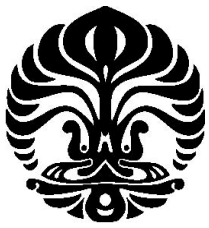

UNIVERSITAS INDONESIA

THE BIOSYSTEMATIC STUDY OF *ENDIANDRA* R.BR. (*LAURACEAE*) IN NEW GUINEA

DISERTASI

DEBY ARIFIANI
0706220940

FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM
PROGRAM STUDI BIOLOGI
PROGRAM PASCASARJANA
DEPOK
JANUARI 2012

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DISERTASI

Diajukan sebagai salah satu syarat untuk memperoleh gelar Doktor dalam bidang Biologi

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FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM
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SUMMARY

Endiandra R.Br. is a genus consisted of more than 100 tree and shrub species that are distributed in Asia and Australia with several species found in Pacific Islands (Rohwer 1993). New Guinea and Australia are the most-rich areas of *Endiandra* with approximately 50 species and 38 species respectively. Unlike Australian *Endiandra* which have been treated thoroughly, the New Guinean species are less known and difficult to recognize. No recent research was done for *Endiandra* from New Guinea since over four decades ago where materials for a revision of *Lauraceae* was prepared by Kostermans in 1969. Moreover, based on observation on the specimens, New Guinea is thought to be the main distribution area of *Endiandra*, therefore it is important to undertake a taxonomic treatment of New Guinean *Endiandra*.

During observation of herbarium specimens of *Endiandra*, it is noted that the flowers of *Endiandra* are composed by different floral parts. Staminal glands located nearby the stamens can be present or absent in different species. It is noted that all species of *Endiandra* from Borneo bear no staminal glands at the base of the stamens, however 31 out of 38 species of Australian *Endiandra* do bear glands. It is important to know the variation of New Guinean species in terms of the presence of glands because the character might be useful for further categorization within *Endiandra*.

Based on the facts above, the study of the genus *Endiandra* was carried in three related topics. The first topic entitled Species enumeration of *Endiandra* R.Br. (*Lauraceae*) in New Guinea. This study was carried out at the Herbarium Bogoriense (BO) using *Endiandra* specimens available at BO and recently collected specimens from Waigeo Island. Loan specimens from Singapore Botanic Gardens (SING) were also studied, including images of type specimens

from The Natural History Museum, London (BM); National Botanic Garden of Belgium (BR); Harvard University Herbaria, Massachusetts (HUH); Royal Botanic Gardens, Kew (K); Nationaal Herbarium Nederland, Leiden (L); Muséum National d'Histoire Naturelle, Paris (P); and Smithsonian Institution, Washington, D.C. (US). Forty six species of *Endiandra* are recognized from New Guinea, with discovery of six new species, i.e., *Endiandra areolata*, *E. crassitepala*, *E. cupulata*, *E. kassamensis*, *E. lanata* and *E. rifaiana*. It is noted that 36 species are endemic to New Guinea, distributed in both West Papua and Papua New Guinea. Ten species are distributed further to the West up to Celebes, Moluccas and to the Southeast in Australia. Most New Guinean species of *Endiandra* bear staminal glands in their flowers, only eight species lack of glands. To understand the importance of staminal glands for creating grouping within *Endiandra*, the second and third topics were carried out in this study.

The second topic entitled The phylogenetic relationships of New Guinean species of *Endiandra* and *Beilschmiedia* (*Lauraceae*) based on morphological characters. The study was aimed to understand the relationships among *Endiandra* species in New Guinea, the distribution of species with and without staminal glands in the cladogram and to understand the relationships of *Endiandra* and *Beilschmiedia*. Selected morphological characters from the study of Topic 1 were analyzed to understand the relationships of *Endiandra* species. Fifty taxa, consisted of 41 species of *Endiandra*, 6 species of *Beilschmiedia* (as in-groups) and 3 species of *Cryptocarya* (as outgroups) with 47 characters were analyzed using Maximum Parsimony method and resulted in 86 most parsimonious trees. Even though the species with staminal glands are grouped together in clades I, II, III, IV and VI, the species with and without staminal glands are grouped together in clade V. Therefore, in this study, the grouping within *Endiandra* based on the presence and absence of staminal glands was not well supported. Moreover, *Endiandra* and *Beilschmiedia* are forming their own clades, suggesting the two genera are monophyletic based on morphological characters. Stamen number and position in the floral whorls determined the generic delimitation between the two genera. *Endiandra* has 3 or 6 stamens in the 3rd whorl or 2nd and 3rd whorls (respectively), whereas *Beilschmiedia* has 9 or 6 stamens in the 1st, 2nd and 3rd whorls or 1st and 2nd whorls (respectively). However, characters selection is

subjective, which different characters used for the phylogenetic analysis will result in different grouping. Therefore, finding new characters that are reliable for grouping is needed, and phylogenetic analysis using those characters are suggested to be carried out to improve the knowledge on the species relationships of *Endiandra*.

The third topic entitled Phylogenetic relationships of *Endiandra* R.Br. (*Lauraceae*) inferred from ITS regions of nrDNA sequences was aimed to understand the relationships among *Endiandra* species and between *Endiandra* and *Beilschmiedia*. Molecular data of ITS region of nrDNA sequences was explored for the first time to understand the phylogenetic relationships of *Endiandra*. Thirty one species of *Endiandra* and *Beilschmiedia* were analysed, including 7 species of *Cryptocarya* used as outgroups. The parsimony analysis of the ITS sequences of nrDNA has resulted in 108 equally parsimonious trees. One of most parsimonious trees suggested that *Beilschmiedia* cannot be separated from *Endiandra* which explained the difficulty of distinguishing the two based on morphology. The staminal glands distributed in the lower clades of the tree, left the terminal clade with a group of glandless species with an exception of *E. monothyra* B. Hyland. Staminal gland is a good character for practical purpose but the grouping based on the present and absence of stamina gland is not well supported by the ITS sequences of nrDNA. Improving the resolutions of the cladogram for more reliable interpretations of the species relationships within *Endiandra* is suggested by adding more samples and introducing more suitable markers.

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Author

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GENERAL INTRODUCTION

Endiandra R.Br. is one of the genera within *Lauraceae* or laurel family, one of the important components of primary and secondary lowland forests. The genus consists of trees and are mainly found in Asia and Australia with several species distributed in Pacific Islands. Thirty eight species of *Endiandra* occurred in Australia (Hyland 1989), and more species are distributed in New Guinea based on the observation of specimens from the island.

Economically, species of *Endiandra* are important source of woods. In Australia, the species produce woods that are utilized by local people. The people recognized the species as Walnut, such as Rose Walnut (*E. cowleyana* Bailey), Brown Walnut (*E. glauca* R.Br.), Pink Walnut (*E. sieberi* Nees), and Queensland Walnut (*E. palmerstonii* (Bailey) C. White). Among those species, Queensland Walnut has produced the best quality of wood, used mainly in high quality furniture production. Other Walnuts produce large logs used for furniture, panelling and wood flooring.

Taxonomically, *Endiandra* consists of over 100 species which can be recognized by these characters: paniculate inflorescence in which the ultimate cyme not strictly oppposite, bisexual flowers, stamens 3 (rarely 2 or more than 3) with 2 locules of anthers, and fruits free on receptacles. *Endiandra* is grouped together with the genera *Beilschmiedia* Nees, *Potameia* Thouars, *Cryptocarya* R.Br. and *Triadodaphne* Kosterm. based on the inflorescence type above in the tribe *Cryptocaryeae* (Werff & Richter, 1996). Vegetatively, *Endiandra* is very close to *Beilschmiedia* which consists of about 250 species and has pantropical distribution. The two genera can only be separated by observing flowering specimens. Typical flowers of *Endiandra* has 3 stamens, whereas *Beilschmiedia* has 9 stamens (Rohwer 1993). Therefore, it is rather difficult to determine to the correct genus without a flowering specimen.

Taxonomic treatment of *Endiandra* has been done for several areas in Malesian regions and Australia. The most recent account was the Bornean species, eight species were reported from Borneo (Arifiani 2001). The taxonomic account of Australian *Lauraceae* was completed in 1989, included 38 species of

Endiandra (Hyland 1989). Backer & Backhuizen (1963) recognized one species of *Endiandra* in Java, i.e., *E. rubescens* and Kochummen (1989) reported 10 species of *Endiandra* from Malay Peninsular. The species of *Endiandra* in New Guinea have not been studied and at the same time, New Guinea is tought to be the main distribution of *Endiandra* with high number of species. Kostermans (1969) had prepared the materials of *Endiandra* for a revision but the complete account has not been finished. Taxonomic study on *Endiandra* from New Guinea was carried out to understand morphological variation within the species from New Guinea. The species enumeration of *Endiandra* in New Guinea was carried out at the Herbarium Bogoriense (BO) using materials from BO, Singapore Botanic Gardens (SING) and images of type specimens from The Natural History Museum, London (BM); National Botanic Garden of Belgium (BR); Harvard University Herbaria, Massachusetts (HUH); Royal Botanic Gardens, Kew (K); Nationaal Herbarium Nederland, Leiden (L); Muséum National d'Histoire Naturelle, Paris (P) and Smithsonian Institution, Washington, D.C. (US).

Morphological variation of vegetative and floral characters within *Endiandra* has created the diversity of the species. At present, there is no grouping within *Endiandra* based on the presence and absence of glands although the different states of glands occurred in the species of *Endiandra*. Therefore, analysis of all morphological characters were carried out to understand the species relationships within *Endiandra* and to understand characters that are important to establish further grouping within *Endiandra*. At the same time, *Beilschmiedia* were included in the analysis to test the monophyly of *Endiandra*. All characters included in the cladistic analysis were collected during taxonomy study of *Endiandra* in New Guinea.

For similar purposes, the phylogenetic relationships analysis of *Endiandra* was done using the ITS sequences of nrDNA that has been used widely in phylogenetic studies of many flowering plants. The ITS nrDNA region possess a higher degree of variation than chloroplast DNA and it is proven useful for elucidating relationships among closely related species and genera (Baldwin *et al*. 1995). ITS is a rapidly evolving genomic non-coding regions that is chosen for this study because it has been proven to be useful in resolving phylogenetic

relationships of difficult and controversial taxa such as in *Oleaceae* (Besnard *et al.* 2009) and *Isatis* **(**Moazzeni *et al*. 2010). Additionally, ITS sequences have been used previously for inferring phylogenetic relationships in other genera of *Lauraceae* (*Litsea*: Li *et al*. 2004; *Neolitsea*: Li *et al*. 2007; *Persea*: Rohwer *et al*. 2009), therefore it is expected that this region will also be informative for inferring phylogenetic relationships within the genus *Endiandra*.

TOPIC 1

SPECIES ENUMERATION OF *ENDIANDRA* R.BR. (*LAURACEAE*) IN NEW GUINEA

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ABSTRACT

Species of *Endiandra* in New Guinea have not been studied completely whereas the island is one of the distribution center of the genus. This study was aimed to record the species of *Endiandra* occurring in New Guinea and how variable are their morphology. Recent collections of *Endiandra* from Waigeo Island and other collections available at BO and from SING were studied morphologically. Type specimens from BM, BR, HUH, K, L, P and US were also studied using images provided by the respective herbaria. Notes for each character states of the herbarium specimens were collected and used to assign the specimens to the appropriate species. Circumscriptions for each species were deliniated and key to the species was formulated. This study showed that New Guinea housed 46 species of *Endiandra*, including six newly described species, i.e., *E. areolata* Arifiani, *E. crassipetala* Arifiani, *E. cupulata* Arifiani, *E. lanata* Arifiani, *E. kassamensis* Arifiani, and *E. rifaiana* Arifiani. There were 36 species recorded as endemic to New Guinea from this study, distributed in both West Papua and Papua New Guinea. Other species were distributed further West in Celebes (*E. papuana*), Moluccas (*E. asymmetrica*, *E. beccariana*, *E. forbesii*, and *E. rifaiana*) and up to the Southeast in Australia (*E. glauca*, *E. hypotephra*, *E. impressicosta*, *E. dielsiana* and *E. montana*). Important characters of the species in New Guinea are described and illustrated.

Keyword(s): Characters, *Endiandra*, New Guinea, species description

1. INTRODUCTION

Endiandra R.Br. is a genus within the laurel family, which represents important components of primary and secondary lowland forests. The genus

consists of trees and are mainly found in Asia and Australia with several species distributed in Pacific Islands. Taxonomically, *Endiandra* consists of over 100 species which can be recognized by the paniculate inflorescence in which the ultimate cyme are not strictly oppposite, bisexual flowers with 3 stamens (rarely 2 or more than 3) having 2 loculated of anthers, producing fruits which are free on receptacles. *Endiandra* was first described by Robert Brown (1810) and is currently grouped together with the genera *Beilschmiedia*, *Potameia*, *Cryptocarya* and *Triadodaphne* in the tribe *Cryptocaryeae* (Werff & Richter 1996). Vegetatively, *Endiandra* is very close to *Beilschmiedia* and both can only be separated by observing flowering specimens. Typical flower of *Endiandra* has 3 stamens, whereas *Beilschmiedia* has 9 stamens. Based on vegetative specimens, it is rather difficult to assign a specimen to the correct genus. Therefore, misidentification frequently occurred and lead to critical problems for further research. Misidentification will lead to wrong interpretation of the respective research results. A correct species name is required for further research such as research on species bioprospectings for medicines and study on species relationships.

Taxonomic studies of *Endiandra* have been done for several areas in Malesian regions and Australia. Malesian regions is also known as Malay archipelago and strecthes from southern part of Thailand, to Malaysia and Indonesia up to the Philippines and Papua New Guinea (Steenis 1950). The taxonomic account of Australian *Lauraceae* was completed in 1989, including 38 species of *Endiandra* (Hyland 1989). Unlike Australian *Endiandra* that have been studied thoroughly, Malesian *Endiandra* have not been completely studied. Only the species of *Endiandra* from Malay Peninsular, Borneo and Java have been reported with ten, eight and one species of *Endiandra*, respectively (Kochummen 1989, Arifiani 2001, Backer & Backhuizen 1963), however, species enumeration of *Endiandra* have not been reported from other areas in Malesian regions. New Guinea is the largest island in the Malesian regions and the second largest island in the world, which has highest diversity of plant species and endemic plant species within Malesia (Welzen *et al*. 2005). However, it is unfortunate that the species of *Endiandra* from New Guinea is poorly studied. The only known report

on New Guinean *Endiandra* was done by Kostermans (1969) who prepared materials of *Endiandra* from New Guinea for a bigger framework project of family revision (*Lauraceae*). Kostermans' study also indicated that New Guinea has many species of *Endiandra*, therefore New Guinea is a strategic place to explore the diversity of *Endiandra*. Based on the facts mentioned above, it is important to undertake a taxonomic study of *Endiandra* from New Guinea. Moreover, this study will advance our future work for Flora Malesiana taxonomic treatment. The aims of the study were 1) to record species of *Endiandra*, including the distribution in New Guinea, 2) to understand morphological variation within the species and 3) to create description for each species and species identification key.

2. MATERIALS AND METHODS

2.1 Materials

Herbarium specimens used for this research consisted of collections of *Endiandra* available at BO and recently collected samples from Waigeo Island. Loan specimens from SING were also examined. In addition, images of type specimens from BM, BR, HUH, K, L, P and US were also studied. In total, there were 378 sheets of herbarium specimens were observed, consisted of 335 sheets of specimens from BO, 33 sheets from SING and 10 sheets from Waigeo Island. Images of type specimens observed were 132 images.

2.2 Methods

2.2.1 Sampling location

Herbarium collection for this study was carried out in Waigeo Island (Raja Ampat) in June 2007 (Figure 1.1).

2.2.2 Sampling and samples treatment

Sampling method used was purposive random sampling, in which sampling localities were randomly selected by considering factors that influence the existence of *Endiandra* in the forest, such as low latitude forests (Rohwer 1993).

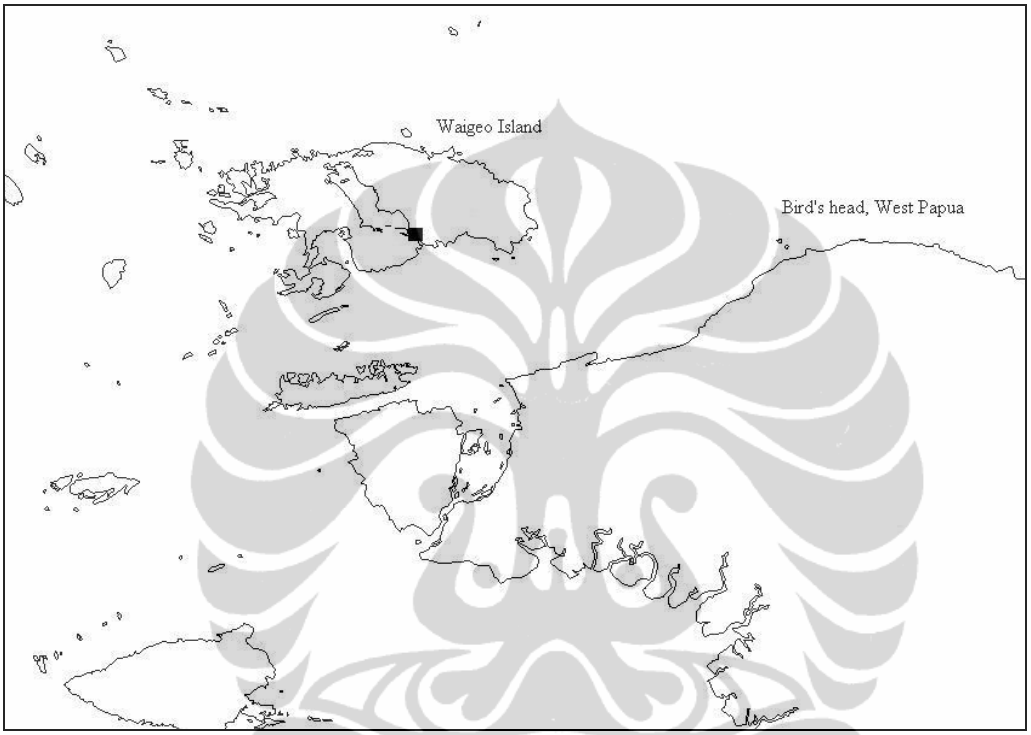

Figure 1.1. Sampling location of *Endiandra beccariana* (■) in Waigeo Island

Research in the area of taxonomy and biodiversity requires plant samples as proof of the research (Rugayah *et al.* 2004). Plant samples were obtained by collecting herbarium specimens. Leafy branches that are in flower or in fruits were collected and numbered to make herbarium specimens. Standardized plant collecting procedure followed method of Balgooy (1987). Information on qualitative characters of the plants that will be dissappear after herbarium processing were noted. Such information are color, fragrance, leaf texture, flowers opening, and also local names and uses when was available. Pictures were taken to document the life specimens. The specimens were later wrapped with old newspapers, piled and squeezed between two corrugated aluminum board and wood *sasak*. Then the pile specimens were strapped and dried in the electric

oven for about 3 days. Dried specimens were then mounted on the herbarium sheets including its label. Specimen labels contained information about the specimens, including species name, family name, collector, collector number, locality, local name, and notes gathered in the collecting process. Before storing the mounted specimens to the herbarium cabinets in the collection rooms, the specimens were kept in the freezer for 2 days. The specimens were ready for identification, which was done mainly by comparing the recently collected herbarium with the type specimens available at BO.

