Pollination studies of *Calamus conjugatus* at Kubah National Park, Kuching, Sarawak

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A thesis submitted in partial fulfilment of the Requirement of The Degree Bachelor of Science with Honours

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ABSTRACT

Calamus conjugatus, a slender clustering thicket forming rattan with stems that only reach the height of 4 meters. Furthermore, because this rattan is rarely used by people, its wild populations are generally intact. *Calamus conjugatus* is thus a useful model species for this research. The study was conducted to discover more information about the pollination biology and pollinator visit of *Calamus* species of natural forest habitats. The study was at Kubah National Park, Kuching, Sarawak. Throughout the study, flowering mechanisms and floral visitors were observed and recorded. The findings of this study should provide useful information on the relationship between the floral characteristics and the floral visitors. In addition, this study can serve as reference for future studies and knowledge on the pollination biology of *C. conjugatus*.

Key words: Pollination, flowering mechanisms, floral visitors.

ABSTRAK

Calamus conjugatus, merupakan rattan lampai yang membentuk belukar berkelompok dengan batang yang hanya mecapai ketinggian setinggi 4 meter. Tambahan, memandangkan rotan ini jarang digunakan oleh orang ramai, populasi liar tumbuhan ini adalah lengkap. Demikian *C. conjugatus* merupakan spesis model yang baik untuk pengajian ini. Pengajian ini dijalankan untuk untuk mengetahui lebih banyak maklumat tentang biologi pendebungaan dan lawatan pendebunga di species Calamus di habitat hutan semula jadi Pengajian ini dijalankan di Taman Negara Kubah, Kuching, Sarawak. Sepanjang pengajian, mekanisme berbunga dan pelawat bunga diperhatikan dan direkodkan. Dapatan kajian ini akan memberikan maklumat berguna tentang hubungan antara sifat bunga dan pelawat bunga. Di samping itu, kajian ini boleh dijadikan rujukan untuk kajian masa depan dan pengetahuan tentang biologi pendebungaan *C. conjugatus*.

Kata kunci: Pendebungaan, mekanisme berbunga, pelawat bunga.

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m	meter
sp.	species
SEM	Scanning Electron Microscopy

CHAPTER 1

INTRODUCTION

1.1 Background

A significant number of new case studies on palm pollination have been published since Henderson's (1986) review of the literature on palm pollination. These studies have produced a range of new information in a variety of groups. *Calamus* species, which are economically important, have been the subject of numerous research. One of the earliest ecological studies of rattans in forest habitats was conducted by Bøgh (1996).

Working in a natural forest is extremely difficult because most of the heavily exploited plants have virtually vanished from the few remaining patches of natural habitat. Furthermore, the enormous height at which most *Calamus* spp. inflorescences are normally found hinders the study of their reproductive processes. Many *Calamus* species are lianas that climb and bloom several tens of metres above the ground at the top of the forest canopy (Dransfield, 1979). *Calamus conjugatus* Futardo, is a slender clustering thicket forming rattan with stems that only reach a height of 4 metres. Furthermore, because this rattan is rarely used by people, its wild populations are generally intact (Dransfield, 1979). *Calamus conjugatus* is thus a useful model species for research.

Reports on pollination of this dioecious genus and other rattans have previously relied on static observations of inflorescences during daylight hours and conclusions from inflorescence structure (Kidyoo and McKey, 2012). Some of these reports includes the occurrence of nectaries in two *Daemonorops* Blume ex Schult.f species, a genus closely related to *Calamus* (Beccari, 1911), *Korthalsia* Blume and *Plectocomia* Mart. & Blume, are

melittophilous hapaxanthic rattans (Corner, 1966), trigonids and honeybees visiting male *Plectocomia* sp. flowers (Dransfield, 1979). *Plectocomia*, which has highly fragrant flowers and visible inflorescences visited by insects during anthesis, also had insect pollination (Madulid, 1980). At anthesis, the inflorescences of most *Daemonorops, Ceratobolus*, *Calospatha* Becc. and *Calamus* section, *Platyspathus* Mart. ex Kunth, species are entirely or partially enclosed by bracts, produce a musty odour, and are visited by many beetles as pollinators (Dransfield, 1979). In other sections of *Calamus*, the inflorescences are lax and unenclosed by bracts, producing a sour odour and being largely visited by wasps and flies (Dransfield, 1979). *Trigona melina* Gribodo visits to the male, but not female, flowers of *Daemonorops didymophylla* Becc., (Kiew and Muid, 1989). Bees are most likely pollinators of many *Calamus* species, although in some instances they may in fact be pollen thieves (Uhl & Dransfield, 1987).

