SPATIAL PATTERN, REPRODUCTIVE PHENOLOGY AND SUGAR PRODUCTION OF NIPA PALM, *Nypa fruticans* IN LABUK BAY, SABAH

NADIRAH BINTI ABD MANAF

FACULTY OF SCIENCE AND NATURAL RESOURCES
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VIVA DATE : **24th AUGUST 2017**

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1. SUPERVISOR

Assoc. Prof. Dr. Berhaman Ahmad

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ABSTRACT

A study on spatial pattern, reproductive phenology and sugar production of nipa palm (*Nypa fruticans*) was done in a small patch of mangrove forest in Labuk Bay Proboscis Monkey Sanctuary (LBPMS), Sandakan, Sabah. The objectives of the study were to determine the spatial pattern of distribution, the cycle of reproductive phenology and to study the sugar sap production of nipa palm using two methods: traditional and heat treatment method. Comparison study of xylem vessels and phloem areas of these methods were also investigated briefly. The pattern of univariate and bivariate association were shown using Ripley K (t) function in R. Most plots exhibit complete spatial randomness except for plots with association to mangrove trees and further inland where water is scarce. Juvenile palms showed attraction towards adult at plots further inland. Independent relationship was seen in area with steady flows of water. Data on time taken (days) for each stages of reproductive phases were collected for 54 palms in a period of 12 months (July, 2014 to July, 2015). Flowering and fruiting events are seasonal. Phase 1 (flower bud) takes an average of 43 days (n=13, SD=23.88). Female flower (Phase 2) and male flower (Phase 3) occurred for each 5 days (n=14, SD=1.83) and 11 days (n=13, SD=3.9), respectively. Phase 4, immature fruit, occurred throughout July until December 2014 (141 days, n=16, SD=31.85). Matured fruits with hardened endosperm (Phase 5) were seen to peaks in July and August (82 days, n=37, SD=46.2). Data for sugar sap productions was done with 11 mature palms chosen that possessed 9 – 13 fronds. In average, by using traditional methods of massage, the palms (n=6) produced average sap from 450.6 mL to 774.1 mL daily with average brix concentration ranging from 17.8% to 19.2% daily. By using heated method: where the infructescence's stalk were decanted with heated water (80-90°C), the palms produced average sap from 71.1 mL to 540.85 mL sap daily with average brix concentration ranging from 18.78% to 20.26% daily. Traditional method is still the best method in obtaining high amount of sap. However, heated method produced higher sugar concentration. In investigation of total area of phloem and xylem vessels from these two different methods of tapping nira, there was a significant difference in total xylem area (p-value=1.95 x 10^{-7} and 0.0196). The heat treatment has resulted in the largest area of xylem (1711.02 μm^2). However, heat treatment did not generate more nira compared to traditional method of massaging the stalk. Therefore, this needs further investigation to explore the best heat method for nira tapping.