2.2.3 Species Enumeration

All specimens of *Endiandra* from New Guinea including recently collected specimens, loan specimens from SING and type specimen images were gathered for the species enumeration study, following methods of Rifai (2011). Firstly, identification of each specimens was done to verify that each of them are belong to the genus *Endiandra* by checking floral characters such as trimerous, bisexual flowers with 6 tepals and 3 or 6 stamens. At the same time, references about *Endiandra* including references for all scientific names used were collected. Secondly, grouping the specimens based on the vegetative characters such as leaf arrangement, reticulation and indument on leaf, twig and inflorescence surfaces were done for species reidentification by comparing them with the type specimens.

Specimens characterization were done to collect morphological data by observing the characters of all specimens in each group under the microscope (Table 1.1). All measurements, the number and states of the characters were noted including their position, color, fragrance, texture, density and shapes. All measurements are for dried specimens or as otherwise stated. Methods and botanical terms used followed Veldkamp (1987). After that, checking the characters observed in the present study were done and correlated them with those of in previous research in order to assign groups of specimens to a discrete taxon.

The next step was to solve nomenclatural problems and assign a valid name to each group. Then, descriptions for each species were created, including information on distribution, habitat and ecology, and notes on the specific characters important for the taxon. Identification key to the species was then created using characters from the species descriptions.

The next step was putting labels (both hanging and mount labels) for each taxon according to the name decided from this research. Illustrations of new species or important characters for publication were also prepared.

Table 1.1. Characters observed in the taxonomic study (Kostermans 1957, Rohwer 1993)

No.	Plant parts	Characters
1	Habit	height; width
2	Twig	color; indument type, orientation and density
3	Terminal bud	indument; shape; size
4	Leaf	arrangement; texture
5	Leaf blade	shape; size; apex; base; surface
6	Midrib	texture
7	Lateral veins	number; angle
8	Minor venation	reticulation density
9	Petiole	shape; indument; length
10	Inflorescence	type; position; length; indument
11	Pedicel	indument; length
12	Bract	shape; size
13	Receptacle	depth; indument
14	Tepal	opening; shape; size; indument
15	Stamens	number; shape; indument; size
16	Glands	number; shape; indument; size
17	Staminodes	number; shape; indument; size
18	Pistil	shape; indument; length
19	Fruit	shape; size

3. RESULTS

3.1 Result of sampling

Two specimens of *Endiandra beccariana* Kosterm. were collected near Warsamdin village, Teluk Mayalibit subdistrict, Waigeo Island, at the altitude of 120 m and 50 m above sea level (DA 596 and DA 652, respectively).

3.2 Species Enumeration

Based on the observation on 378 sheets of herbarium specimens of BO collection and 132 type specimen images, there are forty six species of *Endiandra* recorded from New Guinea, including six new species. The new species of *Endiandra* found in New Guinea are *E. areolata* Arifiani, *E. crassitepala* Arifiani, *E. cupulata* Arifiani, *E. lanata* Arifiani, *E. kassamensis* Arifiani, and *E. rifaiana* Arifiani.

In this study, five species of *Endiandra* are categorized as imperfectly known species because of several reasons. *Endiandra albiramea* Kosterm. and *E. spathulata* Kosterm. are considered imperfectly known because each was described from a single sterile specimen. *Endiandra ferruginea* Teschner, *E. oblonga* Teschner and *E. teschneriana* are placed in imperfectly known species for the time being until more specimens available for the study.

In the present study, *E. acuminata* Teschner (1923) is sunk in *E. asymmetrica* Teschner because the priority of the epithet goes to *E. acuminata* C.White & Francis (1920). *E. asymmetrica* accommodates other species such as *E. clemensii* Allen, *E. brassii* Allen and *E. formicaria* Kosterm.

The species of *Endiandra* in New Guinea are distributed from the Northwest part in Raja Ampat island, Indonesia to the Southwest part in Kokoda village area of Papua New Guinea (Figure 1.2), with some species are distributed further West in Celebes (*E. papuana*) and up to the Southeast in Australia (*E. dielsiana*, *E. glauca*, *E. hypotephra*, *E. impressicosta* and *E. montana*). Based on

this study, the species of *Endiandra* in New Guinea are mainly endemic to the region except of the six species above and several other species (*E. asymmetrica*, *E. beccariana*, *E. forbesii*, and *E. rifaiana*) that distributed up to Moluccas and Aru Island, which gave total of 36 endemic species.

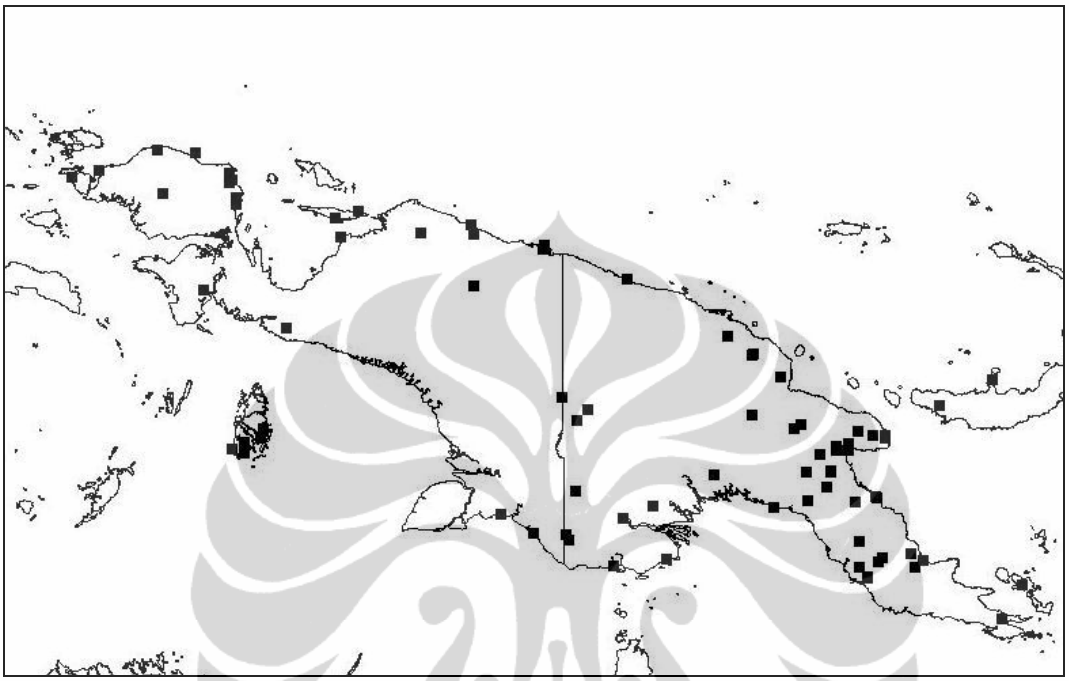

Figure 1.2. Species distribution of *Endiandra* in New Guinea

The species of *Endiandra* occurred generally in lowland forests (from 0 – 600 m above sea level) and the number of species will decrease at higher altitude in montane forest (above 1000 m, Figure 1.3).

3.3 Morphological characterization of Endiandra in New Guinea

Forty six species of *Endiandra*, including six undescribed species were recorded from New Guinea based on the morphological characterization of 378 sheets of specimens consisting of collections of BO, SING, recently collected specimens and images of type specimens from BM, BR, HUH, K, L, P and US. The evaluation of vegetative and floral characters of the species of *Endiandra* in New Guinea are presented below.

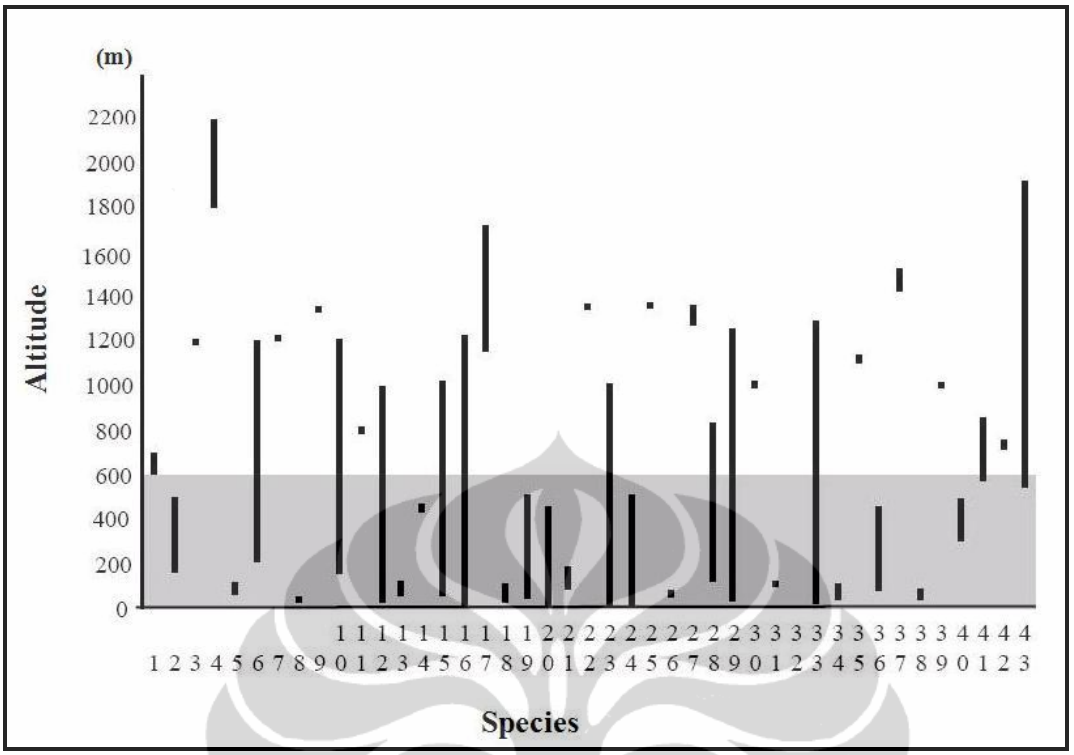

Figure 1.3. Altitude distribution of *Endiandra* species in New Guinea, 1. *E. aggregata*, 2. *E. archiboldiana*, 3. *E. arfakensis*, 4. *E. aurea*, 5. *E. beccariana*, 6. *E. carrii*, 7. *E. crassipetala*, 8. *E. cupulata*, 9. *E. cyphellophora*, 10. *E. dielsiana*, 11. *E. djamuensis*, 12. *E. engleriana*, 13. *E. euadenia*, 14. *E. faceta*, 15. *E. flavinervis*, 16. *E. forbesii*, 17. *E. fulva*, 18. *E. gem*, 19. *E. gemopsis*, 20. *E. glauca*, 21. *E. grandifolia*, 22. *E. havelii*, 23. *E. hypotephra*, 24. *E. impressicosta*, 25. *E. inaequitepala*, 26. *E. invasorium*, 27. *E. kassamensis*, 28. *E. lanata*, 29. *E. latifolia*, 30. *E. ledermannii*, 31. *E. macrostemon*, 32. *E. magnilimba*, 33. *E. montana*, 34. *E. multiflora*, 35. *E. oviformis*, 36. *E. papuana*, 37. *E. pilosa*, 38. *E. rifaiana*, 39. *E. schlechteri*, 40. *E. sericea*, 41. *E. sleumeri*, 42. *E. versteeghii*, 43. *E. xylophylla*

3.3.1 Indument

Indument is an important character for delimiting and identifying species of *Endiandra*. The presence or absence state of hairs on the vegetative parts, inflorescences and floral parts may be used to expedite the identification process to a proper species. The species of *Endiandra* from New Guinea vary from having dense, sparse indument to glabrous in their parts. When indument is present, it may covered twigs, terminal buds, petioles, leaves, inflorescences, or flowers, including floral parts. Dense pubescence on twigs and lower leaf surface can be used as indicators of the presence of indument in other parts. If the twig is densely pubescent, lower leaf surface is usually also pubescent, together with petiole,

inflorescence, flowers and floral parts. On the contrary, if twigs are glabrous, the rest of plant parts are usually glabrous. Apart from hair density that covers the surface, pubesence in New Guinean *Endiandra* can be categorized based on its orientation (appressed or erect), based on its length (long: 3-6 mm, short: 1-2 mm) and based on its straightness (straight, wavy or curly) (Figure 1.4).

Upper parts (young parts) of the plant are usually covered densely by indument that may stay pubescent when get older or becoming glabrous. However, it is noted that terminal buds and inflorescence stalks of *Endiandra* in New Guinea are pubescent and stay pubescent when get older. Only few species in New Guinea have their terminal buds are glabrous or covered very sparsely with minute hairs, i.e., *E. carrii* Kosterm. *Endiandra carrii* has somewhat glabrous terminal buds but some parts are thinly covered by dark yellow crust. Inflorescence stalks of New Guinean *Endiandra* are generally covered by dense or sparse hairs, but *E. dielsiana* Teschner have nearly glabrous inflorescences.

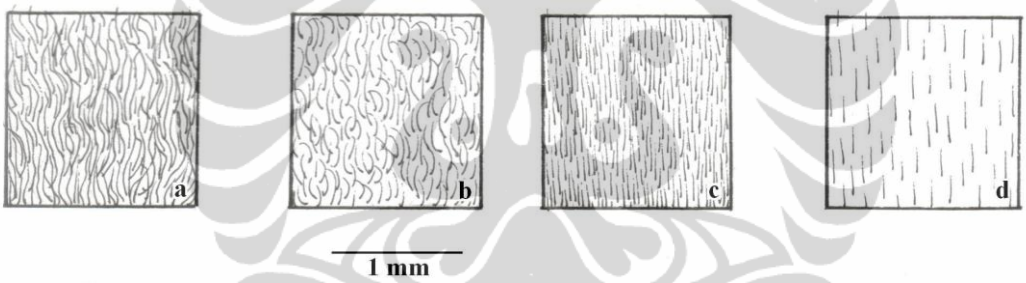

Figure 1.4. Indument types on lower leaf surface. a. wavy hairs (*Kairo NGF44085*); b. curly hairs (*Hoogland 4919*); c. dense short straight hairs (*Royen NGF20161*); d. sparse short straight hairs (*Brass 13198*)

Flowers are following the inflorescences in their indument, outer surfaces of tepals are clothed with same hairs as inflorescences. Inner surfaces of tepals of most *Endiandra* species are covered with long curly or wavy hairs, especially the triangular patch in the basal part. The triangular patches are formed by the anthers that are squeezed inside the tepals. However, there are seven species that have glabrous inner surface of tepals, i.e, *E. arfakensis* Kosterm., *E. crassitepala* Arifiani, *E. euadenia* Kosterm., *E. flavinervis* Teschner, *E. gemopsis* Kosterm., *E. invasorium* Kosterm. and *E. lanata* Arifiani. Therefore, glabrousness of tepal inner surface is considered as useful character in distinguishing these seven species from the rest, that have indument in their outer surface of tepals.

3.3.2 Leaves

The leaves are alternately arranged, subopposite or slightly clustered. Most species of *Endiandra* in New Guinea are with alternately arranged leaves, however in some species, the alternate leaves become subopposite or slightly clustered near the tip of each twig.

Petioles are mostly slender but *E. grandifolia* Teschner, *E. latifolia* Kosterm., *E. magnilimba* Kosterm. and *E. xylophylla* Kosterm. have stout petioles. The petioles can be flat to canaliculate in upper surface.

Leaf blade ranges from chartaceous to stiffly coriaceous, and from lanceolate, elliptic, obovate to rounded with various leaf size (5.5-9 x 2-3.6 cm in *E. glauca* to 23-42 x 13.5-24 cm in *E. grandifolia*). Most species in New Guinea have elliptic leaf blades, obovate and rounded leaf shapes are few (such as *E. aggregata*, *E. latifolia* and *E. minutiflora*).

Leaf venation is useful to delimit species because it is stable within a species. The appearance of leaf veins on the leaf surfaces (raised, immersed, or impressed) and pattern of lateral and minor venation (fine or coarse) are important, and those can be seen in *E. areolata* Arifiani which has conspicuously prominent minor venation and in *E. impressicosta* Allen, which has immersed minor veins (Figure 1.5).

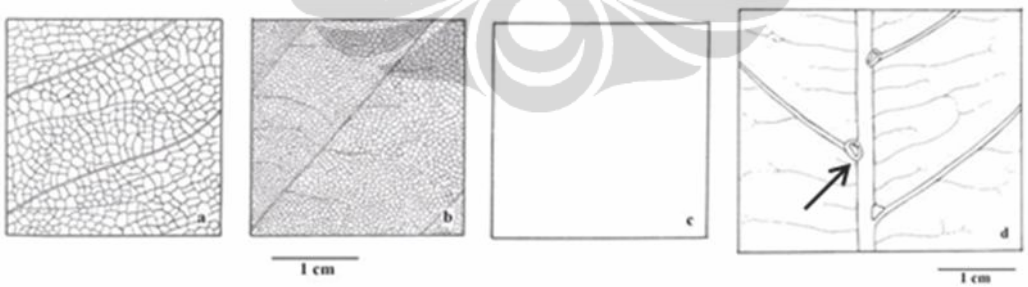

Figure 1.5. Leaf minor venation/reticulation and domatia, a. coarse (*Streimann NGF47811*), b. fine (*Reksodihardjo 238*), c. smooth/immersed (*Brass 8224*), d. domatia (*Hoogland 8947*)

Domatia are present on the lower leaf surfaces of *E. schlechteri* Teschner and *E. faceta* Kosterm. and situated between midrib and lateral veins. Leaf domatia are small chambers that house ants or mites (Figure 1.5).

3.3.3 Inflorescences

The inflorescences of the New Guinean *Endiandra* species are generally paniculate with ultimate divisions not strictly opposite. However, in *E. gemopsis*, the inflorescence becomes somewhat spicate and in *E. glauca*, the inflorescence is racemose. The inflorescences of *Endiandra* in New Guinea vary in length from very short (up to 3 cm long) to very long (5 to 30 cm) and in the number of flowers from few to many.

Inflorescence bracts are caducous in most species, but in some species the bracts still persist at anthesis. The species with persistent bracts are *E. aggregata* Kosterm., *E. gemopsis*, and *E. grandifolia* have large bracts (6-12 mm long); *E. aurea* Kosterm., *E. cupulata* Arifiani, *E. glauca*, *E. hypotephra* F.Muell., *E. invasorium* Kosterm., *E. lanata* Arifiani, *E. latifolia* Kosterm., *E. minutiflora* Kosterm., *E. pilosa* Kosterm., *E. schlechteri* Teschner, and *E. sericea* Kosterm. have small bracts (up to 3 mm long).

3.3.4 Flowers

The flowers of *Endiandra* in New Guinea are trimerous, bisexual and ranges from white, cream, pale yellow, pale green to pale brown. The species of *Endiandra* are usually not scented but it is reported that *E. cupulata* Arifiani and *E. impressicosta* have nice fragrant. The flowers are small ranges from 1.5 mm to 8 mm in diameter, and tepals can be erect, half-erect, or spreading (Figure 1.6).

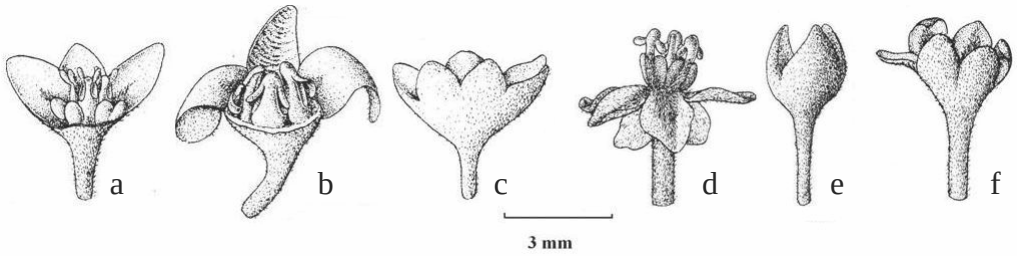

Figure 1.6. Variation of flower opening. a & c. Half-erect (*Endiandra pilosa*), b. Spreading (*E. impressicosta*), d. Spreading (*E. rifaiana*), e. Erect (*E. areolata*), f. Erect (*E. kassamensis*)

Regular floral parts consist of 3 stamens, with or without the presence of glands or staminodes (figure 1.7). Glands are 3 pairs, each pair flanks the stamen or glands can be united forming ring-like appendages, surround the stamens such that the anthers protrude from the center of the ring-like gland. Some exception occur in species of *Endiandra* in New Guinea, for example, *E. montana* C.White has 6 instead of 3 stamens, positioned in the second and third whorls. The outer 3 at the second whorl are bigger than the inner ones at the third whorl. The absence of glands in *Endiandra* is usually followed by the absence of staminodes, except in *E. crassitepala* Arifiani and *E. kassamensis* Arifiani which bear no glands in their flowers but have 3 staminodes.