The current study was conducted to discover more about the pollination biology of the *Calamus* species.

1.2 Problem Statements

This project was to study and solve the following problems, firstly is the lack of information on pollination biology in *Calamus conjugatus*. The only published information on pollination biology in *Calamus* is a few notes dispersed across the literature (Kiew and Muid, 1989). The current study will be conducted to discover more about the pollination biology of the *Calamus* species. Next is the lack of pollination studies and information on the relationship between the floral characteristics, flowering mechanisms and the floral visitors of *Calamus conjugatus* in natural forest habitats.

1.3 Objectives

The objectives of this project were:

i. To investigate on the pollination biology of the *Calamus conjugatus*.
ii. To correlate the relationship between the floral characteristics, flowering mechanisms and the floral visitors of *Calamus conjugatus* in natural forest habitats.

CHAPTER 2

LITERATURE REVIEW

2.1 Palms

Although palms are diverse groups, they usually have a constant construction pattern (Yousefi et al., 2020). The palm trees are typically attractive because of their beautiful architectural design (Lim et al., 2020). Palms are very distinct to other plant groups, because of their fan-shaped leaves and pleated leaves. Without prior knowledge, it may be confused with ferns or cycads. There are around 2700 palm species in the world in approximately 200 genera of palms (Li et al., 2019) usually found in tropical and subtropical regions. The palms are very diverse in ever humid tropics such as Malaysia, which got around 410 species, about 15 percent of the global species, and most likely the highest diversity per unit area in the world (Saw, 2003). Due to their basic structure and attractive features, the palm trade is a lucrative business globally, ranging from landscaping, ornaments made from their seed, and palm oil which endangers the plant if not well taken care of (Yousefi et al., 2020). The palm enthusiasts, gardeners, and societies usually got an enormous following, especially on social media platforms.

Most palm species have upright stems, with others like *Nypa* Wurmb, with massive undergrowing limbs found on the river mouths and riverbanks mudflats (Li et al., 2019). Some species are solitary while others cluster. The clustering ones have sympodial habits, i.e., basal branching like some orchids, while the solitary ones got monopodial patterns (Salomón-Torres et al., 2021). Most palm species trunks do not produce branches; only a few species like *Dypsis lutescens* (H.Wendl.) Beentje & J.Dransf., do branch on the upper shoots (Yousefi et al., 2020).

Like the other monocots, the palms has one terminal apex in which only one leaf is produced at a time.

2.2 Palms in Sarawak

Palms are all members of the Arecaceae family (Midot et al., 2019) with Sarawak having around 260 species belonging to 31 genera as mentioned by Official Website of Forest Department Sarawak. Some of the palms found in Sarawak include *Pinanga*, *Areca*, and *Calamus* with different size range from small palms to massive palms such as *Livistona* R.Br., *Salacca* Reinw., *Caryota* L., *Nypa fruticans* Wurmb, and *Oncosperma* Blume. Some palm species produce edible starch, shoots, and fruits (Lim et al., 2020).

The species are well distributed throughout Sarawak, showing high endemism in their natural habitats (Jana & Jusoh, 2021). In Sarawak cultivation schemes, a closely related palm genus to *Johannesteijsmannia* H.E.Moore is gaining popularity among large-scale farmers (Ching et al., 2019). The genus consists of large-sized palms. The *Maxburretia* Furtado genus is also found in Sarawak and is a medium-sized palm and contains three species worldwide (Li et al., 2019). The species has attractive features, but unfortunately, they are hard to grow. However, the indigenous species are challenged by the ongoing human activities in Sarawak that aim to support the species with high commercial value at the expense of the other palm species.

