthalsi* (Dozy & Molk) were new records for Sabah (Suleiman and Akiyama, 2007). The latest account on the moss flora of Sabah was by Suleiman *et al.* (2009). Their study was the first published report for moss flora of oil plantation area in Malaysia. The inventory effort listed a total of 55 taxa in 31 genera and 14 of families of mosses from Golden Hope oil palm plantation and adjacent area (Suleiman *et al.* 2009). *Acroporium convolutum* var. *horridulum* (Bartr.) B. C. Tan, T. J. Kop & D. H. Norris, was new record for Borneo. Meanwhile, *Ectropotheciella distichophylla* (Hampe) M. Fleisch. was a new addition for Sabah.

The state of Sarawak and the Kalimantan region of Indonesia have also been explored by bryologists. In 1932, an expedition by the Oxford University to Sarawak had collected valuable specimens from an area near the native village of Long Kapah and Mount Dulit, and those specimens are kept in British Museum (BM) (Dixon, 1935; Frahm *et al.*, 1990). Earlier, between years 1865 to 1867, Ordoardo Beccari, an Itallian naturalist, collected bryophyte specimens from Sarawak (Frahm *et al.*, 1990). The comprehensive checklist of mosses reported from Borneo by Touw (1978) listed 241 taxa of mosses from Sarawak. Mohamed *et al.* (2003) listed a total of 77 species of mosses from 37 genera and 17 families for Mount Serapi. The study has also found five species as new records for Borneo and 17 species as new addition to Sarawak moss flora. Another study of Sarawak moss flora was conducted by Mohamed *et al.* (2004). Meanwhile, Suleiman *et al.* (2006) listed a total of 330 taxa of mosses from Sarawak. The most recent study of Sarawak moss flora was carried out in Lanjak Entimau Wildlife Sanctuary. The research team has successfully produced a list of 129 mosses taxa from 53 genera and 23 families (Mohamed *et. al.*, 2010). The study also added substantial figures to moss flora of Sarawak with 24 species were reported as new to the state. Meanwhile, *Distichophyllum brevicuspes* M. Fleisch. and *Exostratum asperum* (Mitt.) L.T. Ellis, were new records for Borneo (Mohamed *et al.*, 2010). Although Sarawak has a large area of land, the moss flora of the state is however under explored.

Touw (1978) has recorded a total of 250 taxa of mosses from Kalimantan. Collections of mosses from West Kalimantan have discovered *Fissidens dalamair* H. Akiyama and *Racopilum niutensis* H. Akiyama & Zanten which were new species to science (Akiyama, 1993; Akiyama and Zanten, 1999). Another study of Kalimantan mosses was carried out by Suleiman and Wiriadinata (2003) in East Kalimantan province. The most recent contributions for Kalimantan bryoflora were made by Suleiman *et al.* (2006). The catalogue included a total of 432 taxa of mosses for Kalimantan (Suleiman *et al.*, 2006). The least studied part of Borneo would be Brunei Darussalam. Touw (1978) reported only three species of mosses from Brunei, to date there is only one publication on moss flora of Brunei, which was carried out by Tan (2000). Tan (2000) listed a total 25 species of mosses from Brunei Darussalam in his paper, and to date the sum of mosses taxa for Brunei Darussalam stands at 40 (Suleiman *et al.*, 2006).

There have been quite a number of publications on the mosses of Borneo. Further research on moss diversity in Borneo indicates we are approaching to document more sufficient data of moss flora from this island. In order to produce a complete knowledge of moss flora, vigorous effort is needed.

2. 3 Introduction to Study Area

Sipitang District is situated 136 km away from Kota Kinabalu and located between latitudes of 115^0 25′ E to 115^0 37′ E and the longitudes of 4^0 7′ N to 5^0 10′ N. The district of 2732.49 square km has 16 km long coastal which is laid on the shoreline of Brunei Bay. Sipitang is drained by four rivers, Sungai Lukutan in the north, Sungai Sipitang in the west, Sungai Mengalong and Sungai Padas in the south (Nurimah, 2005). The mountainous surface of Sipitang terrain begins from the coastal area, with Crocker Range (1800 m) as the most dominant feature. The western side of Crocker Range assembles with the Meligan Range in the west at altitude of 1500 m. Meligan range is extended to Sarawak and has three prominent peaks which are Mount Lumaku (1965 m), Ibul Hill (1506 m), and Bisan Hill (1571 m).

2.3.1 Vegetation

The Muaya Education Centre is made up of three type of forests; lowland dipterocarp forest (below 750 m a.s.l), upper dipterocarp (upper 750 m a.s.l), and heath forest (700-750 m alt.). Meanwhile, some of important Dipterocarpaceae species such as *Shorea* tree and other species from family Fabaceae, like *Koompassia* tree could be found or seen in the Muaya Education Centre area. Besides populated with family of Dipterocarpaceae, the forest of Mount Lumaku is also rich in Orchidaceae, Zingiberaceae, and Nepenthaceae. Area of Mount Lumaku has been involved with forest plantation programme to harvest pulp log. *Acacia mangium* and *Eucalyptus* sp. are the main species that planted in the converted area.