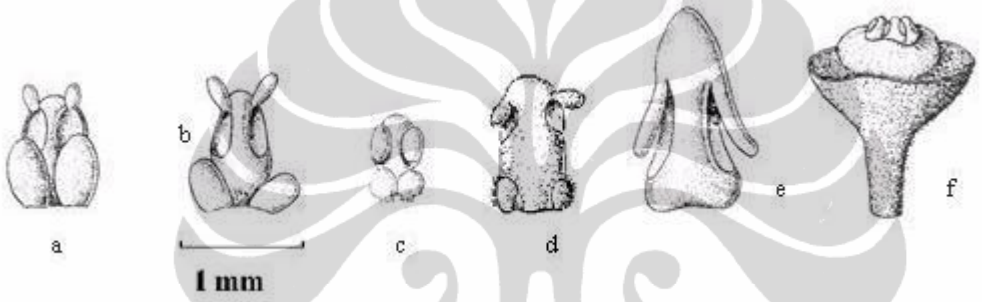

Figure 1.7. Variation of stamens in *Endiandra* species a-d. with separate glands, e. without glands, f. fused glands. (a). *Endiandra grandifolia* (b). *E. pilosa* (c). *E. archiboldiana* (d). *E. areolata* (e). *E. impressicosta* (f). *E. lanata*

3.3.5 Fruits

The fruits are mostly ellipsoid, but some are globose, ovoid, oblong or obovoid. *Endiandra montana* and *E. papuana* Lauterb. have globose fruits; the fruits of *E. grandifolia* and *E. havelii* are oblong; and *E. hypotephra* has obovoid fruits. Most fruits of *Endiandra* are freely seated on pedicels, but persistent tepals occur in *E. hypotephra* and *E. havelii* Kosterm. at the base of the fruits (Figure 1.8).

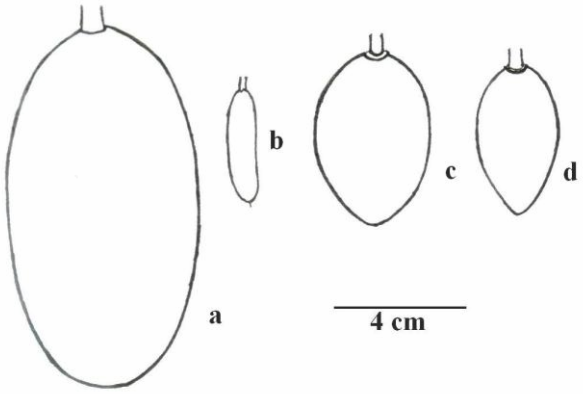

Figure 1.8. Fruit shapes, a. ellipsoid (*E. magnilimba, White NGF10270*), b. oblong (*E. flavinervis, Havel & Kairo NGF15488*), c. subglobose (*E. oviformis, Streimann NGF47811*), d. ellipsoid (*E. impressicosta, Brass 8224*)

The morphology of the *Endiandra* species in New Guinea vary greatly so that it is difficult to properly divide all species into groups based on certain combination of characters. However, two groups can be recognized informally based on the absence and presence of glands; and beyond those groups, lower level categories based on gland arrangement and minor leaf venation can be recognized:

1. Non staminal glands group includes *E. crassitepala*, *E. cyphellophora*, *E. djamuensis*, *E. faceta*, *E. impressicosta*, *E. inaequitepala*, *E. kassamensis*, and *E. macrostemon*.
2. Staminal glands group, divided into two group:
   a. Fused glands, fine reticulation group includes *E. beccariana*, *E. euadenia*, *E. flavinervis*, *E. forbesii*, *E. gemopsis*, *E. glauca*, *E. hypotephra*, *E. invasorium*, *E. papuana*, and *E. lanata*.
   Fused glands, coarse reticulation group includes *E. arfakensis*.
   b. Separate glands, fine reticulation group includes *E. archiboldiana*, *E. clemensii*, *E. engleriana*, *E. fulva*, *E. gem*, *E. grandiflora*, *E. latifolia*, *E. rifaiana*, *E. sericea*, *E. sleumeri*, and *E. xylophylla*.
   Separate glands, coarse reticulation group includes *E. aggregata*, *E. areolata*, *E. carrii*, *E. cupulata*, *E. dielsiana*, *E. ledermannii*, *E. minutiflora*, E. *montana*, *E. multiflora*, *E. pilosa*, and *E. schlechteri*.

Because not all New Guinean *Endiandra* in this treatment were in flower, these groupings have not incorporated all the species of *Endiandra* in New Guinea.

They are found to be very useful for immediate categorization in the species identification.

3.4 Key to the Species of *Endiandra* from New Guinea

3.4.1 For flowering materials

1a. Staminal glands absent 2
b. Staminal glands present 9
2a. Minor leaf venation obscure (smooth) or finely reticulate 3
b. Minor leaf venation coarsely reticulate 4
3a. Leaf apex acute; minor venation obscure (smooth) ..... **26. E. impressicosta**
b. Leaf apex acuminate; minor venation fine ..... **13. E. djamuensis**
4a. Inflorescences up to 25 cm; ovary pubescent ..... **27. E. inaequitepala**
b. Inflorescences less than 13 cm; ovary glabrous 5
5a. Leaf domatia present, infundibuliform ..... **11. E. cyphellophora**
b. Leaf domatia absent 6
6a. Twig whitish; petioles flat above ..... **16. E. faceta**
b. Twig dark-colored; petioles canaliculate above 7
7a. Lower leaf surface papillose, base attenuate; staminodes absent .....
..... **33. E. macrostemon**
b. Lower leaf surface glabrous, base cuneate; staminodes present 8
8a. Tepals thick, hard, glabrous inside ..... **9. E. crassitepala**
b. Tepals thin, soft, with curly hairs inside ..... **29. E. kassamensis**
9a. Fertile stamens 6 ..... **36. E. montana**
b. Fertile stamens 3 10
10a. Glands fused 11
b. Glands separate, basal 21
11a. Inflorescences spicate, bracts > 6 mm long; flowers erect .... **21. E. gemopsis**
b. Inflorescences paniculate, bracts ≤ 3 mm long, or caducous; flowers spreading 12

12a. Flowers small, 3-3.5 mm in diameter ……...…… 13
b. Flowers larger, 4-8 mm in diameter ……..... 15
13a. Petioles flat above; each pair of glands adnate to the filament; staminodes present ……..……...….. **28. E. invasorium**
b. Petioles canaliculate above; 3 pairs of glands connate forming ring-like appendage; staminodes absent ……..…….…….. 14
14a. Lower leaf surface shiny, glabrous ……...…..... **4. E. arfakensis**
b. Lower leaf surface glaucous, with appressed hairs ……...……. **22. E. glauca**
15a. Twigs, petioles and lower leaf surface with curly hairs ……..… **30. E. lanata**
b. Twigs, petioles and lower leaf surface glabrous or with straight hairs ……. 16
16a. Twigs densely pubescent; petioles flat above ..……...…… 17
b. Twigs sparsely pubescent or glabrous; petioles canaliculate above ……... 18
17a. Minor leaf venation raised above; tepals glabrous outside ... **7. E. beccariana**
b. Minor leaf venation obscure (smooth) above; tepals with dense curly hairs outside ……..…….…….. **39. E. papuana**
18a. Twigs whitish; minor leaf venation slightly immersed …..… **15. E. euadenia**
b. Twigs brown; minor leaf venation prominent ……....……..…….. 19
19a. Leaf blade large, 18-25 x 6-10 cm, base attenuate; lateral leaf veins 12-14 pairs …...…..…… **18. E. forbesii**
b. Leaf blade smaller, 9-17 x 3-5.5 cm, base cuneate; lateral leaf veins 6-10 pairs ……...… 20
20a. Lateral leaf veins flat above; inflorescences up to 16 cm long, with dense curly hairs; tepals with dense curly hairs outside ……..... **17. E. flavinervis**
b. Lateral leaf veins slightly impressed above; inflorescences 1-6 cm long, with dense erect hairs; tepals with sparse or dense erect hairs outside …… …… **25. E. hypotephra**
21a. Lower leaf surface glabrous ……..…… 22
b. Lower leaf surface densely or sparsely pubescent ……...……..... 32
22a. Minor leaf venation finely reticulate ……..…….. 23
b. Minor leaf venation coarsely reticulate ……..……..…… 27
23a. Lateral leaf veins thread-like, obscured by minor leaf venation ….……. 24
b. Lateral leaf veins obvious …….……... 25

24a. Leaf base cuneate; inflorescences glabrous ……..…..…..... **14. E. engleriana**

b. Leaf base attenuate; inflorescences covered with curly long hairs …..…….

……... **19. E. fulva**

25a. Twigs with appressed hairs; leaf blade chartaceous ……...…...… **20. E. gem**

b. Twigs glabrous; leaf blade subcoriaceous or coriaceous ……..……..…. 26

26a. Leaf blade subcoriaceous, base obtuse; tepals subequal ……...……

…….. **2. E. archiboldiana**

b. Leaf blade coriaceous, base cuneate; tepals equal ……. **5. E. asymmetrica**

27a. Twigs hollow ……..…….. 28

b. Twigs solid ……..…… 29

28a. Leaf blade obovate; petiole 2-2.5 cm; minor leaf venation prominent above; inflorescences 9-12 cm long …… **1. E. aggregata**

b. Leaf blade rounded; petiole 1.2-1.5 cm; minor leaf venation immersed, smooth above; inflorescences 2-2.5 cm long ….....…… **35. E. minutiflora**

29a. Leaves slightly clustered, base attenuate …...……..……. 30

b. Leaves single, base cuneate ……..…… 31

30a. Leaves stiffly coriaceous, broadly elliptic or rounded; lateral leaf veins thread-like, obscured by minor leaf venation ……...…… **3. E. areolata**

b. Leaves subcoriaceous, narrowly elliptic; lateral leaf veins obvious, 8-9 pairs

……..... **10. E. cupulata**

31a. Leaves chartaceous; pedicels with sparse short erect hairs; staminodes globose ……..…….. **42. E. schlechteri**

b. Leaves coriaceous; pedicels glabrous; staminodes cordate ……..

……... **32. E. ledermannii**

32a. Lower leaf surface densely pubescent …...……..……. 33

b. Lower leaf surface sparsely pubescent ……. 38

33a. Leaf base rounded; lateral veins spreading ……..…..…….. 34

b. Leaf base cuneate; lateral veins diverging …….……..…… 35

34a. Leaf blade broadly elliptic, 23-42 x 13.5-24 cm; lateral leaf veins 10-15 pairs; inflorescence bracts large, c. 1.2 cm long ……. **23. E. grandifolia**

b. Leaf blade rounded, 15-22 x 12-17 cm; lateral leaf veins 8-9 pairs; inflorescence bracts small ....……...……..…….. **31. E. latifolia**

35a. Minor leaf venation coarsely reticulate ……..…….. 36
b. Minor leaf venation finely reticulate or obscure (smooth) ……..…. 37
36a. Twigs lenticellate; leaf coriaceous, blade 5-9 x 2-5.5 cm; tepals glabrous outside ……..…… **12. E. dielsiana**
b. Twigs not lenticellate; leaf chartaceous, blade 11-22.4 x 6-10 cm; tepals with wavy hairs outside ……..…… **40. E. pilosa**
37a. Minor leaf venation obscure, smooth on both surfaces; inflorescences up to 3 cm long; basal glands orbicular …… **6. E. aurea**
b. Minor leaf venation fine, prominent on both surfaces; inflorescences up to 11 cm long; basal glands reniform ……..……..……..…… **43. E. sericea**
38a. Leaf subcoriaceous, apex acuminate; lateral veins 3-4 pairs .....
…….. **41. E. rifaiana**
b. Leaf coriaceous, apex rounded or acute; lateral veins 6-8 to 11 pairs …….
……..... 39
39a. Petioles thin; minor venation coarsely reticulate ……..……. 40
b. Petioles stout; minor venation finely reticulate ...……..……..….. 41
40a. Petioles flat above, glabrous; lateral veins 6-8 pairs ……..…… **8. E. carrii**
b. Petioles slightly canaliculate, appressed pubescent; lateral veins 11 pairs …...
……..…… **37. E. multiflora**
41a. Leaves alternate, lower surface sericeous ……..…… **44. E. sleumeri**
b. Leaves subopposite, lower surface with curly hairs ..…… **46. E. xylophylla**

3.4.2 For fruiting materials

1a. Lower leaf surface glabrous; minor leaf venation coarse 2
b. Lower leaf surface sericeous; minor leaf venation fine 3
2a. Leaf blade stiffly coriaceous; lateral leaf veins obscure, almost similar with minor veins, about 11 pairs, fruits subglobose ..... **38. E. oviformis**
b. Leaf blade chartaceous; lateral leaf veins obvious, 7-8 pairs, fruits ellipsoid
……..… **34. E. magnilimba**
3a. Twigs and petioles glabrous; leaf base cuneate. Fruit oblong with persistent

tepals ..... **24. E. havelii**

b. Twigs and petioles with dense appressed short hairs; leaf base attenuate. Fruit ellipsoid, tepals not persistent …..……..…..….. **45. E. versteeghii**

3.5 Species Descriptions

1. Endiandra aggregata Kosterm. – Figure 1.11.

Endiandra aggregata Kosterm., Reinwardtia 7 (1969) 472. – Type: *Clemens 1421* (holo L; iso BO, BR, L), Wareo, Sattelberg, New Guinea.

Tree 30 m high or more, 40-60 cm in diameter. *Twigs* hollow, stout, brown, smooth, glabrous. *Terminal buds* conical, 4 mm long, with silky straight appressed hairs. *Leaves* alternate; petiole stout, slightly canaliculate above, 2.0-2.5 x 0.2 cm, glabrous; blade subcoriaceous, obovate, 11.5-18.5 x 6.0-10.5 cm, shiny, glabrous, apex acute, base cuneate; midrib flat or slightly impressed above, raised below, glabrous; lateral veins diverging, 7-9 pairs, flat, obscure, glabrous above, prominent below, arcuate towards margin; minor venation coarsely reticulate, prominent. *Inflorescences* paniculate, 9-12 cm long, terminal or axillary, dense wooly hairs towards tip, otherwise glabrescent; upper bracts elliptic, 3.0-3.5 x 1.2-1.5 mm, with dense curly hairs; lower bracts elliptic, 6 x 2 mm; pedicels slender, 2-5 mm long. *Flowers* dull yellow (fresh), erect, 2.0-2.2 x 2-3 mm; tepals almost equal, elliptic, 1.5-2.1 x 0.9-1.0 mm, with dense curly indument outside; glands separate, basal, 3 pairs, each pair flanks stamens, globose, 0.3 mm; stamens 3, anthers ovate almost rounded, 0.5 x 0.5 mm, sparsely pubescent; filament 0.3 mm long; locules small; staminodia 3, small; ovary ovoid, 0.7 mm long, glabrous; style 0.1 mm long; stigma inconspicuous. *Fruits* unknown.

Distribution – Morobe (PNG).

Habitat & Ecology – Forest; alt. 600-700 m.

Specimens examined (6 sheets) – Clemens 1421.

Notes – This species was described by Kostermans based on the specimen previously annotated as *E. brassii* Allen by Allen (1942) which in the present

treatment is placed under *E. asymmetrica* Teschner. *Endiandra aggregata* is closely related to *E. asymmetrica* Teschner, but it differs from the latter by its obovate lamina and hollow twigs. *E. aggregata* is also recognized by its persistent flower bracts.

2. Endiandra archiboldiana Allen – Figure 1.8, 1.9.

Endiandra archiboldiana Allen, J. Arnold Arb. 23 (1942) 153. – Type: *Brass 3813* (holo A; iso BO, NY), Dieni, Central Division, New Guinea.

Tree 20-30 m high, diam. 25 cm. *Twigs* solid, slightly angular, dark brown, glabrous. *Terminal buds* conical, 3 mm long, pubescent. *Leaves* subopposite; petiole thick, flat above, 1.5 cm long, glabrous; blade subcoriaceous, elliptic, 8-15 x 4.5-8.5 cm, glabrous on both surfaces, apex apiculate, base obtuse; midrib flat and slightly impressed above, raised below, glabrous; lateral veins diverging, 4-6 pairs, slightly impressed, glabrous, prominent below; minor venation finely reticulate. *Inflorescences* paniculate, up to 7 cm long, subterminal or axillary, yellowish brown, few-flowered, appressed pubescent; bracts caducous; pedicels slender, 1.2 mm long, with long curly hairs. *Flowers* cream to yellow (fresh), erect, ca. 2.5 mm in diameter; tepals fragile, subequal, ovate, 1.3 x 0.9 mm, inside glabrous except basal triangular patch with appressed long hairs, outside pubescent; glands separate, basal, 3 pairs, each pair flanks stamen, heart-shaped or broadly ovate, 0.3 x 0.4 mm, covering more than half of anthers, short stalked; stamens 3, anthers obovate, flat tip, 0.5 x 0.4 mm long, glabrous; filament short, 0.2 mm long; locules large covering about half of anthers; staminodia 3; receptacle shallow, pubescent; ovary ovoid, 0.9-1 x 0.6 mm, glabrous; style ca. 0.3 mm long; stigma inconspicuous. *Fruits* unknown.

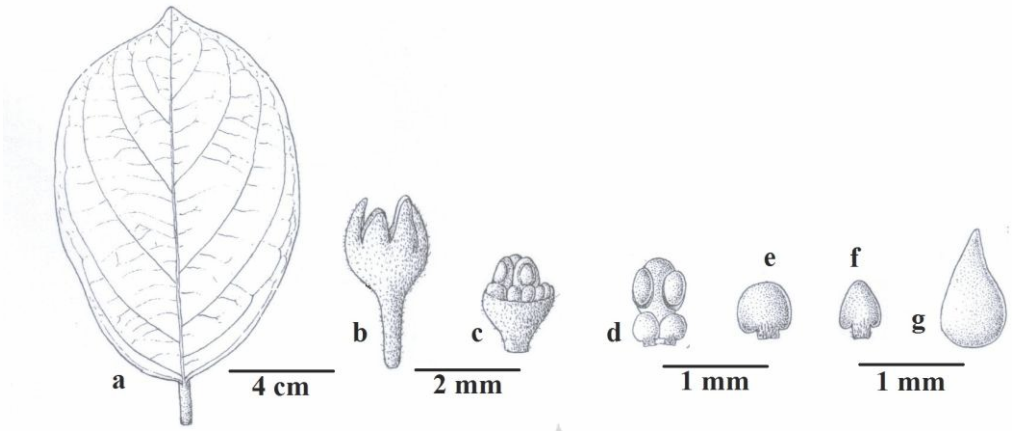

Figure 1.9. *Endiandra archiboldiana* Allen. a. leaf, b. intact flower, c. open flower, d. stamen with a pair of glands, e. gland, f. staminode, g. pistil (*Brass 3813*).

Distribution – Atzera Range, Dieni (PNG).

Habitat & Ecology – Rain forest, alt. 150-500 m.

