MORPHOLOGICAL STUDY ON THE GENUS *FREYCINETIA*
FROM SUMATRA

Introduction

Despite the fact that the morphology of the genus *Freylinetia* has been discussed in several publications prior to this current study such as by Ridley (1907) and Stone (1968, 1983), it mostly concerns to the well-known species such as *F. insignis* or *F. sumatrana*, very little have been done for less known species. This study discusses the results of morphological study carried out on the genus found in Sumatra and adjacent islands. New characters found then were incorporated into the already known set of characters in order to have a better understanding in the morphology of the genus, especially when variations existed.

Conducting study on the morphology of *Freylinetia* has long been considered as a daunting task due to several difficulties, particularly regarding the limited number of specimens. The situation is worsened by the fact that most of these few specimens are in sterile conditions. As the consequence many taxa had been inaccurately identified or being misplaced. Although vegetative characters, particularly in leaves and auricles, can be used as good identification characters for few species or infrageneric classification, in most cases they are useless as in most of the species they are almost uniform. Field observations on living materials carried out in this study have helped in clarifying many distinctive morphological characters that usually absent or hardly seen in the herbarium specimens.

The morphological species concept is implemented in this study. The concept defines species as the smallest groups that are consistently and consistently distinct and distinguishable by ordinary means (Cronquist 1978; Stuessy 1990; Winston 1999). The concept is described as a strictly operational and non-explanatory, based only on the observable facts of similarity and continuity (Winston 1999). The concept is regarded as the most frequently employed by revisionary workers or museum taxonomists (Stuessy 1990) and the
vast majorities of monographers now adopt the morphological species concept and use morphological differences to delimit taxa (McDade 1995).

In pandan, as in the other monocotyledonous taxa like palms, the most common species concept and the one that continues to be used now a day is undoubtedly the morphological species concept (Keim 2003). Distinction is based on perceived discontinuities in morphological variation. Dransfield (1999) described in detail the advantages of this concept, which are related to one of the most significant aspects of a good taxonomy, in that it allows predictability: related taxa often have a range of similar properties. In other words, the concept provides a series of reference points to describe diversity and to which further information can be linked.

However, Mayden (1997) pointed that the phenomena of sibling or cryptic species or the retention of plesiomorphic morphologies as the real problem faced when implementing the concept. Dransfield (1999) also described disadvantages the concept mostly due to limited herbarium specimens both quantity and quality. This disadvantage has to be taken seriously when working with *nycinetia*, where the limited number of herbarium specimens affects observations on discontinuities in morphological variations.

The decision to adopt the morphological species concept in this study does not indicate that the other concepts are inferior compare to it. The decision is based on the practical nature of the concept. The aim of this study is to have a better understanding on the morphology of the genus in order to improve the species delimitation, particularly for the species found in Sumatra.

**Materials and methods**

Materials used to provide morphological data for the present study were herbarium specimens including preserved materials deposited in BO, ANDA (Indonesian University Herbarium), and MEDA (North Sumatra University Herbarium) and many new specimens recently collected by the authors particularly from the areas which have not been visited by former researchers or
collectors. Specimens were made by using standard preparation guidelines to
*Pandanaceae* (Stone 1983). A total of 500 herbarium sheets were observed in this
study. These herbarium specimens are kept at the Herbarium Bogoriense (BO) at
Cibinong, West Java-Indonesia, the Herbarium of the Andalas University
(ANDA) at Padang, West Sumatra-Indonesia, and the Herbarium of the North
Sumatra University (MEDA) at Medan, North Sumatra-Indonesia. Recently
collected specimens from field study proceeded in this current study particularly
from areas, which have not been visited previously are also incorporated. Short
visits to observe other specimens were made to the Rijksherbarium, Leiden
University (L), now (after Jan 1, 2010) Netherlands Centre for Biodiversity
naturalis (section National Herbarium of The Netherlands, NHN), Leiden
University, and the Kew Herbarium (K) Royal Botanic Gardens, Kew. The
procedure for morphological observations followed the steps described by Davis
Heywood (1963), Rifai (1976), and De Vogel (1987).

Results and Discussions

Habit

All species of *Freycinetia* found in Sumatra are basically climbers or have
ability to undergo a climbing habit. This climbing habit distinguished *Freycinetia*
from the other three genera of *Pandanaceae* (*Martellidendron*, *Pandanus*, and
*Varanara*) that possess the tree habits (Stone 1970a; Callmander *et al*. 2003).
The species of *Freycinetia* climb using aerial (i.e. climbing) roots that develop
from the stem nodes. Sometimes the stems are found hanging on trees or falling
the ground to form dense clumps.

