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Cover images: *Begonia hooverina* Wiriad. *spec. nov.*

THE UNIQUE CHARACTERS AND HABITAT OF FREYCINETIA (PANDANACEAE) WITH SEVEN NEW SPECIES IN TIMIKA, WEST PAPUA, INDONESIA

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ABSTRACT

SINAGA, N. I., KEIM, A. P. & PURADYATMIKA, P. 2013. The unique characters and habitat of *Freycinetia* (Pandanaceae) with seven new species in Timika, West Papua, Indonesia. *Reinwardtia* 13(5): 405–418. —This current study of *Freycinetia* was carried out in Timika, West Papua. Results indicate that species vary in both morphological characters and habitat preferences. Timika is unique as only in this area species with highest number of segments in a berry and of stigmatic remains are found. Exceptional characters regarding to auricles, areolas, and stigmatic remains are observed in many species in this area. The result of this current study suggests that the ability of species to adapt to the widespread forest disturbances in Timika leads to their differences in morphological features compare to other Papuan species. Subsequently, seven new species are described here.

Key words: *Freycinetia*, New Guinea, Pandanaceae, Papua, Timika.

ABSTRAK

SINAGA, N. I., KEIM, A. P. & PURADYATMIKA, P. 2013. Karakter unik dan habitat *Freycinetia* (Pandanaceae) serta tujuh jenis baru dari Timika, Papua Barat. *Reinwardtia* 13(5): 405–418. — Studi mengenai *Freycinetia* dilakukan di Timika, Papua. Hasil penelitian menunjukkan bahwa variasi ditemukan pada karakter morfologi dan habitat. Timika menjadi unik karena hanya di areal ini jenis tumbuhan tersebut memiliki jumlah segmen beri dan stigma tertinggal terbanyak dari yang pernah ditemukan. Karakter khusus pada aurikel, areola dan stigma tertinggal diamati pada banyak jenis di areal ini. Hasil penelitian memberikan dugaan bahwa kemampuan jenis untuk beradaptasi secara luas dalam hutan yang terganggu di Timika membawa perbedaan pada pembentukan karakter morfologi dibandingkan dengan jenis *Freycinetia* Papua lainnya. Dengan demikian, sebanyak 7 jenis baru Timika dipertelakan dalam tulisan ini.

Kata kunci: *Freycinetia*, New Guinea, Pandanaceae, Papua, Timika.

INTRODUCTION

The island of New Guinea (both the Indonesian part and Papua New Guinea) is well known for its richness of tropical rainforests and biodiversity. Regarding the genus *Freycinetia* (Pandanaceae: Freycinetoidae) the island is also known as the center of diversity. One of the area that possess outstanding diversity in Papua (West New Guinea) is Timika in the Indonesian part of the island.

Prior to this current study several species have already been collected from Timika such as by Meijer-Drees in 1938, Boden-Kloss in 1939, Brass

in 1939, and Johns from 1994 to 1999.

The collections are kept in BO, K, L, LAE, and MAN. Most of the specimens are still unidentified or just labeled as *Freycinetia* sp. Thus, this current study is aimed at specifying the exact number of species existing in this area, especially in Timika, based on these specimens including their biological and ecological aspects.

MATERIALS & METHOD

The current study was carried out from October 2005 to March 2009. The study was started by col-

lecting activities in Timika (2005) then followed by herbarium studies conducted in Herbarium Bogoriense (BO) Indonesia in 2006 and 2008, (Herbarium Manowariense (MAN) Indonesia in 2006, Lae Herbarium (LAE) Papua New Guinea in 2006, the National Herbarium of the Netherlands Leiden Branch (formerly Rijksherbarium Leiden, L) in 2008, and the Kew Herbarium (K) UK in 2009.

RESULTS AND DISCUSSION

Groupings and unique variations in morphology

The result of this current study indicates that there are 38 species of *Freycinetia* found in Timika, grouped into 4 non-taxonomical groups (Sinaga *et al.*, 2010): The imbricate-leaved *Freycinetia angustissima* Group (consisting of 3 species), the semi-imbricate-leaved *F. funicularis* Group (consisting of 8 species), the non-imbricate-leaved *F. macrostachya* Group (consisting of 14 species), and the grass-like-leaved *F. oblanceolata* Group (consisting of 13 species). Among the four groupings described above, unique morphological characters can be observed in the members of the two groups, *F. macrostachya* and *F. funicularis* Groups.

The result of this current study shows that the largest auricle and highest number of stigmatic remains ever recorded in the genus (18 to 32) is found in *F. megaauriculata*, which is a member of *Freycinetia macrostachya* Group. Fusion of stigmatic remains with areolas that caused a distinctive brocoli-like arrangement is also observed in this species. This kind of arrangement has never been recorded before.

Morphological variations in the fruit characters are also observed in the two other members of the group: *Freycinetia circuita* and *F. clavata*. In *F. circuita* the stigmatic remains are circular, while *F. clavata* possesses three rigidly segmented berries each with four or five stigmatic remains. In the fused berries the number of stigmatic remains is not in equal to the number of berries. The same phenomenon can be seen in *F. megaauriculata*.

In *F. frutonumerata* and *F. frutaspiralica* the most obvious morphological variation are observed in the cephalia. In *F. frutonumerata* the highest number of cephalia per infructescence is 12; this is the largest number of cephalia per infructescence ever recorded in the genus. In *F. frutaspiralica* the cephalia are spirally arranged. Species with spirally arranged cephalia are rare in New Guinea. So far this character is only shared with *F. arfakiana*, a species found in Manokwari.

In the *F. funicularis* Group the main morphological character lies in the unique arrangement of stigmatic remains and areola. *Freycinetia pleurantha* possesses stigmatic remains and areola arranged in 4 lines but separated in two combined lines by a series of holes. In *F. imbristigma* the stigmatic remains and areola are imbricately arranged in 2 combined lines. In *F. fusiforma* and *F. magnoareola* the characters are primarily those of the the areolas. In *F. fusiforma* the stigmatic remains and areolas are fused (hence the epithet “fusiforma”) and form the centrally located areolas. On the contrary, *F. magnoareola* has the largest areolas in the genus, so large the areolas entirely cover the stigmatic remains. The variations in the stigmatic remains and areolas in this group are usually found in species that inhabit the highlands of central part of Western New Guinea.

Habitat

The results of our study indicate that in Timika *Freycinetia* species are present in primary, open and secondary forests (Table 1). The result of this present study shows that 38 species inhabit the primary forests, while 18 species inhabit both primary forests and disturbed forests, including the Modified of Ajkwa Deposition Area (Mod-ADA) in the lowland area of PT Freeport Indonesia project area, which was designated to manage tailings. Tailings are produced from ore-processing to obtain valuable minerals. The production process results in 3 % concentrate containing copper, gold and silver, and 97% tailings. Several areas in Mod-ADA are recovering by the natural succession process, which has reached the stage of secondary forest of pioneer plants. One of plants that found in the tailings natural succession area is *Freycinetia* sp. (Sinaga and Puradyatmika, 2006). Thus, in Timika species of *Freycinetia* prefer humid primary forests – especially close to rivers or creeks—over disturbed forests, as the genus usually does (Stone, 1982); except for *F. concolor* which is present in more open areas.