2.3.2 Climate

The rainfall data was recorded from Mendulong Sabah Forest Industries Station (Mendulong-SFI). The station is located in southeast of Sipitang and put under Forest Management Unit No. 7 of the Sabah Forestry Department. The wettest month recorded at Mendulong-SFI 2008 was on April with 27.5 mm. Meanwhile, the lowest rainfall was on September with only 8.5 mm mean rainfall recorded (Figure 2.1).

The record of temperature and relative humidity were not available in Mendulong-SFI station. Thus, Labuan Airport is the closest station which records temperature and relative humidity. The highest daily mean temperature was recorded on April, 24.6 ^{0}C. Meanwhile, the lowest daily mean temperature was recorded on February, 23.6 ^{0}C (Figure 2.2).

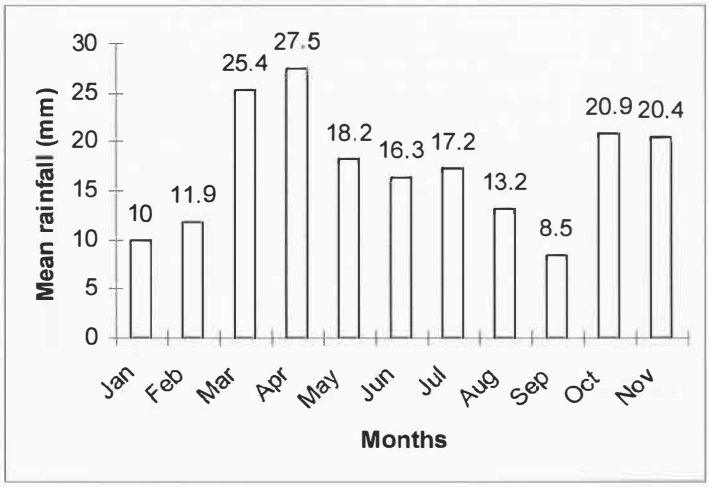

Figure 2.1: Mean monthly rainfall (mm) at Mendulong SFI Station for year 2008.

Source: Malaysian Meteorological Department (Sabah).

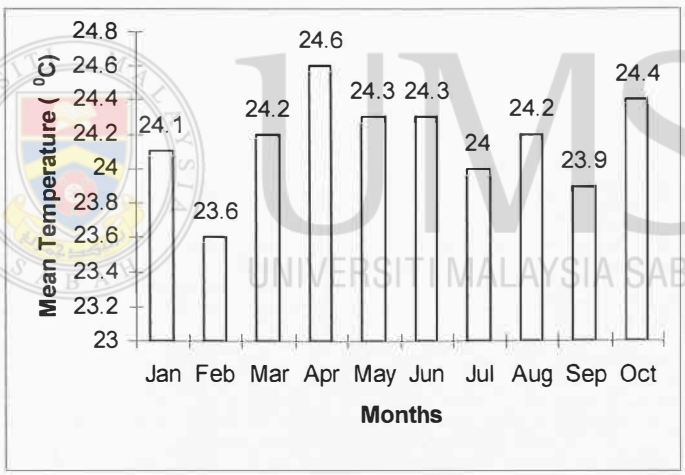

Figure 2.2: Mean of daily temperature (^{0}C) at Labuan Airport for year 2008.

Source: Malaysian Meteorological Department (Sabah).

The relative humidity was rather high in 2008; the range was between 80-84 %. The highest percentage of relative humidity was recorded on month of February, March, and October. The lowest percentage of relative humidity was occurred on September (Figure 2.3).

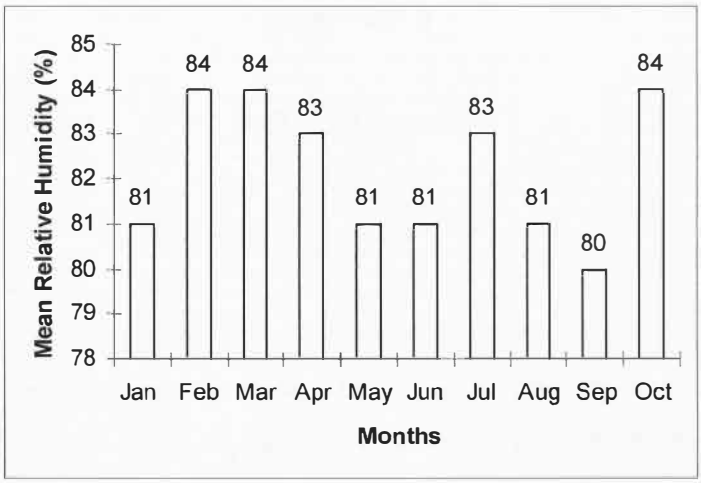

Figure 2.3: Mean relative humidity (%) at Labuan Airport for year 2008.

Source: Malaysian Meteorological Department (Sabah).