ABSTRAK

POLA SPATIAL, FENOLOGI REPRODUKTIF DAN PENGHASILAN GULA POKOK NIPAH DI LABUK BAY, SABAH

Kajian mengenai pola spatial, fenologi reproduktif dan penghasilan gula pokok nipah (Nypa fruticans) telah dijalankan di hutan bakau di Labuk Bay Proboscis Monkey Sanctuary (LBPMS), Sandakan, Sabah. Objektif kajian ini adalah untuk menentukan corak spatial taburan, kitaran fenologi reproduktif dan mengkaji pengeluaran gula nipah menggunakan dua kaedah: kaedah tradisional dan rawatan haba. Kajian perbandingan xilem dan floem melalui kaedah-kaedah ini juga dibuat secara ringkas. Pola corak univariat dan bivariat ditunjukkan menggunakan fungsi Ripley K (t) dalam R. Kebanyakan plot menunjukkan pola spatial rawak lengkap kecuali plot yang hampir dengan pokok-pokok bakau dan kawasan yang jauh dari sungai di mana air adalah sukar didapati. Pokok juvenil menunjukkan daya tarikan ke arah pokok dewasa di plot di kawasan jauh dari sungai. Hubungan bebas diantara pokok juvenil dan dewasa dapat dilihat pada kawasan yang sentiasa terdapat pengaliran air. Data untuk masa yang diambil (hari) bagi setiap peringkat fasa reproduktif telah dicerap ke atas untuk 54 pokok selama 12 bulan (Julai 2014 hingga Julai, 2015). Tempoh berbunga dan berbuah adalah bermusim. Fasa 1 (bunga putik) mengambil masa purata 43 hari (n = 13, SD = 23.88). Bunga betina (Fasa 2) dan bunga jantan (Fasa 3) berlaku dalam tempoh 5 hari (n = 14, SD = 1.83) dan 11 hari (n = 13, SD = 3.9). Fasa 4, fasa buah yang tidak matang, berlaku sepanjang bulan Julai hingga Disember 2014 (141 hari, n = 16, SD = 31.85). Buah matang (Fasa 5) dilihat berpuncak pada Julai dan Ogos (82 hari, n = 37, SD = 46.2). Data untuk penghasilan gula nira telah dilakukan dengan 11 pokok matang yang memiliki 9-13 pelepah. Secara purata, dengan menggunakan kaedah tradisional diurut, pokok (n = 6) menghasilkan secara purata dari 450.6 mL ke 774.1 mL setiap hari dengan purata kepekatan Brix yang terdiri daripada 17.8% ke 19.2% setiap hari. Dengan menggunakan kaedah dipanaskan: di mana tangkai buah dituang dengan air panas, (80-90°C), pokok yang menghasilkan nira dari 71.1 mL ke 540.85 mL sap setiap hari dengan purata kepekatan Brix daripada 18.78% ke 20.26% setiap hari. Kaedah tradisional masih merupakan cara yang terbaik untuk mendapatkan jumlah nira yang tinggi. Walau bagaimanapun, kaedah dipanaskan menghasilkan kepekatan gula yang lebih tinggi. Dalam kajian jumlah keluasan floem dan zilem daripada kedua-dua kaedah yang berbeza ini, terdapat perbezaan yang signifikan dalam jumlah kawasan zilem (p-value = 1.95×10^{-7} dan 0.0196). Rawatan haba mempunyai kawasan terbesar xilem (1711.02 μm^2). Walau bagaimanapun, rawatan haba tidak menjana lebih nira berbanding kaedah tradisional. Oleh itu, kajian yang lebih lanjut diperlukan untuk meneroka kaedah haba terbaik untuk mendapatkan nira.

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LIST OF SYMBOLS

°C	**-**	Degree Celsius
%	**-**	Percentage(s)
CO_2	-	Carbon dioxide
cm	**-**	Centimeter(s)
d	**-**	Days
L	**-**	Litre
mL	**-**	Millilitre(s)
m	**-**	Meter(s)
mm	**-**	Millimeter(s)
n	**-**	Number of sample/individual
SD	**-**	Standard deviation

LIST OF ABBREVIATIONS

a.m.	**-**	Before noon (Latin *ante meridiem*)
p.m.	**-**	After noon (Latin *past meridiem*)
brix%	**-**	Percentage of brix (percentage of sugar content in a solution)
CSR	-	Complete spatial randomness
FRC	**-**	Forest Research Centre
LBPMS	-	Labuk Bay Proboscis Monkey Sanctuary
MARDI	**-**	Malaysian Agricultural Research and Development Institute
MET	-	Malaysia Meteorological Department
NL	**-**	Nipah Lodge
SFD	-	Sabah Forestry Department

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CHAPTER 1

INTRODUCTION

1.1 Introduction

After Indonesia and Australia, Malaysia possesses the third largest mangrove area in Asia-Pacific. Taking up to 567,000 hectares (ha), or 1.7% of the total land, 99,800 ha of this is located in Peninsular Malaysia while the other 467,000 ha are located in Sabah and Sarawak (Wong, 2004).