2.3 Plants diversity in Kubah National Park

Kubah national park is an ecologically diverse ground that portrays the indigenous palm species varieties, especially in the Sarawak Forest. On the island of Borneo, Sarawak is presently one of Malaysia's last frontiers for palm oil expansion. Despite the fact that the land

surrounding Kubah National Park has changed considerably from forest to shopping centres to agriculture, the park itself remains cloaked in sky-touching mixed dipterocarp trees.

Kubah National Park is a mixed dipterocarp forest with palms, orchids, and pitcher plants that encompasses 2,230 hectares. Mount Serapi, which stands at 911 meters high and provides a spectacular backdrop to sunsets across the Kuching Waterfront, dominates the park. Kubah's forest is mixed dipterocarp, with isolated patches of kerangas or heath forest and small portions of scrub forest (Christharina and Abang, 2014). Dipterocarp comes from the Greek words for "two-winged fruit". For instance, 291 species of trees from the Dipterocarpacea family have been identified in Borneo (Hazebroek and Abang Morshidi, 2000). However, some of the three that were documented in Borneo have three or five expanded fruit wings some will not (Carter, 1994). Family Dipterocarpacea are distinctive from other types of forests because they frequently dominate the upper canopy with numerous large trees. Lowland dipterocarp forest, hill dipterocarp forest, summit ridge forest, and submontane forest are only a few of the different types of forests that contain mixed dipterocarp forests (Anderson and Chai, 1982).

Additionally, the available vegetation is diverse, including lianas, herbs, ferns, palms, and an abundance of parasitic plants and animals. A widespread and dense mixed dipterocarp forest exists. There are five layers of the canopy that have been identified. The top layer is made up of the tallest tree, which can reach a height of 60 metres. The second layer is an understorey of trees that are 23 to 30 metres tall that occasionally intermeshes the main canopy. The fourth layer of the forest is made up of shorter woody treelets and shrubs, and the last layer is the forest floor covered in herbs and seedlings. The closely woven canopy and deep shadow hinder sunlight's ability to reach the forest floor (Hazebroek and Abang Morshidi, 2000).

2.4 Pollination

Pollination is the process by which pollen grains are transferred from an anther to the stigma of a flowering plant. This procedure enables the interaction of the male gametes with the female ovum, which results in fertilization, seed formation, and hence a new plant (sexual reproduction) (Allaby, 1998). After the development of the sexual organs, pollination is the first stage of plant reproduction. Palms are primarily insect-pollinated by various insects such as beetles, flies, wasps, and bees, while a few species pollination is aided by wind (Ismail, 2020). The palm flowers are usually not conspicuous and often small. They appear in different colors ranging from red, yellow, cream, and white and are mostly grouped in typical inflorescence structures (Yousefi et al., 2020). Most palm species have unisexual flowers, but in some more primitive palm species such as Coryphoid palms, the flowers are bisexual. The female and male flowers may be hosted on the same plant for the monoecious species or different plants for the dioecious palm species. Many of the palm species have pleonanthic characteristics where they produce inflorescences for an extended period, for example, the coconuts (Aljuboori et al., 2018). Depending on its species, it takes a palm tree from 3 to 40 years to flower for the first time. In agricultural farms, the pollen from the male flowers is transported manually to the female flowers by the farmers since the number of seeds produced by the palm flower is dependent on how well the flower is pollinated (Ismail, 2020). However, significant expertise is required for manual pollination.

2.4.1 Pollination study of palms

Pollination biology is incompletely defined in West Malaysia, where plant reproductive phenology, fauna, and flora differ significantly from those found in the Neotropics. On the subject of plant reproductive phenology, the occurrence known as general flowering has been recorded from West Malaysia, and as one might anticipate, this has

implications for plant-pollinator co-evolutionary processes. More than 80% of emergent and canopy tree species bloom for 3–4 months at 2–10 year intervals (Ashton et al., 1988). In general flowering periods, a significant number of species bloom in such a short time that pollinator shortages may emerge unless pollinators that can respond rapidly to the general flowering period are present (Ashton et al., 1988). Thrips, according to these authors, are capable of such a reaction. During flowerless seasons, thrips use floral resources to maintain a low population density. They have a short generation time and a high fertility, so as soon as a general flowering period begins, they can quickly increase their numbers by utilizing the vast floral resources. However, thrip pollination was only observed in the genus *Shorea* Roxb. ex C.F.Gaertn., sect. Mutica in the Malay Peninsula (Appanah and Chan, 1981).