Specimens examined (5 sheets) – Brass 3813, NGF16718.

Notes – *Endiandra archiboldiana* Allen is similar to *E. asymmetrica* Teschner by their glabrous twigs and leaf surfaces, but different because the former has somewhat bullate leaf blade and cuneate leaf base.

3. Endiandra areolata Arifiani, *spec. nov.* − Figure 1.10, 1.11.

Endiandra areolata − Type: *Pleyte 733* (holo BO; iso L), Near Remoe, Sorong, West Papua.

Tree up to 25 m, up to 20 cm in diameter. *Twigs* brown, solid, striate, glaborus. *Terminal buds* narrowly elliptic, straight, 2-3 mm long, with dense appressed hairs. *Leaves* slightly clustered; petiole thin, slightly canaliculate, 1-1.2 cm long, glabrous; blade stiffly coriaceous, broadly elliptic, 9-11.4 x 4.2-5.6 cm, glabrous, apex acute, base attenuate; midrib flat to slightly impressed above, raised below, glabrous; lateral veins spreading, obscure, thread-like, slightly raised on both surfaces, as prominent as minor veins**;** minor venation coarsely areoate, prominent. *Inflorescences* paniculate, axillary or terminal, ca. 5 cm long, bear many flowers, sparsely pubescent, glabrescent; bracts caducous; pedicel slender, 0.5-1 mm long, pubescent. *Flowers* light brown (fresh), very small, erect, ca. 1.5 mm in diameter, pubescent; tepals ovate, ca. 0.6 mm long, pubescent

outside, glabrous inside; glands separate, basal, 3 pairs, each pair flanks stamen, stalked; stamens 3; anthers rectangular, ca. 0.7 x 0.3 mm, sessile, glabrous; locule small, nearly rounded; staminodes none; receptacles shallow, glabrous; ovary ovoid, 0.6-0.7 mm long, glabrous; style 0.5 mm long, stigma unconspicous. *Fruits* unknown.

Distribution – Sorong, Idenburg River (W Papua).

Habitat & Ecology – Forest, swamp forest.

Specimens examined (5 sheets) – Pleyte 733; Brass & Versteegh 13142; Kostermans 1260.

Notes – *Endiandra areolata* is a newly described species and is different from other species of *Endiandra* in New Guinea because of its stiffly coriaceous leaf, lateral veins obscured by coarsely areolate minor veins, and small, erect flowers. Its coriaceous leaf is similar to that of *E. oviformis* Kosterm., but their leaf color and surface texture are distinct (dark-colored and prominent surface in *E. areolata* vs pale-colored and smooth in *E. oviformis*).

4. Endiandra arfakensis Kosterm. – Figure 1.11.

Endiandra arfakensis Kosterm., Reinwardtia 7 (1969) 473. – Type: *Mayr 184* (holo BO), Arfak, W Papua.

Tree. *Twigs* solid, thin, sparsely appressed pubescent toward tip. *Terminal buds* small, sparsely pubescent. *Leaves* alternate; petiole thin, canaliculate above, 0.8 cm long, sparsely pubescent; blade chartaceous, elliptic, 6.5-10.5 x 2.5-4 cm, glabrous, shiny on both surfaces, apex acuminate, base cuneate; midrib flat above, raised below, glabrous; lateral veins diverging, 7-9 pairs, obscure, slightly impressed to flat above, slightly raised below; minor venation finely reticulate, prominent. *Inflorescences* paniculate, axillary, short, up to 2 cm long, few-flowered, minutely sericeous towards apex; bracts caducous; pedicels slender, 2 mm long. *Flowers* spreading, ca. 3 mm in diameter; tepals subequal (inner ones smaller), ovate, acute, 2 mm long, glabrous inside, sparsely pubescent outside; glands fused to form a fleshy ring; stamens 3, anthers ovate, glabrous; filament

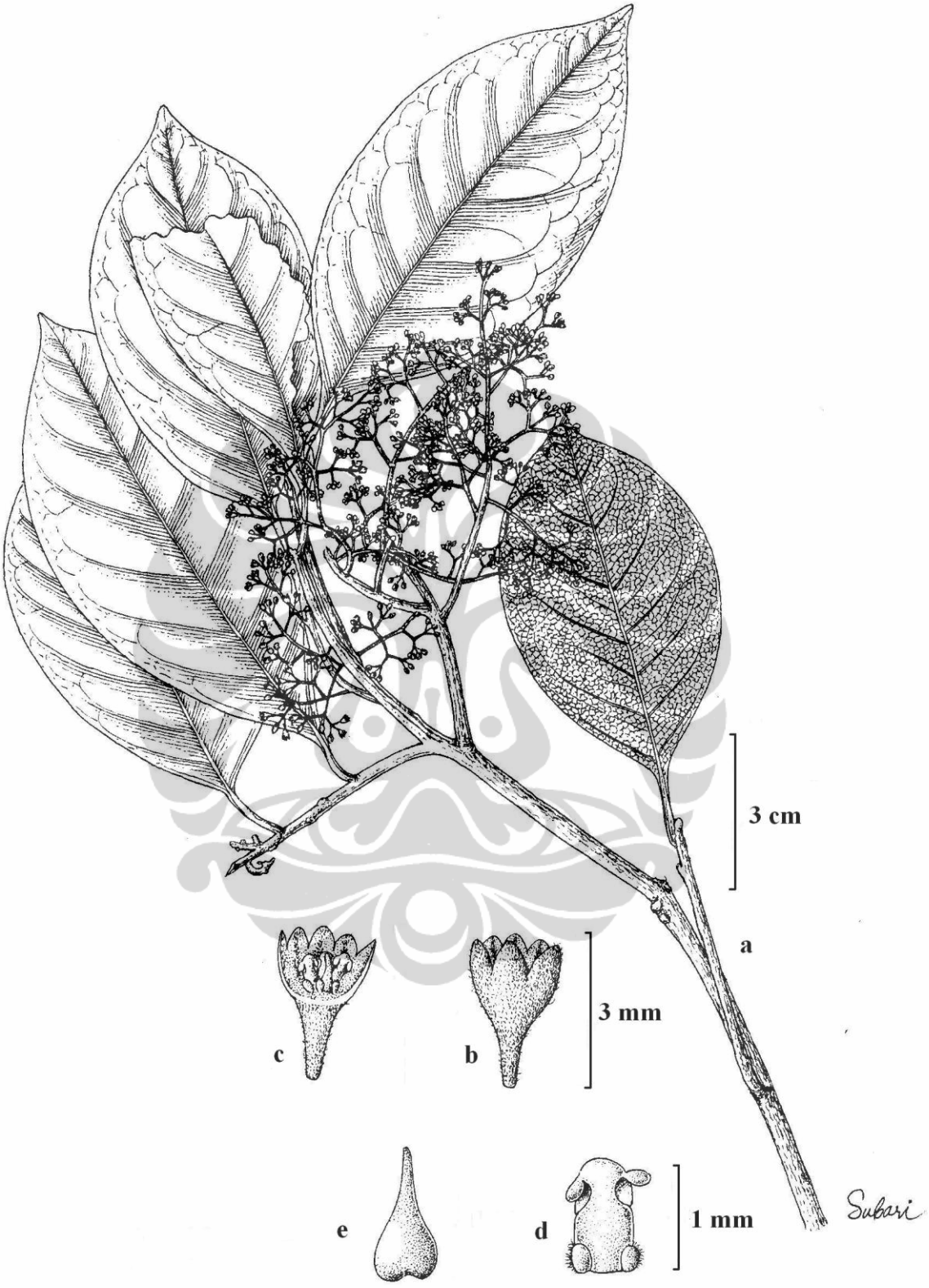

Figure 1.10. *Endiandra areolata* Arifiani. a. habit; b. intact flower; c. flower (front tepals removed); d. anther; e. pistil (*Pleyte 733*).

short, broad; locules elongated, slit-like; staminodia none; ovary ellipsoid-ovoid, glabrous; style and stigma inconspicuous. *Fruits* unknown.

Distribution – Arfak Mts. (W Papua).

Habitat & Ecology – Forest; alt. 1200 m.

Specimen Examined (1 sheet) – Mayr 184.

Notes – The species can be recognized by its obscure lateral veins, the veins as raised as minor venation.

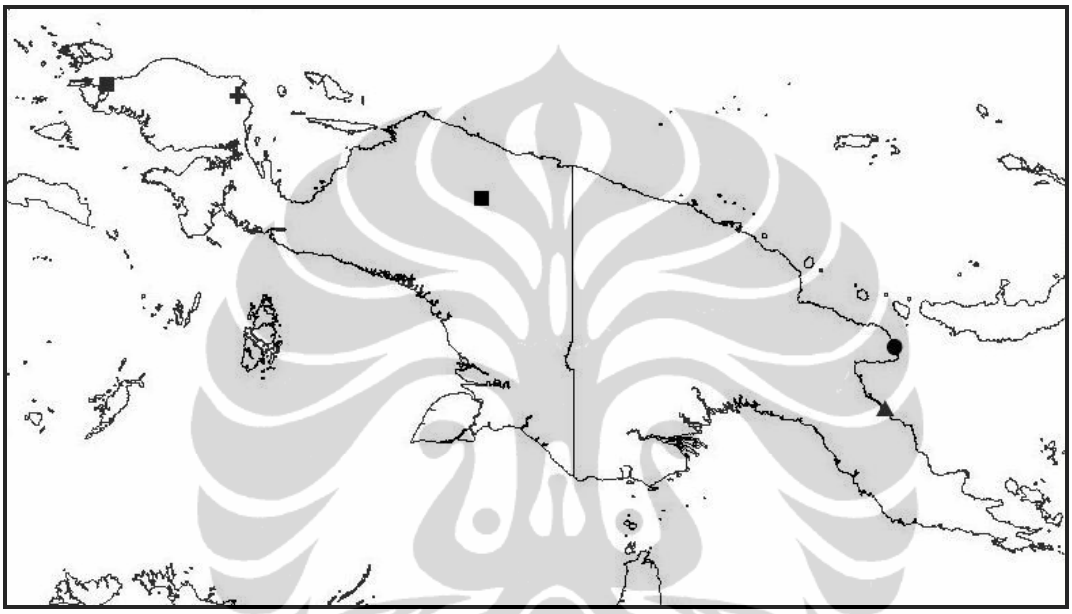

Figure 1.11. Species distribution of *E. aggregata* (●), *E. archiboldiana* (▲), *E. areolata* (■) and *E. arfakensis* (✚)

5. Endiandra asymmetrica Teschner – Figure 1.14.

Endiandra asymmetrica Teschner, Engl. Bot. Jahrb. 58 (1923) 416 – Type: *Ledermann 9562* (iso L), Sepik-Gebiet, PNG.

Endiandra acuminata Teschner non *E. acuminata* C.White & Francis, Engl. Bot. Jahrb. 58 (1923) 418 – Type: *Ledermann 9458* (holo), Sepik-Gebiet, PNG.

Endiandra brassii Allen , J. Arnold Arb. 23 (1942) 147 – Type: *Brass & Versteegh 14101* (holo A; iso BO, HUH, L, NY), Bernhard Camp, Idenburg River, W Papua.

Endiandra clemensii Allen, J. Arnold Arb. 23 (1942) 147 – Type: *Clemens 1742* (holo A; iso BO, NY), Sattleberg, Morobe District, PNG.

Endiandra formicaria Kosterm., Reinwardtia 7 (1969) 481 – Type: *Brass 6921* (holo BO; iso BO, G, K, L), Inggembit, W Papua.

Tree up to 20 m tall, 30 cm in diameter. *Twigs* light to dark brown, solid, somewhat rectangular to terete, glabrous. *Terminal buds* 4-6 mm long, densely appressed pubescent (*silver*). *Leaves* alternate; petiole thin, terete**,** canaliculate or sometimes flat, 1.2-1.5 x 0.2 cm, glabrous; blade coriaceous, elliptic, 14-22 x 5.5-11 cm, glabrous both surfaces, apex acuminate (0.5-1 cm acumen), base cuneate; midrib flat or slightly impressed above, raised below, glaborus; lateral veins spreading, 6-9 pairs, flat above, raised below, glabrous; minor venation finely reticulate, prominent. *Inflorescences* paniculate, 7-17 cm long, terminal or rarely axillary, many-flowered, sparsely pubescent; bracts caducous; pedicels slender, 1-2.8 x 0.5 mm, sparsely pubescent. *Flowers* green, half-erect, 3-3.3 x 2.5 mm; tepals equal, thin (chartaceous), elliptic, 1.7-2 x 0.7-1.2 mm, inside glabrous or with erect indument where anthers attached, sparsely pubescent outside; glands separate, basal, 3 pairs, each pair flanks stamen, reniform, 0.5 x 0.4 mm; stamens 3; anthers broadly triangular, 0.6-0.9 x 0.6-0.8 mm, pubescent; locules large covering most of anther space; staminodia unknown; ovary ellipsoid, ca. 1-1.3 mm long, glabrous; style 0.5 mm long; stigma inconspicuous. *Fruits* unknown.

Distribution – Serui, Moluccas; W Papua; Morobe, Eastern Highlands (PNG).

Habitat & Ecology – Primary, secondary, disturbed forest, or riverine forest, on sandy loam soil, alluvial, or clay.

Specimens examined (27 sheets) – Aet & Idjan 565; Brass 6921, 14101, 32429; Brass & Versteegh 13589; Clemens 1742, 1848; Drees 380; Havel & Kairo NGF17236; Iwanggin BW10038; Ledermann 5458, 9384, 9562; Martin LAE54756; Reksodihardjo 313; Schlecter 16776; Streimann 45187; White NGF10462.

Notes – *Endiandra asymmetrica* Teschner is selected for the new name of *E. acuminata* Teschner (1923). The latter was an invalid name because the priority of the name *E. acuminata* went to *E. acuminata* C. White & Francis (1920). Several species treated as synonyms under *E. asymmetrica* are *E. brassii* Allen, *E. clemensii* Allen and *E. formicaria* Kosterm.

Endiandra brassii Allen and *E. clemensii* Allen are treated as synonyms here because both are conspecific with *E. asymmetrica*, and this is in agreement with Kostermans treatment (1969). *Endiandra formicaria* Kosterm. was described

by Kostermans (1969) based on Brass 6921 which was previously placed under *E. brassii* Allen by Allen (1942). However, the species is still conform with *E. asymmetrica* group, therefore *E. formicaria* is treated as synonym of *E. asymmetrica*.

Kostermans (1969) has reported that the specimens cited by Teschner (1923) for *E. acuminata*, i.e., Ledermann 9458, 9384 were extinct, only Schlechter 16776 is extant, and he accepted it as the lectotype. However, actually Ledermann 9384 is still exist in L, together with Ledermann 5458, annotated also as *E. acuminata* Teschner, so that lectotypification for *E. acuminata* Teschner (Schlechter 16776) by Kostermans was not necessary.

6. Endiandra aurea Kosterm.

Endiandra aurea Kosterm., Bull. Bot. Gard. Buitenzorg, Ser. 3, 18 (1950) 442. – Type: *Kostermans 2014* (holo P; iso HUH), Isuarava, New Guinea.

Tree up to 20 m high, 45 cm in diameter. *Twigs* solid, thick, brown, warty, with dense short appressed rusty hairs. *Terminal buds* with a dense rusty indument. *Leaves* subopposite; petiole thick, flat, 1-1.5 cm, pubescent; blade coriaceous, narrowly elliptic, 7-12 x 2.5-5 cm, smooth, shiny, glabrescent above, very densely rusty or golden appressed pubescent below, apex apiculate, base cuneate; midrib flat or slightly impressed above, raised below, both surfaces densely rusty pubescent; lateral veins diverging, 5-6 pairs, straight to curved, disappearing towards margin; minor venation obscure, smooth. *Inflorescences* paniculate, 1.5-3 cm long, terminal, densely tomentose; bracts lanceolate, subacute, keeled, up to 2 mm long, caducous; pedicels very short, stout, up to 1 mm long, pubescent. *Flowers* cup-shaped, 2 x 2 mm; tepals equal, fleshy, ovate-lanceolate, acute, keeled, 1.5 mm long, densely pubescent outside; glands separate, basal, 3 pairs, each pair flanks stamen, orbicular; stamens 3, anthers ovate, acute or slightly apiculate, 3-3.25 mm long, glabrous; filament short, 0.25 mm long, hirsute; locules large; staminodia none; ovary ovoid, ca. 0.5 mm long,

glabrous; style short; stigma inconspicuous. *Fruits* green, turning black-violet, smooth, ellipsoid, 1.8 x 1 cm, subacute; tepals subpersistent.

Distribution – Arfak Mts. (W Papua).

Habitat & Ecology – Moist, mossy forest, on granitic sandstone; alt. 1800-2200 m.

Specimens examined (2 images) – Kostermans 2014.

Notes – *Endiandra aurea* Kosterm. can easily be recognized by its obscure and smooth reticulation. Lateral veins are also hardly seen. Floral characters are following Kostermans description (1950).

7. Endiandra beccariana Kosterm. – Figure 1.12, 1.14.

Endiandra beccariana Kosterm., Reinwardtia 7 (1969) 474. – Type: *Kostermans & Tangkilisan 146* (holo BO; iso L), Tobelo, N Halmahera, Moluccas.

Tree up to 32 m, 40 cm in diameter. *Young twigs* rusty colored, becoming grayish brown when older, solid, lenticellate, dense erect pubescent. *Terminal buds* rusty colored, conical, 8 x 3 mm, densely pubescent. *Leaves* alternate; petiole slender, terete, flat above, 1.2-2.3 cm long, densely pubescent to glabrescent; blade subcoriaceous, elliptic, 8.5-19 x 6-11 cm, glabrous, shiny above, sparsely pilose or glabrescent below, apex acuminate, base cuneate; midrib flat above, raised below; lateral veins spreading, 7-10 pairs, slightly impressed above, prominent below, arcuate towards margin; minor venation finely reticulate, prominent. *Inflorescences* paniculate, axillary, 4-11 cm long, few-flowered, pubescent; bracts caducous; pedicels slender, ca. 3 mm long. *Flowers* yellow, ca. 6 mm in diameter; tepals spreading, narrowly elliptic, slightly acuminate, 2.5-3 mm long, glabrous; glands brownish yellow, fused forming a disc, ca. 0.75 mm thick; stamens 3, anthers widely triangular, emerge from disc-like united glands, glabrous; locules large; staminodia none; receptacles shallow, pubescent inside; ovary ellipsoid, glabrous; style 0.5 mm long; stigma unconspicous. *Fruits* immature, green, ellipsoid, ca. 1-2 cm long, free on the receptacle.

Distribution – Moluccas; Raja Ampat (W Papua).

Habitat & Ecology – Lowland rain forest on clay soils; alt. 30-120 m.

Specimens Examined (32 sheets) – Arifiani & Obaja 596, 652; Kostermans 373, 448, 491, 854, 890, 934; Kostermans & Tangkilisan 146; Main 592; Moll BW 12908; Schram BW6059; Versteegh BW10350.

Notes – This species is similar to the *E. papuana* Lauterb., but differs in less indument on lower leaf surface and inflorescences. Kostermans (1969) noted that the panicles of *E. beccariana* Kosterm. are glabrous but they do bear a sparsely erect indument.

The species was previously known from Moluccas and Northwest part of West Papua. The occurrence of *E. beccariana* in Waigeo Island (Raja Ampat) may connect its dispersal from Moluccas to Papua or vice versa.

8. Endiandra carrii Kosterm. – Figure 1.13.

Endiandra carrii Kosterm., Reinwardtia 7 (1969) 474. – Type: *Carr 14330* (holo BM; iso BO, K, L, SING), Alola, Boridi, New Guinea.