In New Guinea *Freycinetia* species that inhabit secondary forests are rare. Only species that belong to the imbricate leaved or *F. macrostachya* Group are known to inhabit this kind of habitat, particularly *F. macrostachya* and *F. marginata*. The other species that also occur in the area but less commonly so are *F. excelsa*, *F. frutonumerata*, *F. klossii*, *F. lacinulata*, *F. megaauriculata*, *F. pallida*, and *F. ultrapedicellata*.

Members of the *F. funicularis* and *F. angustissi-*

Table 1. Species distribution in Timika (+ indicates presence, - absence).

No	Groups and species members	Type of forests	
		Disturbed	Primary
<i>Freycinetia angustissima</i> group			
1	<i>F. angustissima</i>	×	×
2	<i>F. pseudoangustissima</i>	×	×
3	<i>F. stenophylla</i>	×	×
<i>F. funicularis</i> group			
4	<i>F. funicularis</i>	×	×
5	<i>F. fusiforma</i>	-	×
6	<i>F. imbristigma</i>	-	×
7	<i>F. lateriflora</i>	-	×
8.	<i>F. magnoareola</i>	-	×
9	<i>F. pleurantha</i>	-	×
10	<i>F. rhodospatha</i>	-	×
11	<i>F. sterrophylla</i>	-	×
<i>F. oblanceolata</i> group			
12	<i>F. concolor</i>	×	×
13	<i>F. ellipsoidalis</i>	×	×
14	<i>F. forbesii</i>	×	×
15	<i>F. frutasolla</i>	-	×
16	<i>F. inermis</i>	×	×
17	<i>F. iriana</i>	-	×
18	<i>F. lenifolia</i>	×	×
19	<i>F. obtusiacuminata</i>	-	×
20	<i>F. oblanceolata</i>	-	×
21	<i>F. oreophila</i>	-	×
22	<i>F. rectangularis</i>	-	×
23	<i>F. scandens</i>	-	×
24	<i>F. tenuis</i>	-	×
<i>F. macrostachya</i> group			
25	<i>F. clavata</i>	-	×
26	<i>F. circuita</i>	-	×
27	<i>F. excelsa</i>	×	×
28	<i>F. fibrosa</i>	-	×
29	<i>F. frutaspiralica</i>	-	×
30	<i>F. frutonumerata</i>	×	×
31	<i>F. klossii</i>	×	×
32	<i>F. lacunculata</i>	×	×
33	<i>F. macrostachya</i>	×	×
34	<i>F. marginata</i>	×	×
35	<i>F. megaauriculata</i>	×	×
36	<i>F. pallida</i>	×	×
37	<i>F. pseudoinsignis</i>	-	×
38	<i>F. ultrapedicellata</i>	×	×

ma Groups grow in mountainous areas up to about 3000 meters altitude (Merrill and Perry, 1939) and are rarely seen in lower-lying areas, except around the Digul River in the vicinity of Merauke and in secondary forest at a Mod-ADA area close to the Aijkwa River, where *F. angustissima* and *F. poly-*

clada are found. In this current study it is assumed that these two species are originally montane but were distributed by river flows to much lower altitudes.

The result of the present study indicate that only in Timika the members of *F. angustissima* and *F.*

The Identification Key of Timika *Freycinetia*

- | | | |
|------|--|-------------------------------|
| 1a. | Inflorescence axillary or both axillary and terminal | 2 |
| 1b. | Inflorescence only arrangement in terminal | 3 |
| 2a. | Cauline and prophyll leaves not present, prophyll bract arrangement in 3 to more than whorls | 4 |
| 2a. | Cauline and prophyll leaves present, prophyll bract arrangement in 1 or 2 whorls | 11 |
| 3a. | Leaves arrangement imbricate, cauline leaves colored, the apex of exterior bracts not linear longest | 25 |
| 3b. | Leaves tufted, cauline leaves not present, the apex of exterior bracts linear longest | 23 |
| 4a. | Leaves have 2 kinds of leaves, the leaves on the middle to the apex are different from the leaves on the middle to the base stem | 11. <i>F. sterophylla</i> |
| 4a. | Leave have only 1 kind of leaves, the leaves on the middle to the apex are similar to the leaves on the middle to the base stem | 5 |
| 5a. | Leaves linear | 6 |
| 5b. | Leaves lanceolate, fusiform | 8 |
| 6a. | Leaves 12 -25 cm long, cephalia sub globose | 7. <i>F. lateriflora</i> |
| 6a. | Leaves more than 30 cm long, cephalia cylindrical | 7 |
| 7a. | Stigma 6 or more; stigma-areola imbricate | 6. <i>F. imbristigma</i> |
| 7b. | Stigma 1-3; stigma-areola not imbricate | 10. <i>F. rhodosphata</i> |
| 8a. | Cephalia obovoid to falcate or falcate; stigma 6-10 | 9 |
| 8b. | Cephalia cylindrical; stigma 14-18 | 9. <i>F. pleurantha</i> |
| 9a. | Areola cunneate centre, bear marginal stigma; leaves fusiform 10-15 cm long | 5. <i>F. fusiforma</i> |
| 9b. | Areola not cunneate centre; not bear marginal stigma; leaves lanceolate | 10 |
| 10a. | Small exterior bracts 5 levels, margin and apex spinulous; stigma hidden by areola; areola valvate wider than stigma, put on the surface berry | 8. <i>F. magnoareola</i> |
| 10b. | Small exterior bracts 8 levels, margin and apex not spinulous; stigma not hidden by areola; valvate bold areola on the centre | 4. <i>F. funicularis</i> |
| 11a. | Cephalia globose | 12 |
| 11b. | Cephalia oblong, cylindrical or others | 16 |
| 12a. | Leaves linear | 13 |
| 12b. | Leaves not linear | 14 |
| 13a. | Auricle narrower than base leaves; cephalia 1 numbers; stigma not put on the place that it looks like hole | 15. <i>F. frutasolla</i> |
| 13b. | Auricle wider than base leaves; cephalia more than 1, stigma put on the place that it looks like hole | 21. <i>F. oreophila</i> |
| 14a. | Leaves ovoid or gladiate; berry ovoid or widely obovoid, without wings; conjugation of base auricle in less than ¼ part | 15 |
| 14b. | Leaves oblong; berry obturbinate, has wings, conjugate of base auricle in ¼ part | 12. <i>F. concolor</i> |
| 15a. | Bracts 2 cm wide or less; cephalia 2 numbers; do not have areola bold until style | 19. <i>F. obtusiacuminata</i> |
| 15b. | Bracts 3-4 cm wide cephalia 1 numbers; areola bold covering until style | 18. <i>F. lenifolia</i> |
| 16a. | Cephalia oblong | 17 |
| 16b. | Cephalia cylindrical | 20 |
| 17a. | Auricle remain just fiber when falling, conjugation on base in ⅓ part; berries pyramidal, has style and wings; leaf gladiate, abaxial smooth; pedicle glabrous | 13. <i>F. ellipsoidalis</i> |
| 17b. | Auricle falling down together when falling, conjugation on base in ½ or more part; berries not pyramidal, without style and wings; leaf gladiate, abaxial smooth; pedicle glabrous | 18 |
| 18a. | Auricle triangular, falling down longitudinally, step by step; leaves oblanceolate | 20. <i>F. oblanceolata</i> |
| 18b. | Auricle tapered, falling down in all part together; leaves slightly elliptic or ensiform | 19 |
| 19a. | Cephalia 2; apex of berry not turning flat when mature; leaves slightly ellips berry obtrullate, black stigma wider than areola | 22. <i>F. rectangularis</i> |
| 19b. | Cephalia 3 rarely 4; apex of berry turning flat when mature, leaves ensiform; black stigma not wider than areola | 16. <i>F. inermis</i> |
| 20a. | Auricle wider than base leaf; leaves lanceolate; berries numerous | 14. <i>F. forbesii</i> |
| 20b. | Auricle not wider than base leaf; leaves oblong, gladiate or ensiform; berries rarely | 21 |