The result of this study shows that *Freycinetia dewildeorum* and
*kamiana* have quite different habit. These two species are found more as
shrubs than climbers. However, the shrubby habit apparently is uncommon in
*Freycinetia* as it is also found in other species, such as *F. olanceolata* from
Aigeo Island, West Papua (Keim *et al*. 2006). The only species that are known
have an obvious non-climbing habit is the Hawaiian endemic *F. arborea*. 
Species of *Freycinetia* are commonly found climbing on dicotyledonous trees. *Freycinetia sumatrana* is the only species observed climbing on monocotyledonous taxon, which is *Gigantochloa alter* (Figure 2.1).

![Image](image-url)

Figure 2.1 Scrambling-shrubby habit of *F. dewildeorum* (A), *F. sumatrana* climbing on the culms of *Gigantochloa alter* (B).

The result of this study shows that five species are found climbing up 10 m or more (*F. angustifolia*, *F. confusa*, *F. javanica*, *F. sumatrana* and *F. winkleriana*). The other 8 species are found climbing to less than 7 m or so (*F. berbakensis*, *F. dewildeorum*, *F. distigmata*, *F. imbricata*, *F. kamiana*, *F. leuserensis*, *F. rigidifolia*, and *F. scandens*). *Freycinetia sumatrana* is the highest climber known in Sumatra. The species is known to be able to climb up to 30 m or higher (Figure 2.2). *Freycinetia sumatrana* is also regarded here as the dominant species, both on ground and canopy levels. The species is observed as most prominent figure in several protected areas visited in this recent study. Only in *F. sumatrana* the aerial roots are found invested with galls. Although the presence and function of galls have been studied in the other groups of plants, there is no information for *Freycinetia*. Galls are abnormal outgrowth of plant tissue and caused by various parasites such as fungi, bacteria, insects or mites, in which galls provide both living spaces and food sources for the parasites. The interior of a gall can contain nutritious starch and other tissues. Some galls act as “physiological sinks” concentrating resources from the surrounding
The sizes of main stems and branches vary from slender to robust. Slender species are *F. angustifolia*, *F. berbakensis*, *F. confusa*, *F. distigmata*, *F. imbricata*, *F. javanica*, *F. kamiana*, *F. rigidaflora*, *F. scandens* and *F. winkleiana*. Robust species include *F. dewildeorum*, *F. leuserensis*, *F. scabrosa* and *F. sumatrana*. The conspicuous variation is also observed in the internodes length. This study shows that the internodes length is not related with the stem diameter. The surface of the stem can be smooth or sulcate. The colour also varies from yellowish green, light brown to deep or blackish brown.

The leaves of *Freycinetia* are usually dark green coloured and glabrous on the upper (adaxial) surface, but light green and glaucous on the lower (abaxial) surface. The surfaces of a leaf are easily recognized even in the dried mounted herbarium specimens. Compare with the other members of *Pandanaceae*, the size
of leaf in *Freyecinetia* is noticeably smaller. In Sumatra, *F. rigidifolia* possesses the smallest and most slender leaves. On the contrary, *F. sumatrana* has the most robust leaves. The leaves arrangement in species of *Freyecinetia* found in Sumatra is imbricate or in spiral. Ten species have imbricate leaves, i.e. *F. berbakensis*, *F. confusa*, *F. dewildeorum*, *F. distigmata*, *F. imbricata*, *F. leuserensis*, *F. scabrosa*, *F. sumatrana* and *F. winkleriana*. The other four species have their leaves spirally arranged, i.e. *F. angustifolia*, *F. kamiana*, *F. javanica*, and *F. scandens*.

The leaves are simple and usually linear and lanceolate-elongate in shapes. However, variations do exist as in some species the leaves are observed in elliptical, oblanceolate. *Freyecinetia javanica* and *F. scandens* have variations in shapes throughout maturity. The leaves are observed elliptical to broad ellipsoidal when young turn into lanceolate or linear in maturity. The apical part can be acute, acuminate, attenuate or caudate. Caudate apices are observed only in species: *F. kamiana* and *F. leuserensis*. The margins can be entire as observed in *F. berbakensis* and *F. kamiana* or noticeably armed with spines throughout the length, except in *F. distigmata*, *F. scabrosa*, and *F. sumatrana*. *Freyecinetia distigmata* possesses densely spines only at the basal part of its leaves, whereas in *F. scabrosa* and *F. sumatrana* it is merely *denticulate* at the base. The laminar part can be chartaceous or coriaceous with longitudinal lines on both surfaces. The lines are more prominent abaxially. In *F. kamiana* and *F. leuserensis* the lines are striate on both surfaces.

### Auricles

A pair of auricles is found in the margins of leaf sheaths. Auricles are usually membranous, transparent, and fragile. Due to the nature of auricles in parburn specimens they are hardly seen in fine and recognisable conditions. This is, good observations on auricles are usually made in the fields. Auricles vary greatly in shapes and colours. In most species the auricles are persistent especially in the upper leaves but sometimes disintegrated easily in the lower ones. In other words, auricles are more easily seen in younger leaves.