Tree 20-33 m high. smooth. *Twigs* thin, dark-colored, solid, smooth, glabrous. *Terminal buds* conical or ovate, 5-10 mm long, somewhat glabrous. *Leaves* alternate; petiole thin, flat above, 1-1.5 cm long, glabrous; blade coriaceous, elliptic to subobovate, 7-9.5 x 3.5-5.6 cm, shiny, glabrous both surfaces, sometimes with a sparse minute hairs below, apex apiculate or rounded, base cuneate or attenuate; midrib flat to slightly raised, glabrous above, raised, with a sparse minute hairs to glabrescent below; lateral veins diverging, 6-8 pairs, curved towards margin, impressed, glabrous above, prominent with spase minute hairs below; minor venation coarsely reticulate, obscure above, slightly prominent below. *Inflorescences* paniculate, up to 8 cm long, terminal or axillary, few-flowered, upper part with dense curly hairs, but sparser than flowers and pedicels;

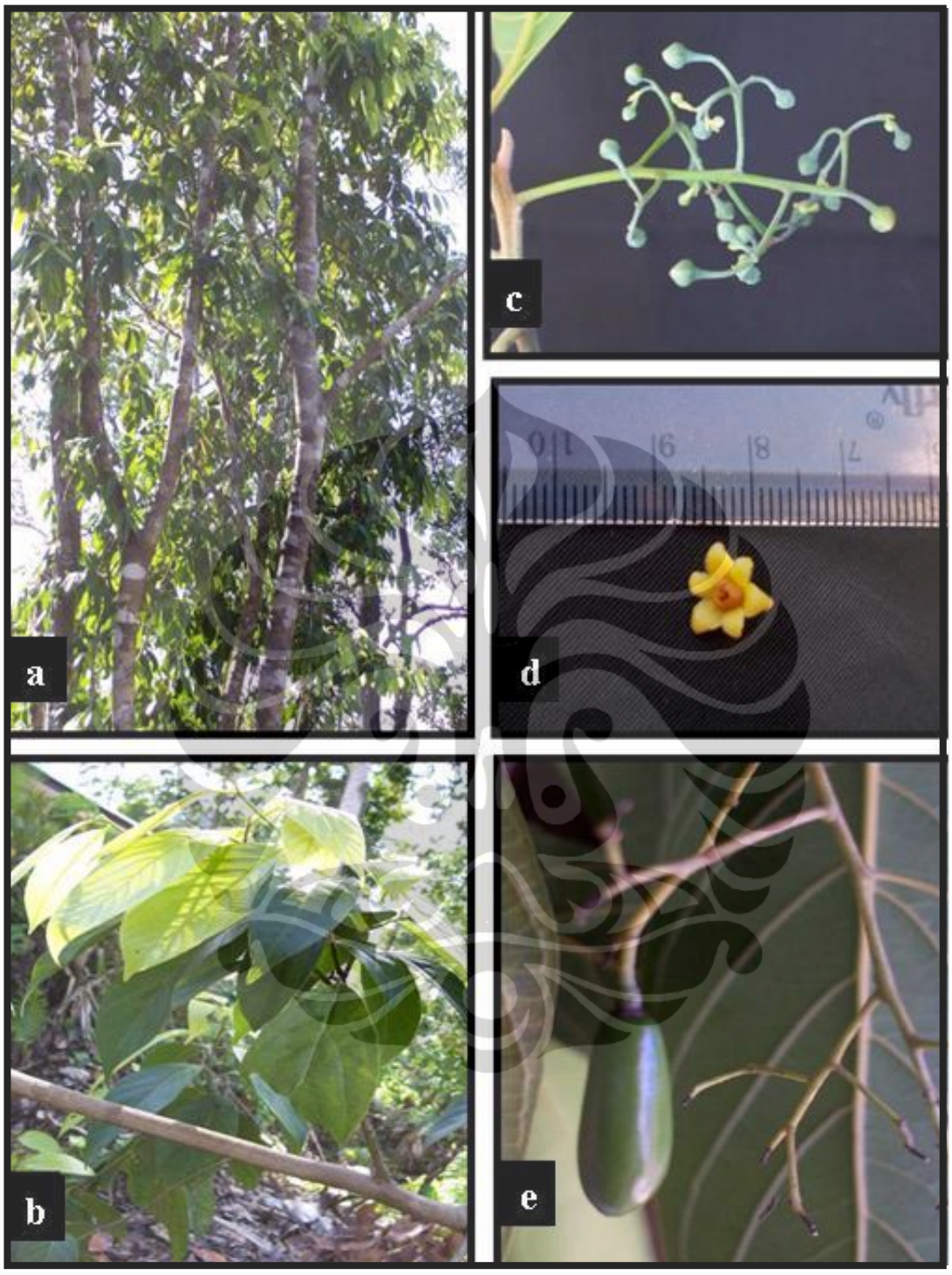

Figure 1.12. *Endiandra beccariana* Kosterm. a. tree habit; b. leaf arrangement; c. flower buds; d. mature flower, glands fused, stamens exposed from the middle; e. young fruit. (*Arifiani & Obaja 652*; *Photos c-e: A. Hidayat*)

bracts caducous; pedicels slender, 1-2 mm long, with dense curly hairs. *Flowers* half-erect, 2.5-3 mm in diameter, with dense curly hairs; tepals nearly equal, ovate, 1.5-2 mm long, inner ones smaller, sparsely pilose outside, densely pubescent inside; glands separate, basal, 3 pairs, each pair flanks stamen, globose or reniform, 0.3-0.4 mm, glabrous; stamens 3; anthers elliptic or conical with flat tip, 0.7-0.9 mm long, back part with curly hairs; locules large, almost as long as anthers, elliptic; filament short, ca. 0.1-0.2 mm long; staminodia 3, cordate, 0.5 mm long, short stalked; receptacle shallow, with dense curly hairs inside; ovary ovoid, 1-1.5 mm, glabrous; style 0.5-0.7 mm; stigma inconspicuous. *Fruits* unknown.

Distribution – Alola, Boridi (PNG).

Habitat & Ecology – Forest; alt. 200-1800 m.

Specimens examined (6 sheets) – Carr 14330, 13849, 14206.

Notes – The species is related to *E. xylophylla* Kosterm., and the two can only be distinguished by its leaves shape and lower leaf surface indument (elliptic to subobovate, glabrous in *E. carrii* vs obovate to rounded, with short hairs in *E. xylophylla*).

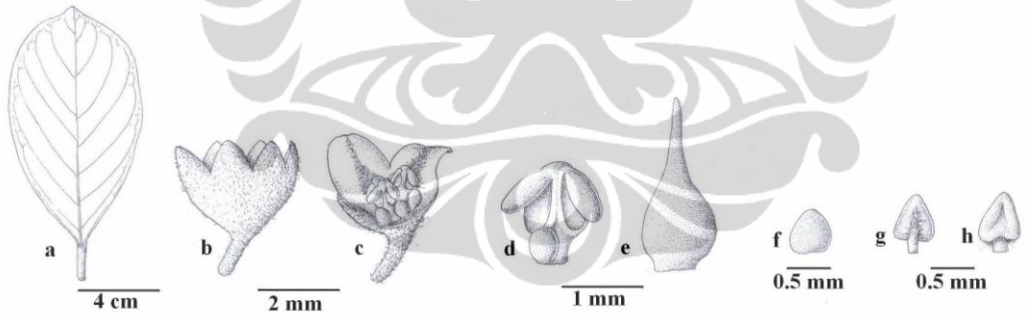

Figure 1.13. *Endiandra carrii* Kosterm. a. leaf, b. intact flower, c. open flower, d. stamen with gland, e. pistil, f. gland, g, h. staminode (*Carr 14330*).

9. Endiandra crassitepala Arifiani, *spec. nov.* – Figure 1.14, 1.15.

Endiandra crassitepala Arifiani Type: Henty NGF29370 (holo BO; iso L, SING), Kassam Passs, Kainantu, Eastern Highlands District, PNG.

Tree up to 22 m tall, 25 cm in diameter. *Twigs* grayish brown, solid, terete, glabrous; bark aromatic. *Terminal buds* lanceolate, curved, 4-5 mm long, with

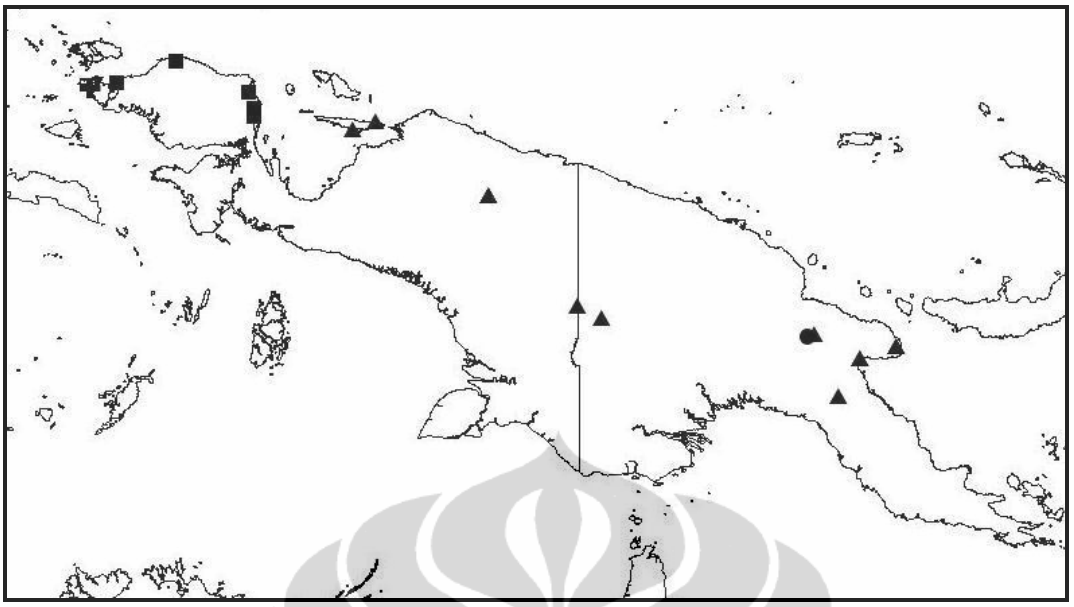

Figure 1.14. Species distribution of *E. crassitepala* (●), *E. asymmetrica* (▲), *E. beccariana* (■) and *E. cupulata* (✚)

dense appressed greyish hairs. *Leaves* alternate; petiole thin, ca. 1 cm long, canaliculate above, glabrous; blade coriaceous, elliptic, 15-17 x 5-8 cm, glabrous on both surfaces, apex acuminate, base cuneate; midrib flat above, raised below, glabrous; lateral veins spreading, 8-9 pairs, slightly raised and glabrous on both surfaces, as raised as minor veins; minor venation coarsely reticulate, slightly raised; domatia absent. *Inflorescences* paniculate, length 6-8 cm, axillary, many-flowered, with dense appressed long hairs, sparser downward; bracts caducous; pedicels thin, 2-3 mm long, indument same as inflorescence. *Flowers* greyish (fresh), erect, 2 mm in diameter; tepals thick, very hard, unequal, inner ones smaller, somewhat ovate, small, glabrous inside, with dense appressed hairs outside; glands none; stamens 3; anthers triangular, 0.8 x 0.5 mm, pubescent; locules slit-like; staminodia narrowly triangular, 0.4 mm long, hairy; receptacles shallow, with dense erect hairs; ovary ovoid, 0.7 mm long, glabrous; style 0.5 mm long; stigma inconspicuous. *Fruits* dark brown.

Distribution – Eastern Highlands (PNG).

Habitat & Ecology – Forest; alt. 1220 m.

Specimens examined (3 sheets) – Henty NGF29370.

Figure 1.15. *Endiandra crassitepala* Arifiani. a. habit; b. intact flower; c. flower (tepals removed); d. anther; e. staminodia; f. pistil (*Henty NGF29370*).

Notes – *Endiandra crassitepala* Arifiani is vegetatively similar to *E. kassamensis* Arifiani but the former has unequal, erect, very thick and hard tepals. Tepals are difficult to crush, the inner ones much smaller.

10. Endiandra cupulata Arifiani, *spec. nov.* – Figure 1.14, 1.16.

Endiandra cupulata Arifiani – Type: *Koster BW1344* (holo BO; iso BO, L), Kaloal, Salawati Island, W Papua.

Tree up to 17 m high, 46 cm in diameter. *Twigs* solid, terete, brown, glabrous**.** *Terminal buds* obovoid, 7-10 mm long**,** with dense erect short hairs. *Leaves* slightly clustered**;** petiole thin, terete, canaliculate above, 1-1.5 cm long, glabrous; blade subcoriaceous, narrowly elliptic, 19-22 x 7-8 cm**,** glabrous on both surfaces, apex acute, base attenuate; midrib flat above, raised below, both surfaces glabrous; lateral veins spreading, 8-9 pairs, flat above**,** prominent below, glabrous on both surfaces, arcuate towards margin; minor venation coarsely reticulate, prominent. *Inflorescences* paniculate, bear many flowers, up to 17 cm long, terminal or axillary, with dense golden curly hairs, sparser downward; bracts ovate, 1.4 mm long, with dense curly hairs both sides; pedicels slender, 2.5-2.8 mm long, with curly hairs. *Flowers* white, fragrant (fresh), spreading, 3 mm in diameter; tepals equal, thin, narrowly elliptic, 2 x 0.5 mm, with dense long curly hairs inside, sparse curly hairs outside; glands separate, basal, 3 pairs, each pair flanks stamen, reniform, 0.3 mm in diameter, glabrous; stamens 3; anthers oblong almost ovate, 0.6 mm long, with sparse curly hairs; filament short, 0.2 mm long; locules roundish; staminodia 3, cordate, pubescent; receptacles shallow, glabrous inside; ovary narrowly ovoid, ca. 0.75 mm long, glabrous; style 0.5 mm long; stigma inconspicuous. *Fruits* unknown.

Distribution – Salawati Island (W Papua).

Habitat & Ecology – Primary forest, on swampy ground, plane area; alt. 3 m.

Local name – Siepmen (Manikiong).

Specimens examined (2 sheets) – Koster BW1344.

Notes – The species is commonly found in Kaloal, Salawati Island and is characterized by somewhat oblong anthers which sparsely covered by curly hairs. *Endiandra cupulata* has elongated secondary axis of the inflorescence.

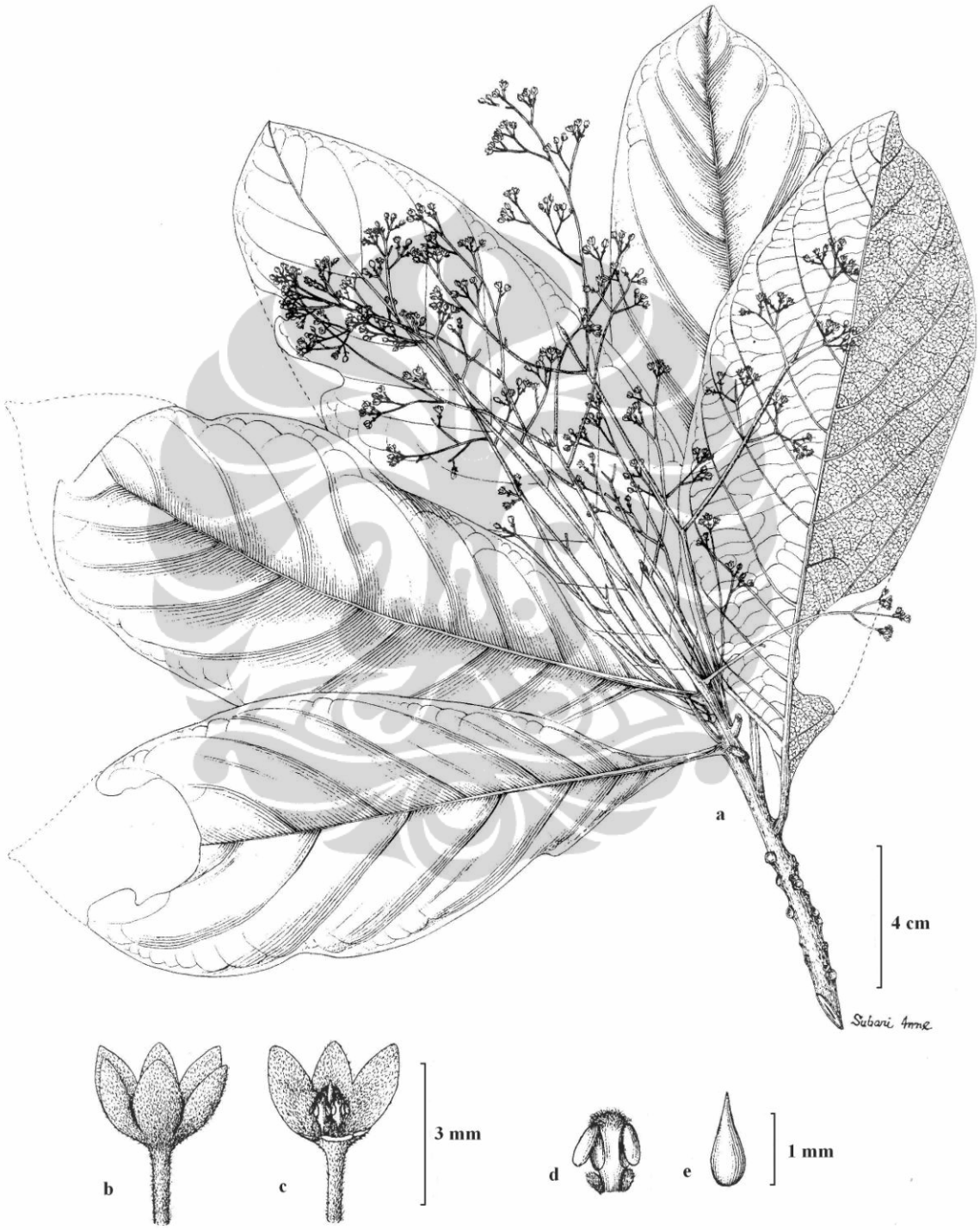

Figure 1.16. *Endiandra cupulata* Arifiani. a. habit; b. intact flower; c. flower with front tepals removed; d. anther with a pair of glands attached; e. pistil (*BW 1344*)

11. Endiandra cyphellophora Kosterm.

Endiandra cyphellophora Kosterm., Bull. Bot. Gard. Buitenzorg, Ser. 3, 18 (1950) 442. – Type: *Carr 15379* (iso BM, K, L), Isuarava, New Guinea.

Tree up to 27 m high. *Twigs* solid, slightly angular, light to dark brown, smooth, glabrous. *Terminal buds* small, somewhat conical, 5 mm, densely pubescent. *Leaves* subopposite; petiole slender, canaliculate above, 1 cm long, glabrous; blade coriaceous, narrowly elliptic, 7.5-15 x 2.5-5.5 cm, shiny, glabrous on both surfaces, apex acuminate, base cuneate; midrib flat or slightly impressed above, slightly raised below, glabrous on both surfaces; lateral veins diverging, 6-7 pairs, flat, glabrous above, raised below, erect, curved towards margin; minor venation coarsely reticulate, prominent; domatia infundibuliform, up to 2 mm long. *Inflorescences* paniculate, 3-5.5 cm long, terminal or axillary, many-flowered, sparsely pubescent towards tip; bracts caducous; pedicels slender, 2-4 mm long, pubescent. *Flowers* cream (fresh), 2-2.5 mm in diameter; tepals ovate, 1.5 mm long, pilose or glabrescent outside, papillose inside, especially towards base (stamens attachment); glands none; stamens 3; anthers ovate or rotundate; locules large; staminodia none; ovary ovoid, 1 mm long, glabrous; style inconspicuous; stigma inconspicuous. *Fruits* unknown.