- 21a. Stigma wider than areola, about 3–4 (6) numbers, mature fruits orange; leaves has prophyll, auricle remain fibers when falling 17. *F. iriana*
- 21b. Stigma wider than areola, about 1–2 numbers, mature fruits red; auricle remain nothing when falling 22
- 22a. Pedicle smooth; auricle conjugation base in $\frac{1}{3}$ part; leaves gladiate 24. *F. tenuis*
- 22b. Pedicle hirsute; auricle conjugation base in $\frac{1}{6}$ part; leaves ensiform 23. *F. scandens*
- 23a. Leaves arranged tritichous looks rosette, tufted to the apex of the branchlet only; stigma smaller than areola 3. *F. stenophylla*
- 23b. Leaves arranged tritichous put along branch..... 24
- 24a. Leaves linear, longer about 10–30 cm long; auricle triangular, without longitudinal nerves; cephalia cylindrical, berries numerous, pyramidal 2. *F. pseudoangustissima*
- 24b. Leaves lanceolate, short about 5–10 cm long; auricle oblong deltoid, has 2 longitudinal nerves; cephalia oblongus, berries unnumerous, cylindrical 1. *F. angustissima*
- 25a. Inflorescence arrange umbel 26
- 25b. Inflorescence arrange raceme or spirally 27
- 26a. Auricle width 1cm; leaves 25–40 cm long; cephalia 4; areola widely on the transversal side 29. *F. frutaspiralica*
- 26b. Auricle width about 2.5–4 cm; leaves more than 100 cm long; cephalia 8–12; berries obtrullate, areola widely on the longitudinal side 30. *F. frutonumerata*
- 27a. Cephalia cylindrical 28
- 27b. Cephalia others 29
- 28a. Leaves longest, about 70 to 100 cm long 30
- 28b. Leaves short, about 10 to 50 cm long 32
- 29a. Cephalia longest, about 10 to 12 cm long 31
- 29b. Cephalia short about 0.5 to 5 cm long 34
- 30a. Auricle red bright, a half circular; berries fusion 3 - 4 berry; berry clavate; stigma irregular arranged looks like brocoli, numerous about 18 -32 numbers, bigger than areola 35. *F. megaauriculata*
- 30b. Auricle dark purple, truncate; without fusion berries; stigma regular dot 2 rarely 3 or 4, not bigger than areola 33. *F. macrostachya*
- 31a. Auricle longest, about 12-23 cm long; leaves lanceolate; pedicle not hirsute; stigma wider than berry, surface convex 34. *F. marginata*
- 31b. Auricle short, about 5-6 cm long; leaves linear; pedicle hirsute; stigma not wider than berry, surface not convex 33
- 32a. Auricle remain fibers; berry ellipsoid; stigma surrounding by flat areola 26. *F. fibrosa*
- 32b. Auricle not remain fibers; berry not ellipsoid; stigma surrounding by not flat areola 35
- 33a. Cephalia clavata, about 11–12 × 2.5 cm; berries stout segmenta; stigma 4–5 numbers rarely 9; auricle tapered, has 2 longitudinal nerveses, apex margin spinulous; length of leave about 45–55 cm 8. *F. clavata*
- 33b. Cephalia oblong, about 2.5 × 1–1.5 cm; berries not has stout segmenta auricle truncate, without 2 longitudinal nerves; length of leave about 70–90 cm 9. *F. circuita*
- 34a. Cephalia slightly globose to globose; lamina of the leaf is thin 36. *F. pallida*
- 34b. Cephalia slightly oblong or ellipsoid; lamina of the leaf not thin 37
- 35a. Cephalia about 2.5 by 0.5 cm; auricle slightly rounded, membranaceous, pale green, with 2 pale yellow longitudinal nerves; stigma 4 rarely 2,3,6,8 33. *F. ultrapedicellata*
- 35a. Cephalia about 3 by 1 or 4–5 by 3 cm; auricle truncated, not membranaceous, dark purple, without 2 pale yellow longitudinal nerves; stigma 1 or 2 rarely 3..... 36
- 36a. Berries rarely; stigma put on longitudinal side of the berry; leaves length about 20–30 cm 11. *F. excelsa*
- 36b. Berries numerous; stigma put on longitudinal side of the berry leaves about 30–50 cm long 17. *F. klosii*
- 37a. Cephalia ellipsoid, mature bright yellow; leaves without distinct spines; auricle slightly fibers, easy drying 32. *F. lacinulata*
- 37b. Cephalia oblong, mature orange–red; leaves with distinct spines; auricle without fibers, not easy drying 37. *F. pseudoinsignis*

funicularis Groups can be found in secondary forests. The same is found in the *F. oblanceolata* Group, where members of this group appear in Mod-ADA areas in both primary and secondary forests. Prior to the current study the members of these three groups were said to be entirely absent from the secondary forests of New Guinea; thus this is new information.

We believe that the relatively high level of rain-

fall in Timika creates more humid conditions (resulting in microclimatic changes) and as a consequence increases the level of organic materials in soil through the decomposition of fallen leaves and other plant parts, up to the level that can sustain the growth of species of *Freycinetia*. Thus, the presence of *Freycinetia* in the area where it was previously absent is caused through the improvement of a forest trilogy: climate, soil, and seed re-

sources.

Furthermore, the result of this study also shows that despite sharing montane habitats the *F. angustissima* and *F. funicularis* Groups differ in distribution areas. Members of *F. angustissima* Group are restricted to New Guinea, whereas members of *F. funicularis* Group are widely distributed from New Guinea further west to Sulawesi.

Freycinetia concolor is regarded in the current study as the only species that possesses the ability to inhabit open areas, an area that it shares it with the other shrubby dominant species, the robust grass *Phragmites karka*. *Freycinetia inermis*, *F. ellipsoidal*, *F. forbesii*, and *F. lenifolia* are found in secondary forest but all species here only found living under trees canopy except *F. inermis*, this species prefers hanging on the stem of the trees that are living at the marginal area of the secondary forest. Only one species can sustain life in the open, fully sunny areas, *i.e.* *F. concolor*.