Sabah is located in the northeastern of Borneo Island and surrounded by large coastal area of South China Sea and the Palawan Thrust, the Celebes Sea and the Sulu Sea. Coastal environments consist of estuarine areas and mangrove and nipa swamp which are majorly in the east side of the state. Apart from the largest river of Sungai (Sg.) Kinabatangan and Padas which both cover an area of 15,385 and 8,726 km^2, Sabah is rich with other 16 major rivers (Sabah State Government, 2006; Mahyam and Wong, 2007). Sabah has a large mangrove area of 280,002.27 ha in 23 protected forest reserves. A part of this is Malaysia's largest Ramsar's site, the Lower Kinabatangan-Segama Wetlands (Sabah Forestry Department, 2015). The extensive rows of nipa palms can be seen favoring brackish water and stand as a border between mangrove forest and swamp water (Tomlinson, 1986).

Nipa palm has been used for a long time by the local people for many purposes. In Sabah, the most common uses are for "atap" or roofing material and cigarette wrappers. Both are still used today. However, nira tapping is still not a popular resource among the locals. Unlike in Peninsular Malaysia where the sugar sap is sold by the roadside and many products were made such as sweets, "gula Melaka", vinegar and many more (Sharifah Samsiah and Siti Hasidah, 2008).

Nipa palm (*Nypa fruticans* Wurmb.), the only species in the genus *Nypa* belongs to family Palmae (Tomlinson, 1986) or Arecaceae (Hamilton and Murphy, 1988). Nipa can be found in the equatorial zone, from Sri Lanka and the Ganges Delta, through Southeast Asia to North Australia with northernmost occurrence in Ryukyu Islands of Japan and southernmost occurrence in the North Australia (Uhl and Dransfield, 1987; Päivöke, 1996). It is the most common, widely distributed and useful palm in South and Southeast Asia (Hamilton and Murphy, 1988). The plant is also introduced in West Africa in the early and middle of 20th century although the resource was not fully utilize by the local people (Sunderland and Morakinyo, 2002).

A review by Tsuji *et al.* in 2011 had pointed out that nipa palm has deficient number of scientific reports in recent years. Last publication in the 90's was done in 1996 (Päivöke, 1996) and before that high interest only lasted in the early 1960's to 1980's with interest in the plant's general use and management, growth and in P.B. Tomlinson's case dozens of studies in dichotomous branching, architecture and ecology (Tomlinson, 1961, 1971, 1973, 1987; Päivöke, 1985; Hamilton and Murphy, 1988; Fong, 1992). The palm's morphology, anatomy and histology, inflorescence's growth and phenology were first described by Uhl (1972) and Uhl and Moore (1977).

The dim interest took a turn in recent years after scientific studies done by Tamunaidu *et al.* (2011; 2013) and Matsui *et al.* (2014) with specific interest on the potential of ethanol production from sugar (nira) produced by nipa palm. A thorough publication on morphology, anatomy and description of germination of nipa by Henderson back in 2006. The genetic variation of nipa palm in six

populations from China, Vietnam and Thailand by Jian (2010). A demographic study and distribution of nipa palm in Carey Island, Klang done by Rozainah and Nasrin (2010). In addition, a reproductive phenology study on nipa done by Mantiquilla *et al.* (2013) in Philippines. Apart from these, there are still numerous aspect of nipa that can still be explored.

A spatial point pattern is defined as a set of locations, irregularly distributed within a region of interest, which have been generated by some unknown spatial process (Diggle, 1983). Spatial pattern in plant populations presents a great interest to ecologist due to information than can be gain including population dynamics, stand history and competition (Haase, 1995).

Phenology is defined as the study of repetitive biological occurrence and its correlation to climate factors (Morellato *et al.* 2010b). In plants, these involve many aspects in reproductive events for example durations of bud formation, flowering and fruiting, together with vegetative phases such as leaf flushing and shedding (Morellato *et al.* 2010b).

Nipa palm is one of the many palms that has the ability to produce sugar sap. Sap yield is rich in glucose, sucrose and fructose which is the same as sugarcane. Traditional method of massaging the infructescence's stalk or peduncle will induces sap flow that will continue until the stalk shorten or the sap flow decreases by itself (Tamunaidu *et al.* 2013). Although new, heated method first introduced in this study induced sap flow as well. Both methods are sustainable due to unnecessary deforestation and nipa palm ability to still flowering even at 100 years old. Comparison on xylem vessels and phloem area between traditional and heated method in this study will fill in the knowledge gap of this species and the methods used.