Distribution – Isuarava (PNG).

Habitat & Ecology – Forest; alt. 1370 m.

Specimens examined (6 sheets) – Carr 15379, 15380.

Notes – The species is easily recognized by the presence of domatia on leaves. Other characters helping with identification are erect lateral veins and coarse reticulation. Floral characters are taken from Kostermans (1950).

12. Endiandra dielsiana Teschner

Endiandra dielsiana Teschner, Bot. Jahrb. Syst. 58 (1923) 417. – Type: *Ledermann 8885* (lecto, SING). *Ledermann 12438* (lectoparatype).

Endiandra glandulosa Allen, J. Arnold Arb. 23 (1942) 148 – Type: *Brass 13678* (holo A; iso BM, L), Bernhard Camp, Idenburg River, W Papua.

Tree up to 35 m high, 120 cm in diameter. *Twigs* dark-colored, solid, terete, occasionally flaky, lenticellate, appressed pubescent. *Terminal buds* small, densely appressed pubescent. *Leaves* subopposite; petiole thin, flat above, 0.6-2.1 cm long, glabrous; blade coriaceous, elliptic, 5-9 x 2-5.5 cm, glabrous above, with densely appressed pubescent when young then glabrescent, glaucous, below, apex acuminate, base cuneate; midrib flat above, raised below, glabrous; lateral veins diverging, 6-8 pairs, flat above, prominent below, arcuate towards margin; minor venation coarsely reticulate, prominent. *Inflorescences* paniculate, up to 5 cm long, pseudoterminal or axillary, many-flowered, nearly glabrous; bracts caducous; pedicels slender, 1.2-1.6 x 0.6-0.9 mm. *Flowers* pale green, greenish yellow, spreading, 1.4-2.5 x 0.4-0.7 mm; tepals equal, elliptic, 1.6-2.2 x 0.9-1.2 mm, glabrous outside, densely pubescent inside especially at the center towards the base; glands separate, basal, 3 pairs, each pair flanks stamen, reniform, 0.4-0.6 x 0.5-0.6 mm, short stalked, 0.2-0.4 mm, hairy; stamens 3, anthers globose, 0.5-0.6 x 0.8-0.9 mm, sparsely pubescent towards the base; filament 0.4-0.5 mm long, pubescent; locules ovate; staminodia 3, distinct, 0.3-0.5 mm long, head glabrous; receptacles shallow, glabrous inside; ovary ovoid, 0.5-0.8 x 0.6-0.8 mm, glabrous; style 0.4-0.5 mm long; stigma inconspicuous. *Fruits* black, ellipsoid, 4 x 2.3-2.7 cm.

Distribution – Idenburg River (W Papua); Sepik (PNG); Queensland.

Habitat & Ecology – Rain forest, on granitic soil; alt. 150-1200 m.

Specimens examined (9 sheets) – Brass 13678; Brass & Versteegh 13144, 12580; Hyland 13176; Kostermans 2004; van Royen & Sleumer 7490.

Notes – *Endiandra dielsiana* Teschner is characterized by lenticellate twigs, coriaceous gland-dotted leaf, small leaf blade, 5-9 x 2-5.5 cm and glabrous tepals. The leaf becomes blackish when dried and it has coarse reticulation.

13. Endiandra djamuensis Kosterm.

Endiandra djamuensis Kosterm., Reinwardtia 7 (1969) 476. – Type: *Schlecter 17341* (holo P; iso BO), Djamu, PNG.

Tree. *Twigs* grayish, solid, smooth, with appressed hairs in upper part, glabrous downward. *Terminal buds* with appressed indument. *Leaves* alternate; petiole thin, flat above, 0.6-1 cm, glabrous; blade subcoriaceous, elliptic, 7-9 x 3-4 cm, glabrous on both surfaces, apex acuminate, base cuneate; midrib slightly raised, with sparse short, appressed hairs and glabrous toward apex above, raised, glabrous below; lateral veins diverging, 8-9 pairs, obscure above, raised below, glabrous disappearing towards margin; minor venation finely reticulate, immersed above, prominent below. *Inflorescences* paniculate, axillary, up to 2 cm long, few-flowered, sparsely pilose; bracts caducous; pedicels slender, 2 mm long. *Flowers* dark cream, 5 mm in diameter; tepals subequal, narrowly ovate, 3 mm long, glabrous outside, inside pubescent in triangular patch at base part, otherwise glabrous; glands none; stamens 3; anthers sessile, narrowly triangular, 1.5 mm long, pilose; locules basal, large; staminodia none; ovary ellipsoid to ovoid, glabrous; style short. *Fruits* unknown.

Distribution – Djamu (PNG).

Habitat & Ecology – Forest; alt. 800 m.

Specimen examined (2 sheets) – Schlecter 17341.

Notes – *Endiandra djamuensis* is a good species even it is based on a single specimen. The spesimen at BO is only leaf fragments so that flower characters are following Kostermans description (1969).

14. Endiandra engleriana Teschner – Figure 1.18.

Endiandra engleriana Teschner, Engl. Bot. Jahrb. 58 (1923) 419.– Type: *Ledermann 10340* (iso L), Sepik-Gebiet, PNG.

Tree 15-32 m high, 50 cm in diameter. *Twigs* solid, thin, dark-colored, glabrous *Terminal buds* ca. 0.6 mm long sparsely pubescent. *Leaves* alternate; petiole stout, terete, canaliculate above, 0.8-1.5 cm long, glabrous; blade coriaceous, narrowly elliptic or slightly obovate, 9-15 x 4-6 cm, glabrous on both surfaces, apex acuminate, base cuneate; midrib impressed above, raised below, both surfaces glabrous; lateral veins spreading, 6-8 pairs, thread-like, slightly

prominent on both surfaces, arcuate towards margin; minor venation finely reticulate, prominent. *Inflorescences* paniculate, ca. 8 cm long, axillary, many-flowered, glabrous; bracts caducous; pedicels slender, 2 x 0.6 mm. *Flowers* green yellow (fresh), erect; tepals subequal, ovate, apex obtuse, sparsely pubescent; glands separate, basal, 3 pairs, each pair flanks stamen, reniform sessile; stamens 3; anthers rhombic, apex obtuse, puberulent; locules roundish; staminodia triangular, pilose, short stalked; receptacles shallow; ovary ovoid, glabrous. *Fruits* unknown.

Distribution – Sarmi subdistrict (W Papua); Sepik-Gebiet (PNG).

Habitat & Ecology – Forest, on sandy clay soil; alt. 5-1000 m.

Specimens examined (3 sheets) – Ledermann 10340; Mangold BW2278; Schlechter 17976.

Notes – *Endiandra engleriana* has thread-like lateral veins that is obscured by minor venation, which is similar to *E. fulva* Teschner. However, the two is distinct in dried-leaf coloration and inflorescence indument (brown leaf color, glabrous inflorescence in *E. engleriana* vs blackish, pubescent inflorescence in *E. fulva*).

15. Endiandra euadenia Kosterm. – Figure 1.18.

Endiandra euadenia Kosterm., Reinwardtia 7 (1969) 477. – Type: White NGF10252 (holo BO; iso BO, K, L), Josephstaal, Madang Distr., New Guinea.

Tree up to 18 m high, 15 cm in diameter. *Twigs* pale-colored, whitish, solid, 0.5-0.6 cm in diameter, glabrous, smooth**.** *Terminal buds* narrowly conical, white, rather curved, 5-9 mm long, densely appressed pubescent. *Leaves* alternate; petiole stout, dark-colored, contrast to the twig, terete, canaliculate above, 1.5-2 x 0.3 cm**,** glabrous; blade coriaceous, elliptic or subobovate, 15-23 x 8-11.5 cm, glabrous on both surfaces, apex apiculate or rounded, base cuneate; midrib slightly impressed above, raised below, both surfaces glabrous; lateral veins diverging, 7-8 pairs, erect, slightly impressed above, prominent below, almost straight, only shortly arcuate towards margin; minor venation finely reticulate, obscure or slightly immersed. *Inflorescences* paniculate, compact, up to 8 cm

long, axillary, reddish brown, many-flowered, densely erect pubescent; bracts caducous; pedicels short, thick, ca. 1 mm long. *Flowers* pale yellowish green (fresh), spreading, 4-6 mm in diameter; tepals equal, broadly ovate, 1.5-2 x 1.5 mm, glabrous inside, with dense erect hairs outside; glands fused to form ring-like structure, 1 mm high; stamens 3; anthers ovate to triangular, protruding from the fused glands, lower part flattened, glabrous; locule roundish; staminodia none; receptacles shallow, appressed pubescent; ovary ellipsoid, ca. 1 mm long, glabrous; style short, obscure; stigma inconspicuous. *Fruits* unknown.

Distribution – Adi Island; Madang District (PNG).

Habitat & Ecology – Forest; alt. 20-80 m.

Local name – Inassen (Biak).

Specimens examined (11 sheets) – Koster BW11231; Moll BW11516; White NGF10252, 10307; Schlaginhaufen 23.

Notes – *Endiandra euadenia* Kosterm. is characterized by the whitish twigs which in contrast with dark petiole and reddish brown inflorescence axis.

16. Endiandra faceta Kosterm.

Endiandra faceta Kosterm., Reinwardtia 7 (1969) 477. – Type: *Carr 12195* (holo BM; iso BM, L, SING), Koitake, PNG.

Tree 13 m high. *Twigs* solid, thin, pale or whitish, becoming dark color toward upper part, smooth, glabrous. *Terminal buds* small, conical, up to 2 mm long, with dense, straight, appressed hairs. *Leaves* alternate; petiole thin, black contrast to pale bark, flat above, up to 1 cm long, glabrous; blade coriaceous, narrowly elliptic, 4-7.5 x 1.5-2.5 cm, glabrous on both surfaces, apex acuminate (0.5-0.8 cm acumen), base cuneate; midrib slightly raised above, raised below, both surfaces glabrous; lateral veins diverging, 6-7 pairs, sometimes veins in between almost as long, erect, flat, obscure, glabrous above, prominent below, arcuate towards margin; minor venation coarsely reticulate; domatia absent. *Inflorescences* paniculate, short, up to 2 cm long, terminal, few-flowered, very sparse pubescent but more hairs toward apex; bracts caducous; pedicels slender, 2

x 0.6 mm. *Flowers* ochre-yellow (fresh), 3 mm long, 2-2.5 mm in diameter; tepals spreading, narrowly ovate, acute, 1.5 mm, almost glabrous outside, with basal triangular hairy patch inside; glands none; stamens 3; anthers elongate, sessile, 1.5 mm long, densely, golden, pulverulently pilose; filament none; locules small; staminodia none; ovary ellipsoid, glabrous; style short; stigma inconspicuous. *Fruits* unknown.

Distribution – Koitake (PNG).

Habitat & Ecology – Forest; alt. 450 m.

Specimens Examined (2 sheets) – Carr 12195.

Notes – *Endiandra faceta* Kosterm. is characterized by whitish or pale-colored bark and coarse minor leaf venation. Some vegetative and floral characters in the description are following Kostermans (1969).

17. Endiandra flavinervis Teschner – Figure 1.17, 1.18.

Endiandra flavinervis Teschner Engl. Bot. Jahrb. 58 (1923) 416. – Type: *Ledermann 10876* (iso BO, BM,L, SING), Sepik-Gebiet, PNG.

Tree 9 to 36 m tall, up to 90 cm in diameter. *Twigs* light to dark brown, solid, lenticellate, sometimes flaky, glabrous. *Terminal buds* small, 2-6 mm long, densely appressed, golden pubescent. *Leaves* alternate; petiole slender, terete**,** canaliculate above, 0.8-1.5 cm long, glabrous; blade subcoriaceous, narrowly elliptic to elliptic, 9-17 x 3-5.5 cm, shiny, glabrous above, with sparsely appressed hairs, sometimes papillose, glaucous below, apex apiculate, base cuneate; midrib flat or impressed, with appressed hairs (at the base) above, raised, glaborus below; lateral veins spreading, 7-10 pairs, thin, flat**,** glabrous above, raised, glabrous below; minor venation finely reticulate, prominent. *Inflorescences* paniculate, up to 16 cm long, terminal or axillary, many-flowered, with dense curly hairs; bracts caducous; pedicels slender, 2-4 mm long. *Flowers* yellow to orange (fresh), spreading, 6-7 mm in diameter; tepals nearly equal, 2-3 x 1-2.4 mm, elliptic, glabrous inside, with dense curly hairs outside; glands united to form a disc-like appendage, yellow (fresh), 0.6-1 mm high; stamens 3, anthers somewhat

triangular or ovate, ca. 0.5-0.75 x 0.7-0.8 mm, glabrous; locules large covering most of anther space; staminodia none; receptacle deep, warty, glabrous; ovary ovoid, ca. 2-3 mm long, smooth or warty, glabrous; style short, 0.5 mm long; stigma inconspicuous. *Fruits* immature, green (fresh), becoming dark purple when mature, oblong or narrowly ellipsoid, 2-2.5 x 1-1.5 cm.

Distribution – Bulolo, Benim, Gelem, Talasea (PNG).

Habitat & Ecology – Rain forest, disturbed mid-mountain forest or logging area, on ridge, on red clay loam with occasional basic volcanic boulders; alt. 15-1067 m.

Local names – Karabum (Benim), Horu Topo (Garaina).

Specimens examined (15 sheets) – Conn & Katik LAE66006; Gillison NGF25065; Gray 5219; Frodin NGF26620; Havel & Henry NGF9187; Havel & Kairo NGF15488; Henty & Frodin NGF27344; Loi & Havel NGF17166; Mc Veigh & Ridgwell NGF7371, 7325; Womersley, Floyd & Havel NGF5281; Womersley & Whitmore NGF15379.

Notes – According to Kostermans (1969), the type specimen of the species was missing and he had annotated several specimens based on the protolog. It is interesting to note that Teschner (1923) had mentioned the absence of glands and the presence of staminodia in this species. Actually, the glands are present but in the form of a ring-like appendage surround the stamens. This species has affinity to *E. forbesii* Gamble in term of floral characters, however *E. flavinervis* is distinct from *E. forbesii* in dried leaf coloration (brownish in *E. flavinervis* vs blackish in *E.* forbesii) and number of lateral veins (7-10 pairs in *E. flavinervis* vs 12-14 pairs in *E. forbesii*).

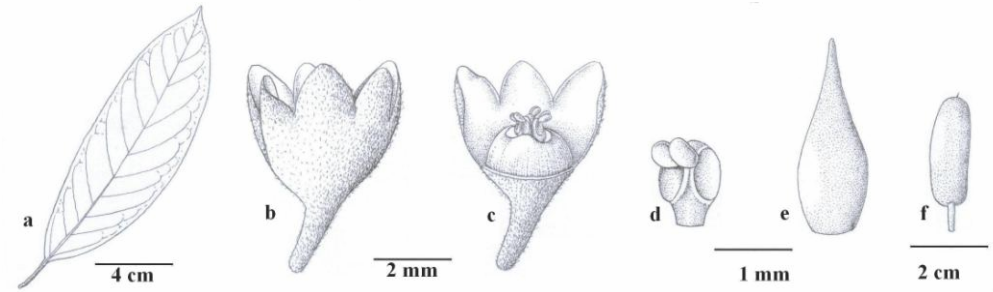

Figure 1.17. *Endiandra flavinervis* Teschner. a. leaf, b. intact flower, c. open flower, d. stamen, e. pistil (*Womersley & Whitmore NGF15379*), f. fruit (*Havel & Kairo NGF15488*)

18. Endiandra forbesii Gamble – Figure 1.18.

Endiandra forbesii Gamble, Bull. Misc. Inform. Kew (1910) 153. – Type: *Forbes 543* (Iso BM, FI, K, L), Sogeri, PNG.

Tree up to 30 m tall, 30 cm in diameter. *Twigs* brown, solid, smooth, sparsely appressed pubescent. *Terminal buds* conical, 6 mm long, with appressed, greyish hairs. *Leaves* alternate; petiole stout, terete, canaliculate above, 1.5-2.6 cm long, glabrous; blade subcoriaceous, narrowly elliptic, 18-25 x 6-10 cm, glabrous above, with sparsely appressed hairs, glaucous below, apex acuminate (1.5-2 cm acumen), base attenuate; midrib impressed above, raised below**,** glaborus; lateral veins diverging, 12-14 pairs, slightly impressed above, raised below, glabrous; minor venation finely reticulate, prominent. *Inflorescences* paniculate, up to 23 cm long, axillary, few-flowered, with dense curly hairs; bracts caducous; pedicels slender, 4-5 mm long. *Flowers* white to yellow (fresh), spreading, 4-7 mm in diameter**;** tepals subequal where inner ones little narrower than outer ones, but almost as long, 2-3.2 x 1.5-2.5 mm, ovate, with sparse minute indument or glabrescent inside, with dense curly hairs outside; glands united to form a disc-like appendage, yellow (fresh), ca. 0.6 mm high; stamens 3; anthers yellow (fresh), somewhat triangular or ovate, ca. 0.4 x 0.6 mm**,** glabrous; locules small, roundish; staminodia none; receptacle deep, pubescent**;** ovary ovoid**,** ca. 2 mm long, smooth, glabrous; style short; stigma inconspicuous. *Fruits* green.

Distribution – Tobelo, Totodoku (Moluccas), Biak, Mimika; Milne Bay, Bulolo, Sogeri (PNG).

Habitat & Ecology – Montane forest; alt. 0-1220 m.

Local names – Tapoko (Tarie), Manaed (Kaibo), Inassen (Biak).

Specimens examined (21 sheets) – Forbes 534 (images), 14099; Exp. Lunquist 152 (bb32871); Henty NGF16963; Kostermans 627, 629, 1689; Kostermans & Tangkilisan 67, 136; Moll BW9553; Rastini 190; White NGF10151; Tangkilisan 269.

Notes – Lateral veins and dried leaves coloration are used to recognized the species at the first place. Erect patent, straight lateral veins and dark leaves will lead to *E. forbesii*. The inflorescence has many branches with dense indument

clothed the shoots and flowers. This species is similar to *E. flavinervis* Teschner (see notes above). Moreover, although the type specimen was collected from high altitude locality, other specimens were collected from lowland forests.

Observation on fused gland development showed that 3 immature stamens were completely covered by fused gland and later when mature, they will burst out of top part of gland. Flower buds already have fused gland structure that covers completely immature stamens and a pistil.

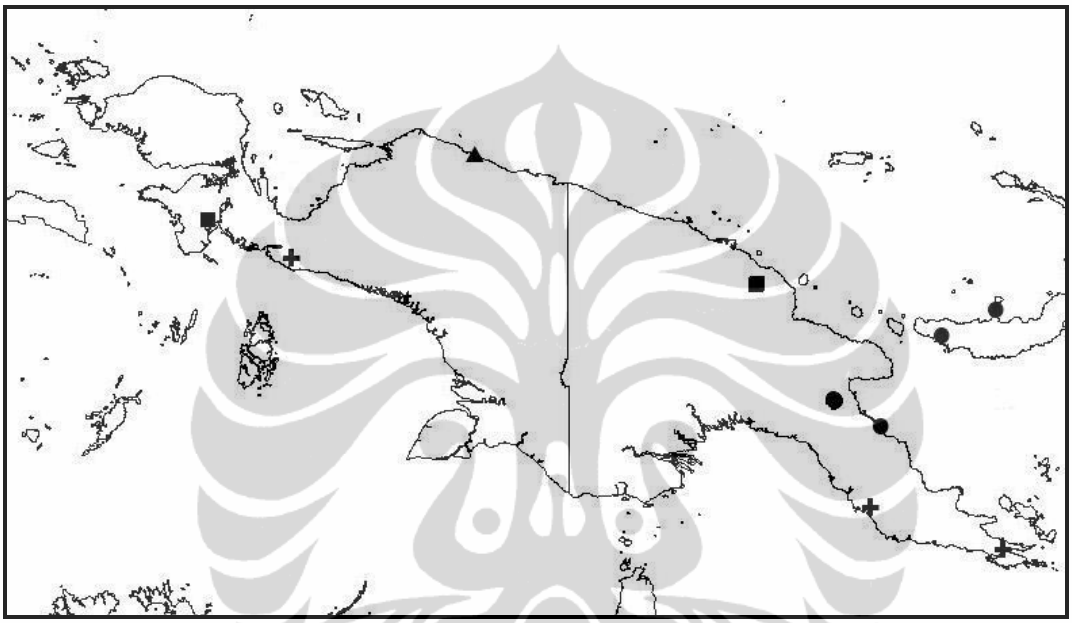

Figure 1.18. Species distribution of *E. flavinervis* (●), *E. engleriana* (▲), *E. euadenia* (■) and *E. forbesii* (✚)

19. Endiandra fulva Teschner – Figure 1.19, 1.20.

Endiandra fulva Teschner, Engl. Bot. Jahrb. 58 (1923) 416. – Types: *Ledermann 11089* (holo), Sepik-Gebiet, PNG.