Description of New Species

1. *Freycinetia circuita* Sinaga, A. P. Keim & Puradyatmika *spec. nov.* — Fig. 1

Frutex scandens foliis imbricatis, linearis, 70–90 cm longis, 2.5 cm basi latis, 1 cm apice latis; venis longitudinalibus adaxialis indistinctis, abaxialis dense striata; auriculis truncatis, 5 cm longis, 1 cm latis. Infructescentia terminalis, 3 spicis cylindricis; pedunculus 1 cm longis, 1 cm latis, pedicellis 30 mm longis, 5 mm latis. Fructus oblongus, 12 cm longis, 2–2.5 cm latis; bacca obtrulloidea, reliquiae stigmatorum circulares. — Type: *L. J. Brass 12967*, Indonesia, Papua, Timika, Idenburg (Holotype: BO!, Isotype: L!).

Slender climbing pandan, climbing up to 10 m, ascending on tree trunk. *Stem* terete, 1–2 cm diam., internodes 1–2 cm long. *Leaves* tristichous, imbricate, linear, 70–90 cm long, 1–2.5 cm wide, apex acuminate; adaxial surface green, slightly glaucous, with closely arranged longitudinal veins, 24–26 on ½ basal part of lamina, 2 indistinct pseudo-longitudinal veins, apical and middle part of lamina with bristles, bristles 5–8 mm long; abaxial surface green, glabrous; auricle truncate, 5 cm long, 2 cm wide. *Cauline leaves* consist of 2 whorls, coloring orange-red; basic cauline leaves linear, 50 by 4 cm; upper cauline leaves linear, 30 by 3–3.5 cm. *Male inflorescence* not observed. *Male flowers* not observed. *Bracts* consist of 3 whorls; outer bracts narrowest, ovate, 10 by 3 cm, outer surface closely terraces with shortly distinct transverse veins; middle bracts ovate, 6–7 by 3 cm; interior bracts lanceolate, fleshy. *Inflorescence* terminal, ternate; peduncle terete, 1 by 1 cm; pedicels semi-terete, 3 by 0.5 cm,

rachis to 10 cm long. *Cephalium* oblong, 12 cm long, 2–2.5 cm wide. Berries sparse; each obovoid, angular, indistinctly segmented; stigmatic remains circular, 1–2, surrounded by areola.

Distribution. Endemic to Papua.

Habitat and Ecology. In forest margins, occasional at 1100 m asl.

Etymology. With circular stigmatic remains.

Specimen examined. Indonesia, Papua, Timika, Idenburg, 1100 m asl, Feb. 1939, *L. J. Brass 12967* (BO, L).

Notes. The circular stigmatic remain is undoubtedly the most distinctive morphological character of *F. circuita* and it is unique to this species. Apart from this *F. circuita* very much resembles *F. aculeata*; however, the two species differ also in four more morphological characters described in Table 2.

2. *Freycinetia frutaspiralis* Sinaga, A. P. Keim & Puradyatmika *spec. nov.* — Fig. 2

Frutex scandens foliis imbricatis, lanceolatis, 25–40 cm longis, 1–2 cm latis. Venis longitudinalibus abaxialibus distinctis, venis transversalis brevi, grossis; adaxialibus tenellis. Auriculis gradatim angustatis, 3 cm longis, 1 cm latis, rubris. Infructescentia terminalis, spiratim, 3–4 spicis cylindricis et oblongis. Cephalia 2–5 cm longis, 1.5–2 cm latis. Bacca pyramidalis. Segmentibus distinctis, stigmatibus 3. — Type: *N. I. Sinaga 3437*, Indonesia, Papua, Timika, Kuala Kencana (Holotypus: MAN!, Isotype: BO!).

Slender climbing pandan, climbing up to 10 m, ascending on tree trunk. *Stem* terete, 1 cm in diam., internodes 1 cm. *Leaves* arrangement tristichous, imbricate, lanceolate, 25–40 cm long, 1 cm wide at base, 2 cm wide in middle, 1 cm wide near apex, spines distinct on the base, lamina glaucous beneath, apex cuneate to cuspidate; adaxial closely set indistinct longitudinal veins; abaxially closely set distinct longitudinal veins, 16 in each leaf half, with short transversal veins, looking rough; auricle tapered, 3 by 1 cm, bright red, transparent. *Prophyll leaves* in 2 whorls, lanceolate, 3 by 1 cm, reddish green. *Staminate flower* small, light orange to fairly pink; anther oblong, same length as filament. *Pistillate inflorescence* not observed. *Pistillate flowers* not observed. *Bracts* consist of outer, middle and inner bract. *Infructescentia* terminal, spirally arranged, with 4 cephalia; peduncle terete, 2 by 1 cm; pedicel semi-terete, 2–3 by 0.5 cm. *Cephalia* cylindrical to oblong, 2–5 by 1.5–2 cm;

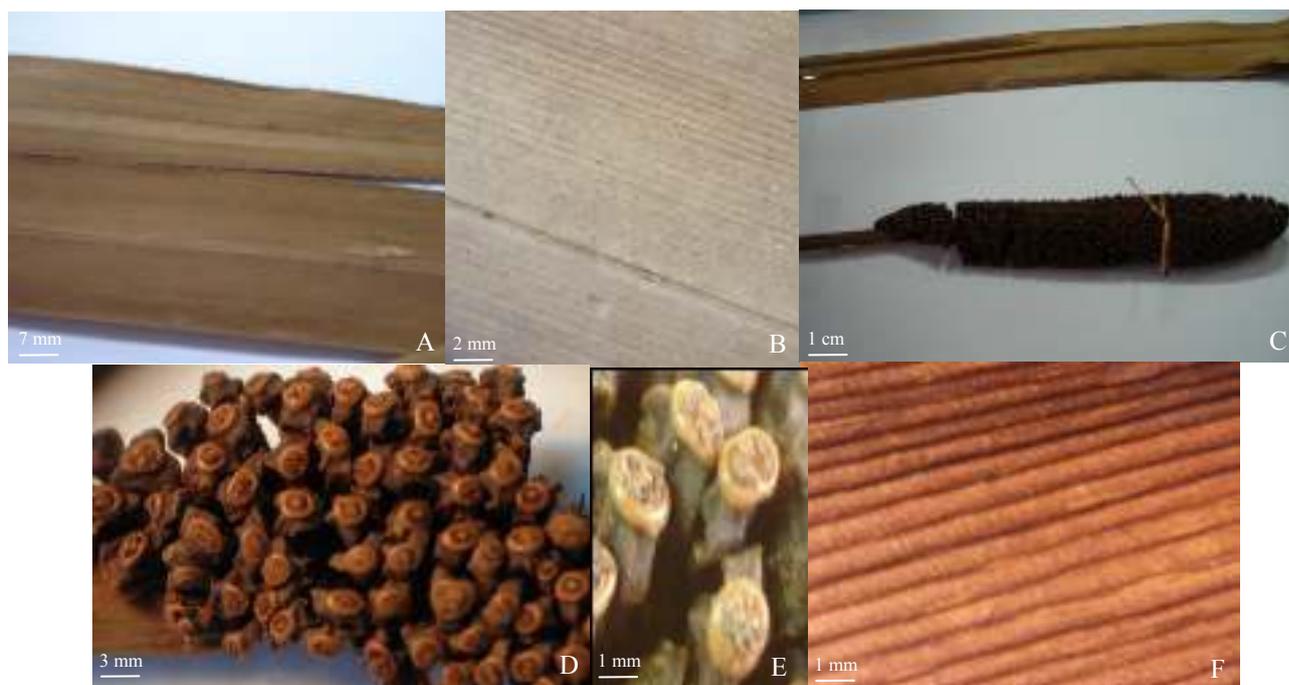


Fig. 1. *F. circuita*. A. Adaxial surface of leaf; B. Closely regular longitudinal nerves on abaxial leaf; C. The fruits; D. Berries with circular stigmas on the apex; E. Ring margin areola; F. Terraces bract with shortly transversal nerves.