1.2 Study Area

In Labuk Bay Proboscis Monkey Sanctuary (LBPMS), nipa palm is among the mangrove trees that can be found in 263 hectares of unlogged private forest for proboscis monkeys habitat (Tangah, 2012). The study areas are within the area of Nipah Lodge, a chalet accommodation provided for visitors of LBPMS.

The site is of interest to the study of nipa palm due to its accessibility and safety factors. LBPMS is a privately owned land of Mr. Michael Tan including the oil palm plantation in the surrounding area.

1.3 Justification

The information gain from this project will first and foremost benefits Sabah Forestry Department. Although sugar and ethanol production are not in great demand yet to Sabah, the statistics and experiments are needed to grasp the full potential of the unknown nipa palm for the future. The information will also benefit the local people which could simultaneously generates household income.

1.4 Aims of Study

The aims of this study are as follows:

1. To study the spatial pattern of distribution of nipa palm. Palms general distribution is determine using univariate analysis while relationship between adults and juveniles is determine using bivariate analysis in Ripley's K(t) function.

2. To study the reproductive phenology cycle of nipa palm. Duration and seasonal activity of flowering and fruiting events in a year were recorded in circular statistics.

3. To study the sugar production of nipa palm using two methods, traditional and heat treatment. Comparative study of xylem vessels and phloem of these methods are also investigated briefly.

CHAPTER 2

LITERATURE REVIEW

2.1 Taxonomy and Morphology

Nypa fruticans (Thunb.) Wurmb. is a part of a large family of monocotyledons; Palmae or Arecaceae with over 200 genera and 2600 species of mostly unbranched, woody trunks with large compound leaves (palmate or pinnately compound) in a terminal crown (Tomlinson, 1986). According to Tomlinson (1986) taxonomic classification of nipa is as follows;

Family: Palmae (Arecaceae)
Subfamily: Nypoideae
Genus: *Nypa* Steck
Species: *Nypa fruticans* (Thunb.) Wurmb.

Nipa palm is described as monoecious palm with underground rhizomatous, dichotomously branched stem. Each terminal shoot consists of paripinnate leaves (7 m long), leaf with terete petiole (1-2 m long) with bulbous leaf base. Leaflets redupicately folded, copious (30 to 40), regularly arranged with each lanceolate up to 70 cm long, with a prominent adaxial midrib (Tomlinson, 1986).

Inflorescence in an erect monopodial axis with up to six branches that ends with pistillate head (Uhl, 1972) which is a definite basic palm type (Tomlinson and Moore, 1968). The inflorescence is compact and the fruits are compound (Van Balgooy, 2015). Nipa is protogynous, in which pistillate head emerges before staminate flowers of the same inflorescence. Although spikes of staminate flower and pistillate head look different in shape and flower type, it is very similar in comparison wherein both have separate perianth parts, and both pistillodes and

staminodes are absent (Uhl, 1972). According to Tomlinson (1990), nipa palm is a Schoute's model which is defined as trees with aerial axes branched by equal dichotomy which is an equal division of the shoot apical meristem. The axes are however underground instead of erected on the ground (Figure 2.1).

Figure 2.1 : Dichotomous branching of underground stem of nipa palm.

The seed of nipa is viviparous (germination on the fruit) (Päivöke, 1996). The plumular axis emerges horizontally and primary root does not surface from seed (Henderson, 2006). The germination is slow growing (7.5 month) or they have a long dormancy (Bacon, 2001). Viability of planted seedling to survive is very low (6% to 8%), where only one was successful out of 10 (Bacon, 2001). Only three seedlings successfully established out of 162 germinated seeds (Rozainah and Nasrin, 2010) making the success rate of 1.85%.

There is little difference of contemporary nipa to mid-Cretaceous and Eocene nipa based on fossils evidence (Muller, 1981; Tralau, 1964 and Uhl, 1972) which showed that the plant undergoes little evolutionary change or adapted early to its estuarine habitat (Uhl, 1972). Several earlier reports stated that there are two to three types of varieties of nipa palm differed in the position of the leaflets in Malaysia according to the local people. Two varieties first reported by Burkill (1935) and mentioned by Päivöke (1996) in passing called 'nipah gala' and 'nipah padi'. This is supported by recent report from Tsuji *et al.* (2011) in which a villager