Tree up to 25 m high, 70 cm in diameter. *Twigs* dark-colored, solid, glabrous. *Terminal buds* narrowly conical, 4-7 mm long, with dense appressed short hairs. *Leaves* alternate; petiole slender, flat, 0.6-1.2 cm long, glabrous; blade coriaceous, narrowly elliptic, 7-10.5 x 2.7-4 cm, glabrous on both sides, apex acuminate, base attenuate; midrib flat above, raised below, both surfaces glabrous; lateral veins spreading, thread-like, 6-7 pairs, thin, flat or slightly impressed above, prominent below**,** glabrous both sides; minor venation finely reticulate,

prominent. *Inflorescences* paniculate, up to 14 cm long, terminal or axillary, many-flowered, with sparse golden long curly hairs**;** bracts caducous; pedicels slender, ca. 1 mm long. *Flowers* white or cream-yellow (fresh), half-erect, 2-2.5 mm in diameter; tepals thin, fragile, subequal, narrowly ovate, 1.4-2.2 x 1-1.2 mm, inside with sparse curly hairs especially where anthers attached; with sparse curly hairs outside; glands 3 pairs, separate, each pair flanks stamens, reniform, 0.4 x 0.4 mm**;** stamens 3; anthers rounded or somewhat rectangular, 0.6-0.7 mm long, glabrous**;** filament short, 0.2 mm long; locules small, roundish; staminodia 3, cordate, glabrous, short stalked; receptacles shallow, with dense curly hairs; ovary ellipsoid, ca. 0.3-1.8 mm long, glabrous; style 0.4-0.5 mm long; stigma inconspicuous. *Fruits* immature, green.

Distribution – Cyclops Mts., Mt. Baboko, Idenburg River (W Papua); Kassam Pass, Alola (PNG).

Habitat & Ecology – Forest along creek; alt. 1150-1738 m.

Specimens examined (6 sheets) – Carr 13895; van Royen NGF5124 & 3701; Versteegh BW904; Versteegh & Brass 12579.

Notes – It is not known where the types are deposited but Kostermans (1969) has cited specimens as new records and his conclusion is adopted here. *Endiandra fulva* is characterized by yellowish grey hairs on inflorescences with blackish twigs and leaves when dried. The flowers bear 3 pairs of separate, basal glands.

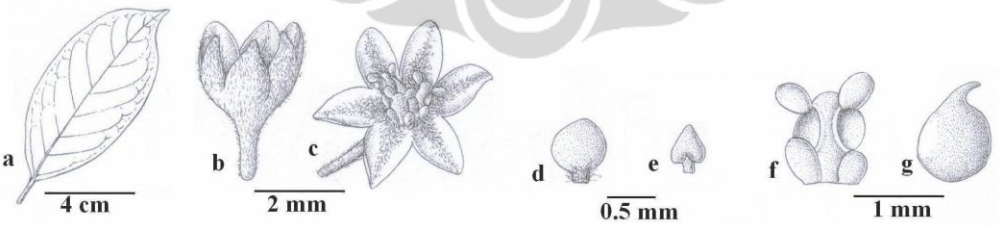

Figure 1.19. *Endiandra fulva* Teschner. a. leaf, b. intact flower, c. open flower, d. gland, e. staminode, f. stamen, g. pistil (*Royen 5124*).

20. Endiandra gem Kosterm.

Endiandra gem Kosterm., Reinwardtia 7 (1969) 483. – Type: *Anta 64* (holo BO; iso BO, G, K, L), Sakur, W Papua.

Tree. *Twigs* slender, grey, solid, with sparse appressed long hairs, sparser downward. *Terminal buds* thin, with appressed hairs. *Leaves* alternate; petiole slender, 1-1.5 cm long, slightly canaliculate above, glabrous; blade chartaceous, elliptic, 8-15 x 3.5-6.5 cm, glabrous on both surfaces, apex apiculate, base cuneate or attenuate; midrib slightly impressed above, raised below, glabrous; lateral veins diverging, 6-7 pairs, slightly impressed above, raised below, glabrous; minor venation finely reticulate. *Inflorescences* unknown. *Flowers* unknown. *Infructescences* axillary, 4-7 cm long, thin, with sparse long straight hairs. *Tepals* ovate-triangular, acute, with appressed straight hairs outside; glands separate, basal, orbicular, as long as the anthers; stamens 3; anthers tranverse-oblong, 0.5-0.75 mm long; locules round, large; staminodia none. *Fruits* black, narrowly ellipsoid, 2.5 x 1 cm.

Distribution – Sakur, Raja Ampat (W Papua).

Habitat & Ecology – Forest, alt. 5-100 m.

Local name – Gem (Sakur).

Specimens examined (3 sheets) – Anta 64; Mirmanto & Ruskandi s.n.

Notes – Kostermans (1969) based his description on a fruiting specimen with remnants of flower observable at the base and described by Kostermans. The species is closely related to *E. glauca* R.Br. however it differs in gland arrangement (separate, basal glands in *E. gem* vs fused glands in *E. glauca*). Flowers characters in this description are following Kostermans (1969).

21. Endiandra gemopsis Kosterm. – Figure 1.20.

Endiandra gemopsis Kosterm., Reinwardtia 8 (1970) 80. – Type: Kostermans 174 (holo BO; A, BISH, BM, BO, K, L, P), Manokwari, W Papua.

Tree 5-12 m tall. Twigs solid, thin, pale-colored, sometimes lenticellate, with sparse appressed short, straight hairs at upper part to glabrous. *Terminal buds* narrowly ovoid, 3-10 mm long, with dense appressed, short, straight hairs**.** *Leaves* alternate; petiole thin to slightly stout, canaliculate**,** dark-colored, sometimes contrast to bark, 0.7-1 cm long, with sparse very short hairs or glabrous; blade

chartaceous, elliptic to broadly elliptic, 11-21 x 5-11 cm, glabrous above, glabrous with brown dots below, apex apiculate, base cuneate; midrib impressed above, raised below, glabrous; lateral veins diverging, 8 pairs, flat or slightly impressed above, raised below, glabrous; minor venation finely reticulate, prominent. *Inflorescences* somewhat spicate, axillary, up to 8 cm, few-flowered, clothed with dense, appressed, short, straight hairs; bracts subtending several flowers, large, rounded, with hairs same as inflorescence; pedicels stout, short, dense pubescent. *Flowers* erect, 1.5-2 mm in diameter; tepals narrowly elliptic, thin (fragile), involute, 1.7 x 0.8 mm, with dense appressed hairs outside, glabrous inside; glands fused, 1 mm width, 0.3 mm high, glabrous; stamens protrude from fused glands, 0.4 mm high (from gland), glabrous; anthers glabrous; locules roundish; staminodia none; receptacle deep, glabrous inside; ovary glabrous. *Fruits* sessile, ellipsoid, 1.8 x 1.2 cm.

Distribution – Manokwari, Sururem (W Papua).

Habitat & Ecology – Forest; alt. 10-540 m.

Local name – Menako (Manikiong)

Specimens examined (5 sheets) – Kostermans 174; van Royen & Sleumer 6877.

Notes – The species shows affinity to *E. beccariana* Kosterm. and *E. gem* Kosterm based on the chartaceous, elliptical leaves and fine minor leaf venation. However, *E. gemopsis* is distinct from *E. beccariana* in the bark color and petiole length (pale-colored and up to 1 cm, respectively in *E. gemopsis* vs dark-colored and up to 2.3 cm) and from *E. gem* in the glands arrangement (fused in *E. gemopsis* vs separate in *E. gem*).

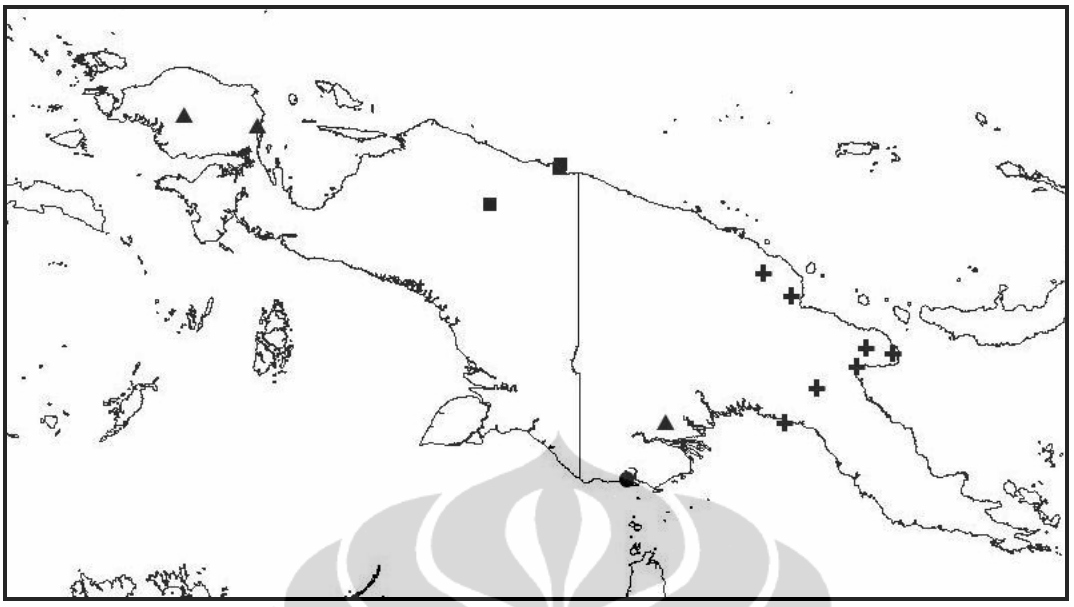

Figure 1.20. Species distribution of *E. glauca* (●), *E. gemopsis* (▲), *E. fulva* (■) and *E. grandifolia* (✚)

22. Endiandra glauca R.Br. – Figure 1.20, 1.21.

Endiandra glauca R.Br., Prodr. (1810) 402. – Type: *Bank & Solander s.n.* (holo BM), Endeavour River, Australia.

Endiandra merrilliana Allen, J. Arnold Arb. 23 (1942) 149. – Type: *Brass 59* (holo A; iso BM, BO, L), Tarara, Wassi Kussa River, Western Division, PNG.

Endiandra microphylla Teschner, Engl. Bot. Jahrb. 58 (1923) 417 – Type: *Ledermann 9106* (iso L), Sepik-Gebiet, PNG.

Tree up to 25 m tall. *Twigs* solid, slender, dark brown, with dense appressed hairs. *Terminal buds* conical, 3 mm long, densely appressed pubescent. *Leaves* alternate; petiole thin, terete, 0.5-0.8 x 0.1 cm, canaliculate above, glabrous or pubescent; blade chartaceous, elliptic, 5.5-9 x 2-3.6 cm, glabrous or with sparse minute appressed hairs above, glaucous and covered with appressed hairs below, apex apiculate, base cuneate; midrib slightly impressed above, raised below, sometimes pubescent below; lateral veins spreading, 6-7 pairs, slightly impressed above, raised below, glabrous; minor venation finely reticulate. *Inflorescences* paniculate, 1-6 cm long, terminal, sometimes axillary, few-flowered, rusty brown, densely erect pubescent; bracts linear or lanceolate, 1-2 mm long; pedicels slender, 1 mm long. *Flowers* greenish (fresh), spreading, ca. 3-

3.5 mm in diameter; tepals nearly equal, elliptic, 1-4 x 1-2 mm, glabrous or pubescent inside, sparsely or densely pubescent outside; glands united to form a disc-like appendage; stamens 3; anthers 0.5-0.8 x 0.2-0.4 mm, protruding from fused glands, glabrous; locules roundish, large covering most of anther space; staminodia none; receptacle shallow, glabrous; ovary subglobose, 1.6 mm long, glabrous; style 0.1-0.3 mm long; stigma inconspicuous. *Fruits* deep purple or blue-black, ellipsoid, 1.5-2.6 x 1.1-1.4 cm.

Distribution – Sepik-Gebiet, Tarara (PNG); Queensland.

Habitat & Ecology – Rain forest, rain forest margin; alt. up to 450 m.

Specimens examined (11 sheets) – Bank & Solander s.n.; Brass 8589; Gray 3211; Hyland 11598 & 12094; Ledermann 9106.

Notes – This species is often confused with *E. hypotephra* F.Muell. because both has glaucous leaves underside. Many specimens previously annotated as *E. glauca* R.Br. were re-annotated as *E. hypotephra* F.Muell. based on the leaf blade and flower size. *Endiandra glauca* has smaller size. *Endiandra merrilliana* Allen is synonymy of *E. glauca* R.Br. because it conforms with the characters of *E. glauca*, i.e., small leaves, glaucous underside, and consists of fused glands.

Kostermans (1969) reported that the type specimen of *E. microphylla* (Ledermann 9106) was lost, but apparently the type is still exist in L, and it conforms with characters of *E. glauca* above. In his protolog, Teschner described that *E. microphylla* bears no glands, however, he actually did not aware that the glands were fused to form ring-like appendages.

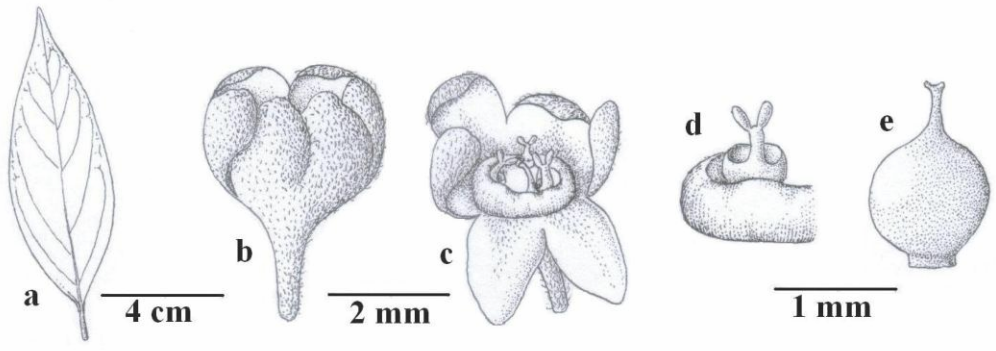

Figure 1.21. *Endiandra glauca* R.Br. a. leaf, b. intact flower, c. open flower, d. a stamen on part of disc-like gland, e. pistil (*Brass 8589*)

23. Endiandra grandifolia Teschner – Figure 1.20, 1.22.

Endiandra grandifolia Teschner, Engl. Bot. Jahrb. 58 (1923) 417. – Type: *Schlechter 17691* (holo K), PNG.

Tree up to 25 m high, 45 cm in diameter. *Twigs* solid, thick, greyish or pale brown with shallow longitudinal fissures, lenticellate, 5-8 mm in diameter, with dense curly hairs. *Terminal buds* stout, conical, 5-10 x 4-5 mm, with dense curly hairs. *Leaves* alternate; petiole stout, slightly canaliculate above, 1.5 x 0.3-0.5 cm, tomentose; blade coriaceous, elliptic to subobovate, 23-42 x 13.5-24 cm, glabrous or with sparsely short hairs above, papillose, densely tomentose below, apex apiculate or rounded, base rounded; midrib flat or slightly raised above, flat or raised below, both surfaces densely pubescent; lateral veins spreading, 10-15 pairs, slightly impressed above, prominent below, both sides with dense curly hairs, arcuate towards margin; minor venation finely reticulate, immersed to impressed above, prominent below. *Inflorescences* paniculate, compact, up to 10 cm long, terminal or axillary, reddish brown, many-flowered, densely tomentose; lower bracts narrowly elliptic, acuminate, up to 1.2 cm long, with dense curly hairs on both sides; upper bracts same as lower bracts but smaller, up to 0.4 cm long; pedicels slender, 2 x 0.6 mm, with dense curly hairs. *Flowers* dark cream, spreading, 2.5-3.0 mm in diameter; tepals nearly equal, narrowly elliptic, 2 x 1.2 mm, densely curly pubescent; glands separate, basal, 3 pairs, each pair flanks stamen, reniform or heart-shaped, 0.4-0.5 x 0.35-0.4 mm, pilose; stamens 3; anthers ovate to rounded, 0.4-0.5 x 0.5-0.6 mm, sparsely pubescent; filament short, 0.2-0.4 mm long, pubescent; locules large, roundish, covering about half of anthers; staminodia 3, cordate, pilose, 0.4-0.6 x 0.4-0.5 mm, almost sessile; receptacles shallow, densely pubescent; ovary ovoid, 0.7-1 mm long, glabrous; style 0.4 mm long; stigma inconspicuous. *Fruits* immature, green, oblong, 5-8 x 4.5 cm.

Distribution – Raja Ampat (W Papua); Madang, Morobe (PNG).

Habitat & Ecology – Lowland forest; alt. 60-180 m.

Specimens examined (12 sheets) – Clemens 1600, 2110; Hoogland 4919; Kairo 426; Katik W2776; Millar NGF12036; Mirmanto & Ruskandi 09305;

Schlechter 17691; Schodde & Craven 4313a; Streimann & Kairo NGF42451; White NGF10269.

Notes – *Endiandra grandifolia* may be differentiated from both *E. beccariana* and *E. papuana* by observing the shape or fusion of the glands. Some species of *Endiandra*, including *E. grandifolia*, bear three pairs of glands at the bases of each stamen. However, these glands sometimes may unite to each other because of the limited space inside the flower and forming a disc-like appendage surrounding the stamens. This is the case with both *E. beccariana* and *E. papuana*.

Previously, the species was only collected from Madang and Morobe districts of Papua New Guinea. The occurrence of *E. grandifolia* in Waigeo Island (Raja Ampat) extend its distribution toward northwestern part of New Guinea.