*Freyecinetia dewildeorum*, *F. imbricata*, and *F. rigidifolia* possess unique auricles (Figure 2.3). The auricles in these three species are horizontally
fragmented (*F. dewildeorum*), transparent (*F. imbricata*), and with obvious spiny margins (*F. rigidifolia*). *Freyecinetia berbakensis* and *F. confusa* possess the smallest auricles, while the most robust and straightforwardly distinguished auricles can be seen in *F. leuserensis* and *F. scabrosa*. Auricles are regarded in this study as an exceptionally important distinctive morphological character as they are almost unique for each species. They are more easily recognised in living (e. fresh) materials due to the differences in colour or membranousness.

![Figure 2.3](image)

**Figure 2.3** Unique auricles in three species of Sumatran *Freyecinetia*. Horizontally fragmented in *F. dewildeorum* (A), transparent in *F. imbricata* (B), and with obviously fimbriated margins in *F. rigidifolia* (C).

Basically there are two types of auricle shapes, lobed (free apices) and tapered (adnate). Only in *F. sumatrana* that the two types of auricles are observed but both types have never been observed in the same individual. Thus, the shape of auricle is still an important field identification character. Colour of auricles also varies in *F. sumatrana* from yellowish to characteristically purplish brown (Figure 4). Even though, the lobed purplish brown coloured auricles are more commonly seen in the field than any other colours, thus it is regarded here as the distinctive morphological feature for *F. sumatrana*. 

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*Note: The text is written in Indonesian and English, with the main content in English.*
Figure 2.4 Shape and colour variations in *Freycinetia sumatrana*, free apices auricles different in colour (A & B); adnate brown auricles and nearly inconspicuous (C).

**acts**

In *Freycinetia* bracts are leaf-like structures produced through modification of leaves at the base of an inflorescence. Bracts usually no longer try out the photosynthesis function and act more to attract possible pollinators fruit dispersal agents and to protect inflorescences.

The result of this study indicates that bracts in pistillate inflorescences usually persistent, on the contrary they are caducous in staminate inflorescences. In other words, bracts are stay much longer in pistillate inflorescences and still exist in infructescences, while in staminate inflorescences they are fallen soon after anthesis. Anthesis in *Freycinetia* takes usually one to three days only (Stone 1983), so bracts in staminate inflorescences are short lived. Based on field observations, bracts open in the morning usually following the rain.

Bracts vary in shapes and sizes. Bracts are usually elongated in shape with margins slightly armed with spines. The sizes of bracts are in concurrent with their habits. Robust species such as *F. javanica*, *F. leuserensis*, and *F. sumatrana* are robust bracts as well. On the contrary, slender species like *F. angustifolia* and *F. winkleriana* possess slender and minute bracts (Figure 2.5). The outermost bracts are leaf-like in forms. The inner bracts are much shorter, broader, thicker, and have wide variation of colours, such as creamy white, light green, bright
yellow, orange, red or purplish red. The innermost bract is often fleshy and edible (Stone 1983, Dahlgren et al. 1985, Brink & Escobin 2003). This bract also produces very strong odour (observed similar to the scent of honey). This correlates with the important function of the innermost bract to attract pollinator agents, the bats (van der Pijl 1956; Cox 1982, 1984; Lord 1991; Cox et al. 1995). Being a nocturnal animal, bats are believed to be attracted to odour rather than colour (van der Pijl 1956). While bright colours are regarded in this current study as attracting views for possible diurnal pollinators such as birds and insects.

Figure 2.5 Variation in the shapes and colours of bracts, (A) Pistillate inflorescences of *F. angustifolia*, (B) Single staminate inflorescence of *F. imbricata*, (C) Pistillate inflorescences of *F. javanica* (D) Pistillate inflorescences of *F. winkleriana*.

The result of this current study suggests that the colour of bracts in *Eucalyptus ceylonica* may correlate with the habitat, elderness and time of anthesis. One example for this is observed in *F. javanica* (Figure 2.6). The species observed in the same area as *Eucalyptus ceylonica* possesses bright yellow bracts, while the same species in Bukit Kaba Ecotourism Park in Bengkulu and Rimbo Tinti in West Sumatra possesses salmon-orange colour.
Figure 2.6 Variation of bract colours in *F. javanica*, bright yellow bracts in Daleng Lancuk (A), pale salmon bracts in Bukit Kaba Ecotourism Park (B), orange bracts in Rimbo Panti (C).