In tropical rainforests in Borneo, the canopy can reach 70 metres above the ground, and up to five forest strata can be distinguished (Yamakura, 1992). Plant reproduction and primary production are highly active in higher strata. Plant reproduction and plant–animal interactions in the forest canopy have been severely constrained due to technological limitations (Lowman and Wittman, 1996). The Canopy Biology Program, Sarawak built a canopy observation system with tree towers and aerial walkways in Lambir Hills National Park in Sarawak, Malaysia (Inoue et al., 1995). The most recent pollination studies in Sarawak is the floral biology and pollination strategy of *Durio* (Malvaceae), where the information on the floral biology and pollination mechanism of four *Durio* species (*D. graveolens, D. griffithii, D. kutejensis,* and *D. zibethinus*) in Sarawak was expanded (Ng et al., 2020).

CHAPTER 3

MATERIALS AND METHODS

3.1 Study Site

The study was carried out in Kubah National Park (1.6128° N, 110.1969° E). It is situated near Matang, approximately 20 kilometres from the state capital of Sarawak, Kuching. Kubah National Park covers 2,230 hectares of mixed dipterocarp forest that is rich in palms, orchids and pitcher plants. The National Park possesses three mountains including Mount Serapi, Mount Selang and Mount Sendok. This study was done during a period which is October 2021 – March 2022.

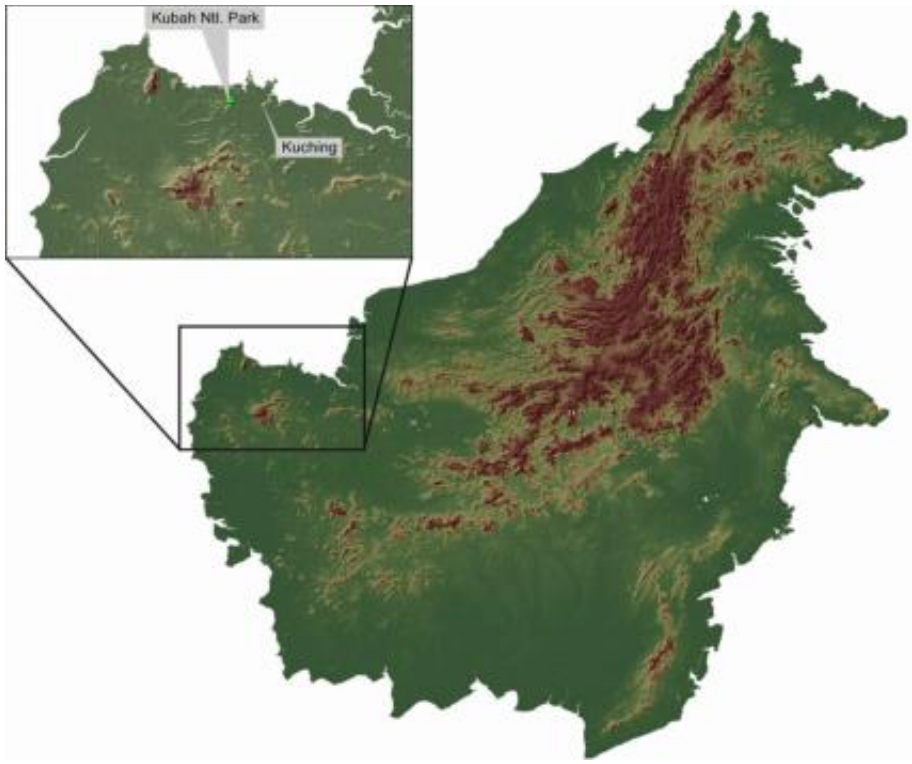

Figure 1: Map of Kubah National Park in Sarawak, Malaysian Borneo
Source: Das & Haas (2010).