Table 2. Morphological differences between *F. aculeata* and *F. circuita*.

Name of species	Shapes of leaves	Outer peduncular bracts	Diameter of pedicels	Length of cephalia	Shapes of stigmatic remains
<i>F. aculeata</i>	Linear	Glabrous when drying	3 mm	12 cm	Not circular
<i>F. circuita</i>	Lanceolate-elongate	Terraces when drying	5 mm	3–4 cm	Obviously circular

berry apex pyramidal, connate at the base, segments distinct, lacking a style; stigmas 3 on the flat area of pyramidal apex berry; areola thin, but some berries with widely transversal areola.

Distribution. Timika in southwestern mainland New Guinea and the island of New Britain.

Habitat and Ecology. Lowland tropical rainforests. Sometimes found climbing on betel nut palm (*Areca catechu*). The species is living on the sea level to 100 m asl.

Etymology. Spirally arranged infructescences, which is referred here as fruits.

Specimens examined. Indonesia, Papua, Timika, Kuala Kencana, 60 m asl, 14 Oct. 2005, *N.I. Sinaga* 3437 (MAN, BO); Papua New Guinea, New Britain, Salae, Hopkins, 100 m asl, 21 Dec. 1967, *M. Coode & R. J. Johns* 3584 (BO, K, LAE).

Notes. *Freycinetia frutaspiralica* shares the posses-

sion of conspicuous red auricles with *F. megaauriculata*; however, they are different in at least five characters (Table 3). *F. frutaspiralica* is straightforwardly distinct from *F. megaauriculata* in the size of auricle and the arrangement of inflorescences or infructescences. In New Guinea species with spirally arranged cephalia are extremely rare. So far this character is only shared with *F. arfakiana*, a species found in Manokwari.

3. Freycinetia frutonumerata Sinaga, A. P. Keim & Puradyatmika *spec.nov.* — Fig. 3

Frutex scandens foliis imbricatis, linearis, 100–110 cm longis, 6 cm latis basi, 2 cm latis apice. Venis longitudinalibus abaxialibus pseudolis, adaxialibus tenellis. Auriculis gradatim angustatis, 8–17 cm longis, 2–4 cm latis, purpureis. Infructescentia terminalis, cephalibus cylindricis 8–10; pedunculus 3 cm longis, 3 cm latis; pedicellis 4–5 cm longis, 5–7 mm latis. Fructus 8–12 cm longis, 2–3 cm latis. Baccarum apices pyramidalis; stigmaticis 2(1,3). — Type: *N. I. Sinaga* 3324, Indonesia, Papua, Timika, Kuala Kencana (Holotype: MAN!)



Fig. 2. *F. frutospiralica*. A. Adaxial surface of leaf; B. Abaxial surface of leaf; C. Leaves and auricle; D. Spirally arrangement of the fruits; E. The climbing plant with reddish green of prophyll leaf F. Berries with rarely widest of the margin areola.

Slender to stout climbing pandan, climbing up to 8 m. *Stem* terete, 2–3 cm in diam., internode 2 cm long. *Leaves* arrangement tristichous, imbricate, ascending, linear, internode between leaves 1–1.5 cm, more than 100 cm long, 6 cm wide at base, 2 cm wide at apex, conduplicate in basal part for 15–20 cm, apex caudate, margin with stout yellow spines; adaxially smooth; abaxial surface with pseudo-longitudinal veins, covered by white indumentum; auricle broadly tapered, half circular, 8–17 by 2–4 cm, dark purple, with longitudinal veins. *Staminate flower* light orange to pink; anther oblong. *Pistillate inflorescence* not observed. *Pistillate flowers* not observed. *Infructescence* terminal, spirally arranged, with 8–10 cephalia; peduncular bracts in 3 whorls: outer bract narrowly ovate, 10–12 by 3–4 cm, apex acuminate to caudate; middle bract cymbiform, 8–10 by 3 cm, apex acuminate; inner bract elongate, fleshy; peduncle terete, 3 by 3 cm; pedicel slightly terete, 4–5 by 0.5–0.7 cm; rachis 4–6 cm long. *Cephalia* cylindrical, or falcate, 8–12 by 2–3 cm; berries apex pyramidal, base slightly narrowly obconic, numerous, 4–5 segments, some berries connate, others separate; style very small; stigma discoid or semi-terete 2 (1) (3) numbers, surface flat to convex, areola surrounding each stigma; areola bigger than stigma.

Distribution. Timika in the southwestern part of Indonesian New Guinea and around East Kuanga in the Western Province of Papua New Guinea.

Habitat and Ecology. Lowland primary tropical rainforests. Living from 20 to 60 m asl.

Etymology. Numerous cephalia, which are referred here as number of fruits.

Specimens examined. Indonesia, Papua, Timika, Mod ADA PT. Freeport Indonesia, 20 m asl, 11 Oct. 2005, *N. I. Sinaga* 3324 (MAN); Papua New Guinea, Western, 40 Km NE of Kunga, 130 m asl, *Huynh* 66 (LAE).

Notes. *Freycinetia frutonumerata* possesses numerous cephalia, 8 to 10 per infructescence. This species shares the spirally arranged infructescences with *F. frutaspiralica* however, the two species differ in the number of cephalia, in which *F. frutonumerata* has conspicuously higher number (8–10 compared to 4).

4. *Freycinetia fusiforma* Sinaga, A. P. Keim & Puradyatmika *spec. nov.* — Fig. 4

Frutex scandens foliis semi-imbricatis, 18–40 cm longis, 2–2.5 cm latis, linearis, venis longitudinalibus distinctis adaxialis, striatis abaxialis cum venis transversalibus brevis. Infructescentia ternata, terminalis. Cephalia oblonga, bacca base oblongis, apice campanuliformis, segmentis distinctis 5, reliquiae stigmatorum 6, marginalibus, areolis punctis centris. — Type: *R. J. Johns & E. Wally* 10523 Indonesia, Papua, Timika, Tembagapura (Holotype: BO!, Isotype: L!, K! MAN!).

Table 3. Morphological differences among *F. frutaspiralica*, *F. megaauriculata* and *F. frutonumerata*.