In this study the phenomenon is best explained with the correlation between production of the anthocyan and the degree of sun exposure. Lindoo & dwell (1978) suggest that exposure to ultraviolet light in some organs, such as ves and bracts would increase the production of anthocyan. Thus the bright low coloured bracts are apparently produced through this process. Indeed the test in Daleng Lancuk, Law Kawar area and Rimbo Panti are more opened to exposure than the other place. Besides, the bracts colour differences in those habitat is presumably as the effects of anthesis. In most plant, bracts colour is usually tend to be brighter during anthesis period.

Inflorescences

The inflorescence in most species of *Freycinetia* is usually found on the apical part (i.e. terminal) of the stem. Inflorescences in species found in Sumatra usually located on the terminal parts of the stems (i.e. terminal inflorescences). Lateral inflorescences are less often seen. Prior to this current study in Sumatra *F. imbricata* has been known to possess both terminal and lateral inflorescences (Stone 1970b). This current study indicates that there is another species that possess the same feature, *F. winkleriana*.

Lateral inflorescences sometime are difficult to be distinguished from the terminal inflorescences in the stem branches or shoots. In lateral inflorescences y bracts present, while in terminal inflorescences in stem branches or shoot
both bracts and leaves present. The inflorescences in most species of Sumatran Freycinetia are unbranched and umbellately arranged. Other kinds of inflorescences are observed as racemose in F. angustifolia, pseudo-umbellate in F. dewildeorum, and singular (i.e. solitary) in F. berbakensis (Figure 2.7). Staminate inflorescences are more rarely seen than pistillate inflorescences and this is due to the anthesis, which takes only one to three days (Stone 1983). By necessity, similar to other genera of Pandanaceae, Freycinetia identification is therefore mainly based on the structure of female inflorescences and frutescences.

Figure 2.7 The inflorescence arrangements in Sumatran species of Freycinetia. The arrangement can be racemose as in F. angustifolia (A), solitary as in F. berbakensis (B), pseudo-umbellate as in F. dewildeorum (C), umbellate as in F. imbricata, F. javanica, and F. scabrosa (D-F), the variation in the shape and colour of cephalia in F. sumatrana (G & H), the slightly falcate cephalia of F. winkleriiana (I).
Cephalia

Cephalium (plural: Cephalia) is the distinctive structure of complex fruit in Pandanaceae. It is both the main generative organ and the foundation of classification. Unlike in the other members of the family (Martelliodendron, Pandanus, and Sararanga), the structure of cephalium in Freycinetia is unique for it is consisting of multiovulate carpels. The cephalia of the other members of Pandanaceae consist of uniovulate carpels. Thus, based on this Freycinetia is placed in its own subfamily, Freycinetoideae (the others are placed together in the other subfamily, Pandanoideae). Nevertheless, Freycinetia shares fleshy cephalia with Sararanga, while Martelliodendron and Pandanus possess dry-hard cephalia.

In the Sumatran species of Freycinetia cephalia vary in shapes, sizes, and colors. Five species (F. berbakensis, F. confusa, F. dewildiœorum and F. imbricata) have globose cephalia, while the other nine species possess indrical cephalia. Freycinetia sumatrana is the only species observed with various shapes of cephalia from globose to oblong (Figure 2.7). The number of flava per infructescence is usually three (ternate), other numbers such as one, (binate), four (quaternate) or five are also present but less seen. In Sumatra on F. distigmata possesses strictly one cephalium per infructescence.

Berries

Berry is the simple fleshy fruit of Freycinetia. In Freycinetia a cephalium consists of numerous berries. However, unlike the other members of Pandanaceae, the berry in Freycinetia is always multi seeded in one locule (uniloculate-multiovulate). Thus, regarding gyrooeicum, in Freycinetia it is always loculate and multiovulate. A berry can be formed by one or more gyrooeia, which is indicated by the number of stigmatic remains. Stigmatic remains can be found in areola with or without distinctive rings. In Pandanus the simple dry fruit also be multi seeded (called phalange), but never multiovulate.

Berries vary in shapes from needle-like (filiform) to rostrate. In most species the berries are densely arranged and stick one another in a cluster (Figure 2.8). Species with rostrate berries are extremely rare. Prior to this current study Neovriesei from Celebes and the Philippines was the only species with rostrate
berries (Merrill 1908; Stone 1969). The result of this study discovers *F. dewildeorum* as the only species in Sumatra to have rostrate berries. Thus, the result of this study is not only adding a new species with the same morphological feature but also records the first presence of a rostrate berries species of *Freycinetia* in West Malesia. The apical part of a berry is usually harder and stiffer. The basal part is usually fleshy.

Figure 2.8 Apical parts of berries showing the stigmatic remains of *F. dewildeorum* (A), *F. distigmata* (B), *F. javanica* (C), *F. kamiana* (D), *F. leuserensis* (E), and *F. rigidifolia* (F).