3.2 Flowering mechanisms

Observations were made one week before and during the anthesis. The inflorescences were identified and observed for a few days before anthesis began. During the anthetic phase, any distinctive inflorescence activity were observed and recorded every one to three hours until the anthetic phase ended. Anthetic phases, floral part movement, floral fragrance emission, were all documented. Due to the studied *Calamus conjugatus* that are nocturnal flowering, torchlights and red led flashlight were used.

3.3 Floral visitors

Observation of the floral visitors were made during anthesis. Presence of insects that visited flowers on a regular basis was recorded. The average number of floral visitors per flower per hour was recorded. Furthermore, insect visitors' visitation behaviours on inflorescences also observed and recorded. Floral visits were separated into two groups: visitors and pollinators, based on their behaviour during visitations and probability of assisting in pollination. Photographs were taken during observations using camera.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Flowering Mechanisms

The field study was made during October 2021, there was a high number of flowering on different plants of *Calamus conjugatus*, where there was frequent rainfall. The inflorescences were identified and observed for a few days before anthesis began. There were no significant intersexual distinctions in microhabitat, size, or vegetative form of plants in the populations of the studied *Calamus conjugatus*, It was observed that the flowering sequence was always from apex to base, and that it was repeated from apex to base (Figure 2.1). Two or more flowers per inflorescence blossomed at the same time most of the time. In the early evening, around 1820 hrs, the mature bud began to open. Gradually, the yellowish white petals began to open and expose the stamens (1845 hrs) and continued to extend until 2040 hrs (Figure 2.2). The anthers dehisced and began to release pollen. The floral scent, a strong pungent ammonia like scent emitted around 1845 hrs and can be detected from 1 m away. Floral odour as flower characteristic that attract pollinators has been observed in many species of *Calamus*. For instance, Kidyoo and McKey (2012) reported that the sweet, slightly musky odour as a main trait that attract pollinators to the studied *Calamus castaneus*.

Figure 2.1: Flowering mechanism of *C. conjugatus*: (A) Inflorescences 5 days before anthesis; (B) Anthesis began from apex to base.

Figure 2.2: Flowering mechanism of *C. conjugatus*. **A – C.** Flowering sequence: (A) Mature bud opening; (B) Stamens exposing; (C) Stamens fully extended.

The anthesis of both sexes of the flowers occurred are nocturnal. The male anthesis began around 1820 hrs where the male anther pore spread out, while the female anthesis begins about an hour later, a frequent occurrence in dioecious plants including certain palms (Henderson et al., 2000). Several causes might provide early blooming males an advantage.

For example, the priority advantage. Female blooming time may vary, and there may be a benefit in fertilising the first flowers they produce (McCall and Primack 1985), because from early to late flowers within inflorescences the probability of fruit-set decreases due to resource allocation or ontogenetic alterations.

The male anthesis ended the next day around 0930 hrs as all parts of the flower dried off and dropped. The colour of the petals changed from yellowish white to pale white after it completely dried and fell. The female flowers however remained receptive for more than two days (Figure 2.3). Insects visitation is most likely influencing the highly varied length of female receptivity. Pistillate flowers may live longer and stay receptive for a longer amount of time, increasing their chances of being pollinated (Steinacher and Wagner 2010). Moreover, Female flowers are often less rewarding than male flowers (Ashman, 2009). The more rewarding staminate flowers, on the other hand, are more likely to be visited rapidly and then dry once their pollen has been spread (Lee and Jong 1995), explaining their short life span. Male individuals have more and larger flowers than females in many dioecious plants, whether they are anemophilous, such as *Corema album*: Empetraceae (Guitián et al. 1997), or entomophilous, such as *Polyscias pancheri*: Araliaceae (Schlessman et al. 1990), *Wurmbea dioica*: Liliaceae (Vaughton and Ramsey 1998), and *Laurus azorica:* Lauraceae (Forfang and Olesen 1998). Most dioecious palms, on the other hand, are characterised by female flowers that are significantly larger than male flowers. However, in *Calamus conjugatus*, male flowers are around the same size as females. This size resemblance might be linked to deception and mimicking pollination. The summarized flowering mechanism data is presented in Table 1.