Name of species	Prophyll length and width of leaves	Auricle	Inflorescence arrangement	Shape of ovary	Number of stigmas
<i>F. frutaspiralica</i>	Prophyll present; leaves 25-40 cm long; 1-2 cm wide	Dark red to purplish; 3 cm wide	Spiral	Prism	3
<i>F. megaauriculata</i>	Prophyll absent; leaves 80-110 cm long; 6-8 cm wide	Bright red; 3-5 cm wide	Umbel	Very clavate	18-32
<i>F. frutonumerata</i>	Prophyll absent; leaves > 100 cm long; 2-6 cm wide	Dark purple; 2-4 cm wide	Spiral	Obrtulloid	2 rarely 1 or 3

Slender climbing pandan, climbing up to 8 m. *Stem* terete, 1 cm diam.; internodes 1.5–2.5 cm, basal part without leaves, middle part with non-imbricate leaves, apical part with semi-imbricate leaves. *Leaves* ubulate, 10–15 cm long, 2–2.5 cm wide, fairly fleshy, apex cuspidate with minute spines, leaf margin with sparsely arranged brown spines, each 1 mm long, 0.5–1 cm distance; adaxial surface green, glabrous, with distinct longitudinal veins and short transverse veins; auricle tapered, reddish green, membranaceous, 2–3 cm long, 0.5–1 cm wide, with 3 longitudinal veins on basal $\frac{1}{3}$ part. *Prophyll bracts* in 4 whorls, reddish orange: in 3 whorls each narrowly ovate, 1–2 cm long, 1 cm wide, cuspidate apex, margin with minute spines; in apical whorl widely ovate, 2 cm long, 1.5 cm wide, with caudate apex. *Staminate inflorescence* interfoliar, lateral, ternate; pedicel 3 cm long, 0.5 cm wide; male flowering part light orange to fairly pink, 4 cm long, 1.5 cm wide. *Staminate flower* small, light orange to fairly pink; anther oblong, same length with filament. *Pistillate inflorescence* not observed. *Pistillate flowers* not observed. *Infructescence* terminal, ternate; peduncular bracts in 3 whorls, deep reddish orange: Outer bract widely ovate, 3 cm long, 2 cm wide, cuspidate apex, margin with minute spines; middle bract widely ovate, 4 cm long, 3 cm wide, cuspidate apex, margin with minute spines; inner bract lanceolate-elongate, 2 cm long, 1 cm wide, fleshy; peduncle terete, 1 cm long, 0.5 cm wide; pedicel scabrous, 20 mm long, 3 mm wide, with small canals (canaliculi); rachis slightly falcate

or oblong, 10 mm long, 4 mm wide. *Cephalium* fairly globose to falcate, 1.5–2 cm long, 1.5 cm wide. *Berry* lanceolate-elongate, 5 mm long, basal ovary oblong, apical bell-shaped, concave, segments not obvious; stigmatic remains irregular, 6, marginal; areola cuneate, in 5 parts, giving the appearance of central corolla.

Distribution. Endemic.

Habitat and Ecology. Grows in primary forest at 2500 to 2900 meters altitude. Commonly found in the transition from Mid-montane *Nothofagus*-dominated to upper montane forests.

Etymology. Fused form, which refers to the fusion of stigmatic remains and areolas.

Specimens examined. Indonesia, Papua, Timika, Tembapapura, 2500–2900 m asl, 24 Apr. 2000, R. J. Johns & E. Wally 10523 (BO, K, L, MAN); 3275 meter asl, 25 Nov. 2000, E. J. Lucas 46 (MAN).

Notes. The fused stigmatic remains and areolas form undoubtedly the most distinctive morphological character of this species. So far this phenomenon has never been recorded in other species. *Freycinetia fusiforma* closely resembles *F. sterrophylla*. Nevertheless, they differ in the leaves, margin of prophyll bracts, shape of ovary, shape of cephalia, and stigmatic remains & areola (Table 4).



Fig. 3. *F. frutonumerata*. A. Fruits on the terminal; B. Ascendent leaves; C. Adaxial leaf; D. Oblong and falcate fruit; E. Purple dark auricle; F. Berries and stigmas.

5. ***Freycinetia imbristigma*** Sinaga, A. P. Keim & Puradyatmika *spec. nov.* — Fig. 5

Frutex scandens foliis semi-imbricatis, 50–55 cm longis, 2–3 cm latis, linearis. Infructescentia ternataaxillaris. Pedunculi teretia, 4 cm longis, 2 cm latis; pedicelli 45–50 mm longis, 3 mm latis. Cephalia cylindrica; bacca conjunctionis ovarii, segmentis distinctis 5, stigmatismbricatis, marginalis 4, areolis punctis centris. — Type: *Meijer Drees 656*, Indonesia, Papua, Timika (Holotype: BO!, Isotype: L!).

Medium climbing pandan, climbing up to 8 m high with leafless stem, no climbing roots observed, basal part of climbing stem also leafless and no climbing roots seen. *Stem* terete, 2 cm diam., internodes 2.5–5 cm long. *Leaves* semi-imbricate on apical part of stem, moderately so on middle part, less in basal part; lamina lanceolate, 50–55 cm long, 2–3 cm wide, apex and margin with minute spines, apex acuminate; adaxial surface green, glabrous, with distinctly longitudinal veins, 16–17 on $\frac{1}{2}$ basal part of lamina; abaxial surface green, fairly glabrous, with indistinct longitudinal veins; auricle tapered, 4–5 cm long, 1 cm wide. *Prophyll bracts* in 8 whorls, individual bracts cymbiform, 1–4 cm long, 1–2.5 cm wide, apex acuminate, margin with minute spines. *Male inflorescence* lateral on leafless stem, ternate, flowering part cylindrical. *Male flowers* not observed. *Pistillate inflorescence* not observed. *Pistillate flowers* not observed. *Infructescentia* terminal; peduncular bracts in 3 whorls; outer bracts ovate, 4 cm long, 4 cm wide, apex acuminate, margin entire; middle broadly ovate, 8–11 cm long, 4–5 cm wide, apex acuminate, margin entire;

inner bracts lanceolate-elongate, 3 cm long, 2 cm wide, fleshy; peduncle terete, 4 cm long, 2 cm wide; pedicel triangular, 45–50 mm long, 3–5 mm wide, hirsute. *Cephalium* cylindrical to oblong, 8–10 cm long, 2–3 cm wide. *Berries* sparse; each transversally oblong, fused, distinctly segmented; stigmatic remains 6, centrally arranged, wider than areolas; areola circular, encircling stigmatic remain, stigmatic remains and areola imbricately arranged.

Distribution. Endemic.

Habitat and Ecology. Commonly found inhabiting the primary forests.

Etymology. Imbricate stigmatic remains that refers to the imbricate arrangement of stigmatic remains and areolas.

Specimens Examined. Indonesia, Papua, Timika, *Meijer-Drees 656* (BO, L).

Notes. *Freycinetia imbristigma* is morphologically similar to *F. funicularis*, but differs in at least four morphological characters: The presence of fused ovaries that forms the characteristic oblong transversal berry, and the imbricate arrangement of stigmatic remains and areolas; also the shape of prophyll bracts, and shape & length of pedicel (Table 5).

6. ***Freycinetia magnoareola*** Sinaga, A. P. Keim & Puradyatmika *spec. nov.* — Fig. 6

Frutex scandens foliis semiimbricatis, lanceolatis, 20–30 cm longis, 2–3 cm latis. Venis longitudinalibus distinctis abaxialis paginalis, minutes adaxialis paginalis. Infructescentia teretea axillaris. Fructus oblongis, 4–6 cm longis, 2–3 cm latis. Bacca campanuliformis; stigmatibus celatis 5–6 (8–10), areolis magnis. — Type: *H. D. Hoogland 4794* Papua New Guinea, Northern District, Tufi, Korea (Holotype: BO!).

Medium to fairly large climbing pandan, climbing up to 10 m high; climbing with leafless stem, no climbing roots observed. Stem terete, 2–3 cm diam., sturdy, internodes 4 cm. Leaves concentrated on middle to apical parts of branches; semi imbricate on apical and middle parts of stem, not imbricate on basal part; lamina elongate-

Table 4. Morphological differences between *F. fusiforma* and *F. sterrophylla*.

Name of species	Leaves	Margin of prophyll bracts	Shape of ovary	Shape of cephalia	Stigmatic remains & areola
<i>F. fusiforma</i>	1 kind: apex and base are same about 10–15 cm long; fusiform shape	Glabrous	Bell shape	Falcate	Areolas cuneate accumulate on centre surrounding stigmas
<i>F. sterrophylla</i>	2 kinds; apical ones longer than basal; apical 30–40 cm compare to 15–20 cm; linear shape	Spinulose	Cylindrical	Globose	Areola irregular surrounding longitudinal stigma



Fig. 4. *F. fusiforma*. A. The fusiform leaves; B. Sharp spine along margin; C. Abaxial lamina with slightly distinct longitudinal nerves and shortly transversal nerves; D. Adaxial lamina with distinctly longitudinal nerves; E. The auricle that conjugate base along one third; F. Prophyll bracts; G. Axillary infructescence with pedicle longer than cephalia; H & J. Falcate cephalia; I. Berries; K. Stigma on the margin and areola on center.

lanceolate, 20–30 cm long, 1–4 cm wide; apex fairly acuminate, 2 cm long, with minute spines; adaxial surface green, glabrous, with distinct longitudinal veins, 12 on $\frac{1}{2}$ basal part of lamina, veins on middle part with bristles; abaxial surface green, glabrous, with pseudo-longitudinal nerves; auricle tapered, 30–40 mm long, 5 mm wide. *Prophyll bracts* in 5 whorls, arranged regularly, triangular, each 1–3 cm long, 1–3 cm wide, apex and margin with minute spines, cuspidate. *Male inflorescence* not observed. *Male flowers* not observed. *Pistillate inflorescence* not observed. *Pistillate flowers* not observed. *Infructescence* lateral, intrafoliar, ternate; peduncular bracts in 3 whorls: outer bracts boat-shaped, red, 6 cm long, 5 cm wide, apex caudate, with minute spines; middle bracts lanceolate-elongate, red, 9 cm long, 5 cm wide, apex caudate, with minute spines; inner bracts lanceolate-elongate, 4 cm long, 2 cm wide, deep red, fleshy; peduncle terete, 3 cm long, 3 cm wide; pedicel semi-terete, 60 mm long, 3 mm wide, covered by hairs in one line, longer than ra-

chis. *Cephalium* obovoid and sometimes slightly curved, 6–8 cm long, 2–3 cm wide. *Berries* few; each bell-shaped, formed by a fusion of 6–10 ovaries, distinctly segmented; stigmatic remains 5–10, totally covered by the large areola; areola obvious, large, robust, central, transversally and longitudinally widespread.

Distribution. This species is assumed here to have a disjunct distribution. One location is within the Mamberamo Basin in the northern central part of Indonesian New Guinea and the other is in the south-eastern part of mainland Papua New Guinea.

Habitat and Ecology. Grows on swamp forests on the 0 to 50 m asl.

Etymology. Large areola, which refers to the large size of the areola.

Specimens examined. Indonesia, Papua, Timika,



Fig. 5. *F. imbristigma*. A. Hirsute pedicle and transversally oblong berry that is built by fusion some berries; B. Leaves: apex acuminate; C. The infructescence on the stemless with remain prophyll bracts to about 2 prophylls on the base and ternate cylindrical cephalia on the apex; D. The imbricate arrangement of the stigma-areola.

Table 5. Morphological differences among *F. imbristigma*, *F. funicularis* and *F. magnoareola*.

Name of species	Shape of prophyll bracts	Shape & length of pedicel	Shape of cephalia	Shape of berry	Fusion of areola - stigmatic remains
<i>F. imbristigma</i>	Cymbiform	Triangular	Cylindrical	Transversally oblong	Imbricate
<i>F. funicularis</i>	Ovate	Semi-terete	Cylindrical to falcate	Cylindrical	Arranged closely in common
<i>F. magnoareola</i>	Triangular	Semi-terete	Obovoid to falcate	Bell shape	Areola hiding stigmas

Benhard Camp, 50 m asl, 8 Aug. 1908, *Meijer-Drees 482* (BO); Papua New Guinea, Northern District, Tufi, Koreaf, sea level, 23 Sept. 1954, *H. D. Hoogland 4794* (BO).

Notes. *Freycinetia magnoareola* possesses a conspicuous large areola that entirely covers the stigmatic remains. In fact *F. magnoareola* possesses the largest areola known in the genus. This species also has the distinctive bell-shaped berry that is formed through the fusion of 6 to 10 ovaries. These two morphological characters distinguish this species from *F. funicularis*, which in the field might look similar in appearance to *F. magnoareola*. These two species also have prophyll bracts that are different in shape (Table 5).

7. *Freycinetia ultrapedicellata* Sinaga, A. P. Keim & Puradyatmika *spec. nov.* — Fig. 7

Frutex scandens foliis imbricatis, linearis, 10–20 cm longis, 1 cm latis. Venis longitudinalibus, adaxialis

tenellis. Infructescentia terminalis, cephalibus cylindricis; pedunculus 20 mm longis, 5 mm latis; peduncellis 30 mm longis, 3 mm latis. Fructus 25 mm longis, 5 mm latis. Bacca obtrulloidea; stigmatibus 4 (8). — Type: *N. I. Sinaga 3997* Indonesia, Papua, Timika, Kuala Kencana (Holotype: MAN).

Small climbing pandan, hanging on the tree trunk. *Stem* terete, 1 cm in diam., internodes 1 cm long, grey. *Leaves* imbricate, linear, 10–20 cm long, 1 cm wide or less; lamina, smooth, thin; sharp yellow spines at the basal margin and median margin; adaxial surface with pseudo-regular longitudinal veins; abaxial surface with indistinct longitudinal veins, 4 per half leaf; auricle slightly rounded, 2 by 0.3 cm, membranaceous, pale green, with 2 pale yellow longitudinal veins and shortly transverse veins. *Cauline leaves* before bracts, in 2 whorls. *Male inflorescence* not observed. *Male flowers* not observed. *Pistillate inflorescence* not observed. *Pistillate flowers* not observed. *Infructescence* terminal, of 2 cylindrical cephalia, green; peduncular bracts in 3 whorls:

Table 6. Morphological differences in the length of leaves & number of abaxial longitudinal veins, shape of auricle, length of pedicel, berry, and number of stigmatic remains between *F. ultrapedicellata* and *F. excelsa*.

Name of species	Length of leaves & number of abaxial longitudinal veins	Shape of auricle	Length of pedicel	Berry	Number of stigmatic remains
<i>Freycinetia ultrapedicellata</i>	10 - 20 cm long; 4 on a half leaves	Slightly rounded	Longer than fruits (3:2)	Obtrulloid, have wings	4 (2,3,6,8)
<i>F. excelsa</i>	20 - 30 cm long; 7-8 on a half leaves	slightly truncated	As long as fruits (3:3)	Slightly cylindrical without wings	2 (3)

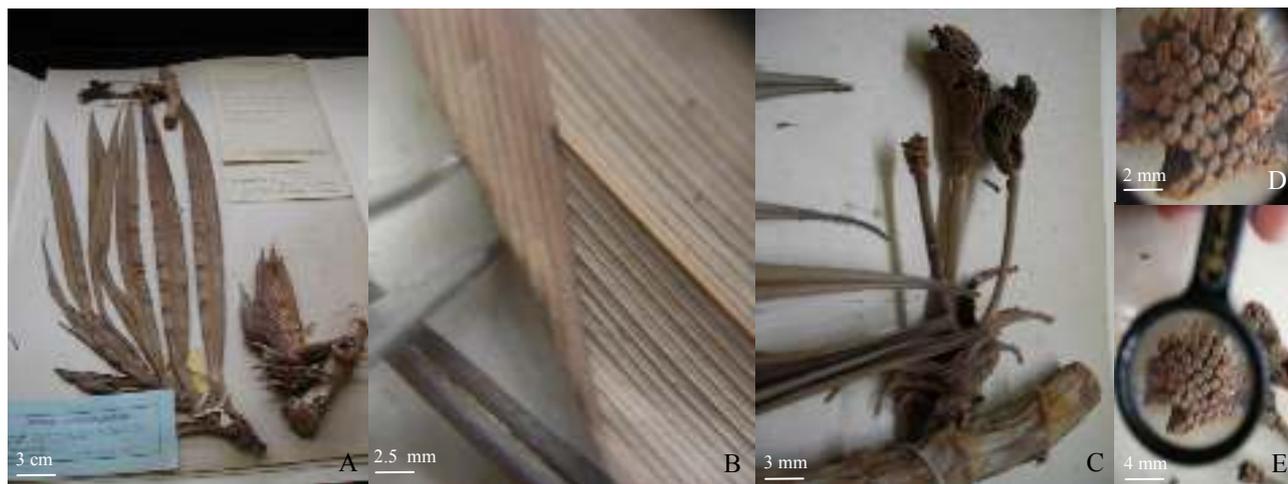


Fig. 6. *F. magnoareola*: A. Lanceolate leaves with aristate apex; A1. Prophyll bracts to about 15 prohylls below and bracts above: exterior bracts smaller than middle one, apex cuspidate. B. Abaxial leaf have regularly distinct nerves; C. The infructescence on leafless stem with pedicle that is longer than cephalia; D. Hidden stigmas, just areola that appears on the surface berry; E. Berries.

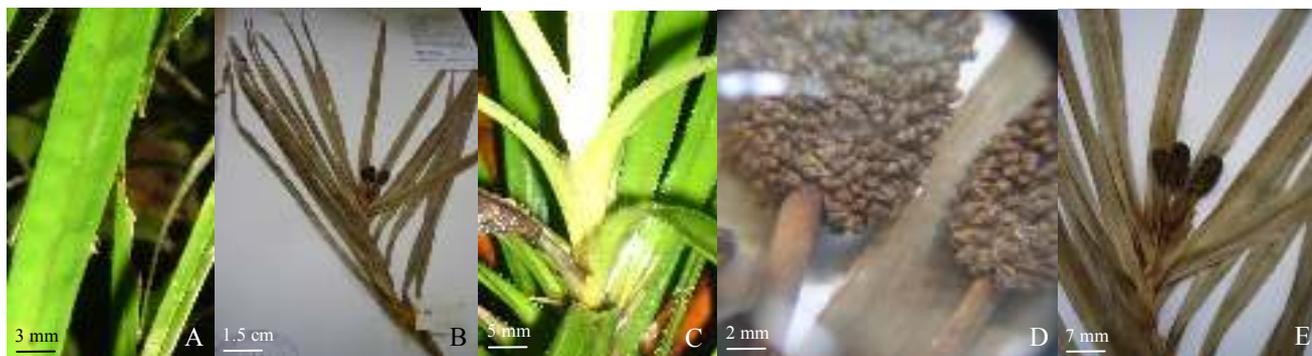


Fig. 7. *F. ultrapedicellata*: A. The thin leaves; B. Leaves; C. The Transparent auricle; D. Berries; E. Small oblong fruits.

exterior bracts ovoid, 3 by 1 cm, apex cuspidate; middle bracts ovoid, 3 by 0.5 cm; interior bracts fleshy when mature; peduncle terete, 2 by 0.5 cm; pedicel terete, 3 by 0.3 cm, covered by hirsute indumentum. *Cephalia* cylindrical, 2.5 by 0.5 cm, green; berries separate; berry obtrulloideus segments stout, with wings; stigmas 4 (2, 3, 6, 8), discoid, surrounded by a bold circular areola.

Distribution. Timika in the southwestern part of Indonesian New Guinea and Lae area in Morobe, Papua New Guinea.

Habitat and Ecology. Lowland primary tropical rainforests (start from sea level to 100 m asl).

Etymology. Long pedicel, which refers to the relatively long pedicel that is the same length as rachis.

Specimens examined. Indonesia, Papua, Timika,

Kuala Kencana, 40 m asl, 30 Nov. 2005, *N. I. Sina-ga* 3997 (MAN); Papua New Guinea, Morobe, Lae, 26 Jun. 1999, *Billy Bau* LAE 82978 (LAE).

Notes. In *Freycinetia* the pedicel is usually shorter than the rachis. The same length of pedicel and rachis so far is only recorded in this species. *Freycinetia ultrapedicellata* also possesses a unique auricle, in which the auricle is slightly rounded, quite small (20 × 3 mm), transparent, light yellow with 2 fairly long longitudinal and short transversal nerves. *Freycinetia ultrapedicellata* is regarded here as having a close affinity with *F. excelsa* but it differs from the latter mainly in the leaves, type of auricles, length of pedicels, berries and stigmatic remains (Table 6).

CONCLUSION

Species of *Freycinetia* found in Timika have ex-

ceptional morphological characters and ecological preferences. These characters are commonly found in the *F. macrostachya* and *F. funicularis* Groups, where *Freycinetia frutonumerata* possesses the highest number of cephalia per infructescence known for the genus *Freycinetia*, while *F. magnoareola* has the largest areola. Unique ecological preferences are observed in the *F. macrostachya* and *F. oblanceolata* Groups. *Freycinetia concolor* so far is the only species known in New Guinea to successfully inhabit open areas rather than closed forest. Species that inhabit secondary forests include *F. excelsa*, *F. frutonumerata*, *F. klosii*, *F. lacinulata*, *F. megaauriculata*, *F. palida*, and *F. ultrapedicellata*.

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Bibliography, list of literature cited or references follow the Harvard system.

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