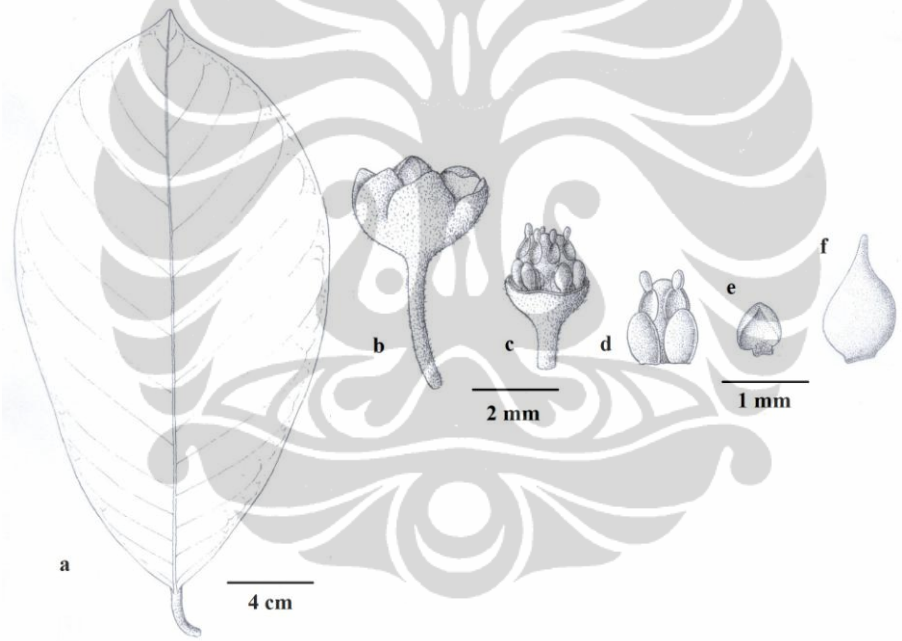

Figure 1.22. *Endiandra grandifolia* Teschner. a. leaves, b. intact flower, c. open flower, d. stamen with a pair of glands, e. staminode, f. pistil (*Hoogland 4919*)

24. Endiandra havelii Kosterm. – Figure 1.25.

Endiandra havelii Kosterm., Reinwardtia 7 (1969). – Type: *Havel & Kongara NGF17291* (holo BO; iso BO, K, L), Watut, Morobe District, PNG.

Tree up to 22 m high, up to 40 cm in diameter. *Twigs* solid, grey or red-brown, smooth, glabrous. *Terminal buds* grey, lanceolate, curved, 8 mm long,

sericeous. *Leaves* alternate; petiole flat above, 1.2-1.8 cm long, glabrous; blade chartaceous, elliptic, 8-10.2 x 3.4-5 cm, glabrous above, sericeous, glaucous below, apex acuminate, base cuneate; midrib flat or slightly impressed above, raised below, both surfaces glabrous; lateral veins erect, straight, 9 pairs, slightly impressed above, prominent below, both surfaces glabrous; minor venation finely reticulate, prominent. *Inflorescences* unknown. *Flowers* unknown. *Infructescences* axillary, up to 12 cm or more, few-branches, glabrous; peduncle up to 4 cm. *Fruits* green (immature), oblong, 1.8 x 0.4 cm, glabrous; tepals persist, ovate, acute, fleshy, up to 7 mm long, glabrous.

Distribution – Wau (PNG).

Habitat & Ecology – Forest, on banks of creek; alt. 1372 m.

Specimens examined (3 sheets) – Havel & Kongara NGF17291.

Local name – Lumupapami (Manki).

Notes – This species has affinity to *E. forbesii* Teschner based on dried leaf coloration and texture, but *E. havelii* bears smaller leaf blade and less number of lateral veins Persistence of tepals in fruits is a good character to recognize the species, other species are commonly with naked fruit.

25. Endiandra hypotephra F. Muell. – Figure 1.23, 1.25.

Endiandra hypotephra F. Muell., Fragm. Phytogr. Austral. 5 (1866) 166. – Type: *Dallachy sn.* (lecto MEL), Rockingham Bay, Australia.

Tree up to 30 m tall, 40 cm in diameter. *Twigs* solid, slender, dark brown, somewhat glabrous. *Terminal buds* small, 2.5 x 0.8 mm, densely pubescent. *Leaves* alternate; petiole slender, terete, 0.5-0.7 x 0.1 cm, canaliculate above, glabrous or pubescent; blade chartaceous, elliptic, 9.5-13 x 3.3-5.2 cm, glabrous both surfaces, whitish or glaucous below, apex acuminate (ca. 1 cm acumen), base cuneate; midrib slightly impressed above, raised below, sometimes pubescent below; lateral veins spreading, 6-7 pairs, slightly impressed above, raised below, glabrous; minor venation finely reticulate. *Inflorescences* raceme or paniculate, 1-

6 cm long, terminal, sometimes axillary, few-flowered, rusty brown, densely erect pubescent; bracts lanceolate, 1-2 x 1 mm; pedicels slender, 1 mm long. *Flowers* dull red (fresh), spreading, ca. 4.5-7 mm in diameter; tepals subequal with inner ones smaller, elliptic, 2-4 x 2-2.5 mm, glabrous or pubescent inside, sparsely or densely pubescent outside; glands united to form a disc-like appendage, hairy; stamens 3, red (fresh), protruding from center of fused glands; anthers triangular, tip obtuse, ca. 0.7-1 x 0.7-1.2 mm, glabrous; locules roundish, small; staminodia none; receptacles ovary ovoid, ca. 3 mm long, glabrous; style 0.5-1 mm long; stigma inconspicuous. *Fruits* black, obovoid, 1.5-2.5 x 1 cm; tepals persist.

Distribution – Aru Island; Manokwari, Merauke (W Papua); Oriomo, Weam, Najaja, Lake Daviumbu (PNG); Queensland.

Habitat & Ecology – Rain forest, open forest, on limestone; alt. 5-1000 m.

Local name – Gotal (Arunese).

Specimens examined (41 sheets) – Aet 328; Balgooy & Mamesah 6465, 6324, 6376; Brass 5940, 7789, 7762; Buwalda 5102, 5394, 411; Dockrill 1502; Grey & White NGF 10377; Hyland 12476; Jaheri sn, 74; Kajewski 1040, 1411; Kanehira & Hatusima 13097, 13112; Mueller s.n.; Reksodihardjo 236; Ridsdale NGF 33563, 33622; White 8017.

Notes – *Endiandra hypotephra* is frequently confused with *E. glauca* R.Br. because of its glaucous lower leaf surface, however the two are different in leaf and flower size (*E. hypotephra* has bigger leaf blade and flower).

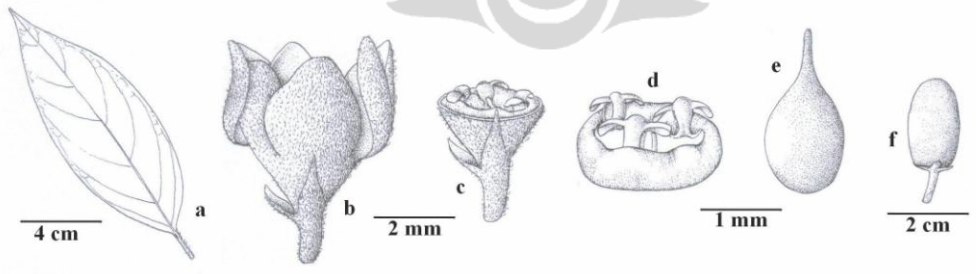

Figure 1.23. *Endiandra hypotephra* F.Muell. a. leaf, b. intact flower, c. open flower, d. stamens with fused glands, e. pistil, f. fruit (*Grey & White NGF 10377*)

26. Endiandra impressicosta Allen – Figure 1.24, 1.25.

Endiandra impressicosta Allen, J. Arnold Arbor. 23 (1942) 151. – Type: *Brass 7619* (holo A; iso BO, L), Lake Daviumbu, Middle Fly River, PNG.

Tree 8 to 25 m tall, up to 35 cm in diameter. *Twigs* solid, brown, terete, glabrous. *Terminal buds* narrowly conical, straight, 3-5 mm long, with dense long appressed indument. *Leaves* alternate; petiole thin, slightly canaliculate, 0.8-1.5 cm long, glabrous; blade coriaceaous, elliptic, 7-13.5 x 2.5-5.5 cm, glabrous both surfaces, apex acute, base cuneate; midrib slightly impressed above, raised below, glaborus; lateral veins spreading, ca. 6 pairs, obscure, glabrous above, slightly raised below, disappearing toward margin; minor venation obscure, smooth. *Inflorescences* paniculate, 3-6 cm long, terminal or axillary, many-flowered, sparsely short, appressed hairs or almost glabrous in main axis, and with dense short, erect hairs in secondary axis; bracts caducous; pedicels thin, short, ca. 1 mm long, with hairs same as secondary inflorescence axis. *Flowers* white or cream (fresh), fragrant (fresh), 4.5-6 mm in diameter, spreading; tepals unequal, outer tepals broadly elliptic, 2.5 x 1.5-1.8 mm, inner tepals elliptic, 2.5 x 1-1.3 mm, with sparse, short, erect hairs inside where stamens attached, glabrous outside; glands none; stamens 3; anthers triangular, 1.5 x 0.8-1 mm long, sessile, basal parts covered with yellow, long, appressed hairs; locules slit-like; staminodia none; receptacles shallow, pubescent inside and outside; ovary subglobose, 0.7-1 x 0.5-0.8 mm, glabrous; style short, 0.2-0.3 mm long; stigma inconspicuous. *Fruits* purple- or blue-black (fresh), ellipsoid, 4-5 x 2.5 cm.

Distribution – Aru Islands; Bagam and Bajampa (W Papua); Lower and Middle Fly Rivers (PNG); Queensland.

Habitat & Ecology – Rain forest, on flooded riverbanks, canopy; alt. 0-500 m.

Specimens examined (14 sheets) – Brass 7619, 8078, 8224; van Balgooy 6770, 6684; van Balgooy & Mamesah 6228, 6395; Gray 04367; Reksodihardjo 240.

Notes – *Endiandra impressicosta* Allen is characterized by the presence of long appressed hairs on anthers and glabrous tepals. Smooth leaf surfaces can be used to recognize the species easily, lateral and minor leaf veins are immersed.

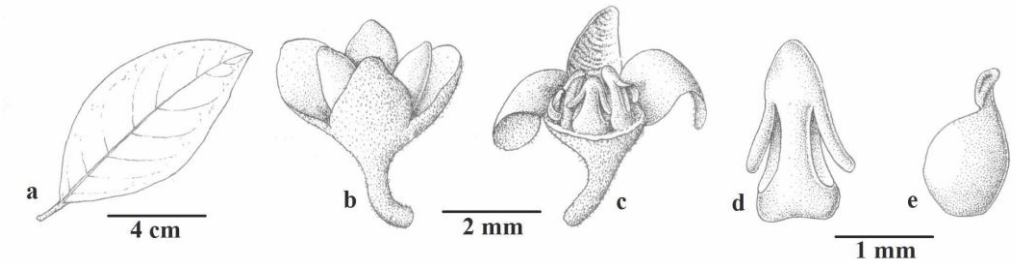

Figure 1.24. *Endiandra impressicosta* Allen. a. leaves, b. intact flower, c. open flower, d. stamen, e. pistil (*Balgooy 6228*)

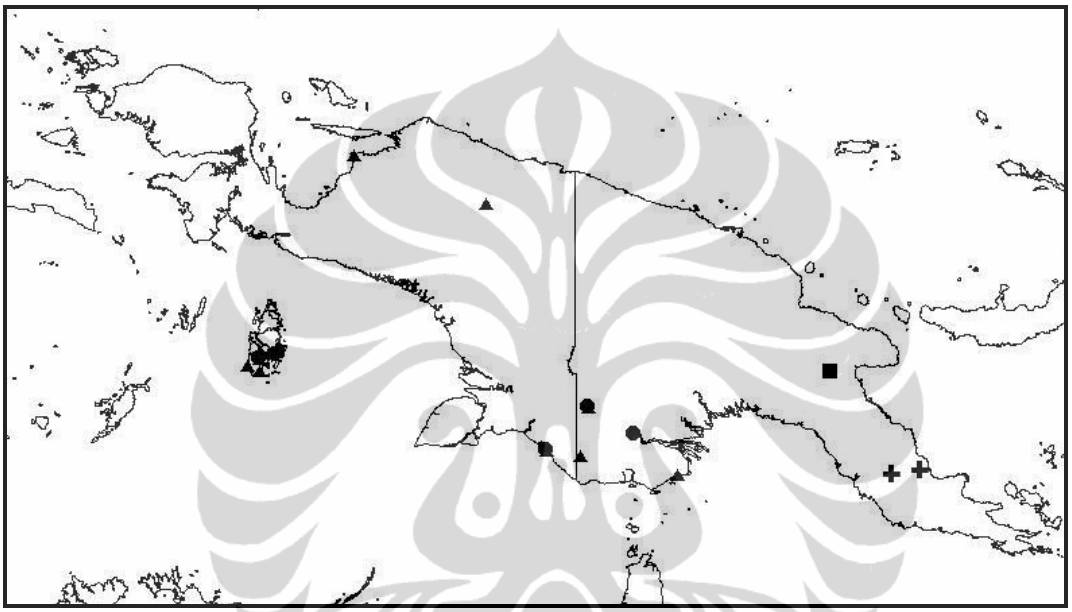

Figure 1.25. Species distribution of *E. impressicosta* (●), *E. hypotephra* (▲), *E. havelii* (■) and *E. inaequitepala* (✚)

27. Endiandra inaequitepala Kosterm. – Figure 1.25.

Endiandra inaequitepala Kosterm., Reinwardtia 7 (1969) 485. – Type: *Carr 15172* (holo BM ; iso BM, K), Isuarava, PNG.

Tree 10 to 32 m tall, 20 cm in diameter. *Twigs* solid, dark-colored, angular at the tip, lenticellate, glabrous**.** *Terminal buds* conical, curved, 5-7 mm long, with dense short erect hairs. *Leaves* alternate, sweet fragrant when crused (fresh); petiole stout**,** canaliculate, 1-2 cm long, with dense short, straight hairs at the tip, glabrous for older leaves**;** blade chartaceous, narrowly elliptic or rarely broadly elliptic, 10-25 x 4.5-9 cm, glabrous both surfaces, apex acute, base cuneate; midrib flat above, raised below, glaborus; lateral veins spreading, 10-13 pairs, slightly raised above, raised below, disappearing toward margin, glabrous on both surfaces; minor venation coarsely reticulate, prominent. *Inflorescences* paniculate, 4-25 cm long, terminal or axillary, yellowish brown, many-flowered, sparsely straight, appressed pubescent in main axis, and dense wavy hairs in secondary axis; bracts caducous; pedicels slender, 3-4 mm long, with dense short, wavy hairs. *Flowers* creamy white (fresh), 3-3.5 mm in diameter, spreading; tepals pinkish (fresh), unequal, outer tepals broadly elliptic, 1.5 x 1.1 mm, inner tepals elliptic, 1 x 0.5 mm, with reddish, dense curly hairs inside, with dense wavy hairs outside; glands none; stamens 3; anthers triangular with truncate tip, 0.5 x 0.4 mm long; locules roundish, large; filament 0.5 mm, pubescent; staminodia none; ovary subglobose, ca. 0.8 mm long, pubescent; style 0.6 mm long; stigma inconspicuous; receptacles shallow, pubescent inside. *Fruits* light brown (fresh), ellipsoid, 9 x 3 cm.

Distribution – Isuarava, Siurang Managalase (PNG).

Habitat & Ecology – Rain forest; alt. 1370 m.

Specimens examined (5 sheets) – Carr 15172, 15370, 16082; Pullen 5556, 5508.

Notes – *Endiandra inaequitepala* was often found in high altitude and recognized by pubescent ovary, coarse reticulation and dense inflorescence.

28. Endiandra invasorium Kosterm. – Figure 1.26, 1.27.

Endiandra invasorium Kosterm., Reinwardtia 7(1969) 486. – Type: *Eddowes & Maru Kumul NGF13129* (holo BO; iso A, BRI, CANB, K, L), Brown River Road, Central District, PNG.

Tree up to 13 m tall, 25 cm in diameter. *Twigs* solid, brown, with dense curly hairs, sparser downward. *Terminal buds* conical, ca. 5 mm long, with dense curly hairs. *Leaves* alternate; petiole thin, terete, 1-1.5 cm long, flat above, curly pubescent; blade subcoriaceous, narrowly elliptic to elliptic, 10-13 x 4.6-6 cm, glabrous above, with curly hairs below, apex acuminate, base cuneate; midrib slightly impressed or flat, with sparse curly hairs above (glabrescent upward), raised, with dense curly hairs below; lateral veins diverging, 7-8 pairs, slightly impressed or flat, glabrous above, raised with dense curly hairs below; minor venation finely reticulate, rather immersed. *Inflorescences* paniculate, length up to 18 cm, axillary or subterminal, many-flowered, rusty brown, densely curly pubescent; bracts linear or lanceolate, ca. 1 mm long; bracts caducous; pedicels slender, 1-2 mm long, with dense curly hairs. *Flowers* yellow (fresh), spreading, 3-3.5 mm in diameter; tepals subequal where inner ones smaller, ovate, 1.5-2 x 1.3-1.5 mm, glabrous inside, with dense curly hairs outside; glands 3 pairs, each pair adnate to filament, 0.5-0.6 mm high; stamens 3; anthers somewhat rounded, 0.5 x 0.5 mm, glabrous; locules roundish, small; staminodia 3, cordate, 0.3 mm, stalked, 0.3 mm, pubescent; receptacle deep, glabrous; ovary ellipsoid, 1.3 mm long, glabrous; style short, ca. 0.3 mm long; stigma inconspicuous. *Fruits* unknown.

Distribution – Brown River Road, Central District (PNG).

Habitat & Ecology – Secondary rain forest; alt. 30 m.

Specimens Examined (3 sheets) – Eddowes & Kumul NGF13129 (3).

Notes – *Endiandra invasorium* Kosterm. is characterized by specific gland presentation, i.e. each pair of glands adnates to filament, where they usually freely reside at the base of filament. The species is similar to the *E. papuana* Lauterb. but differs in gland arrangement (*E. papuana* bears united, disc-like glands, compared to fused basal glands in *E. invasorium*).

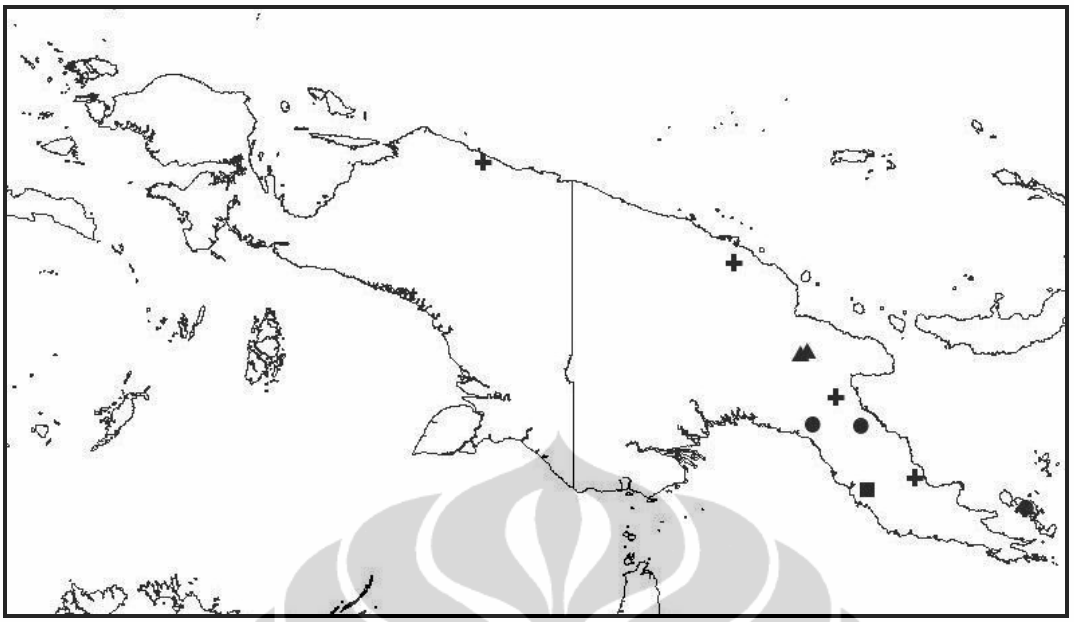

Figure 1.26. Species distribution of *E. lanata* (●), *E. kassamensis* (▲), *E. invasorium* (■) and *E. latifolia* (✚)

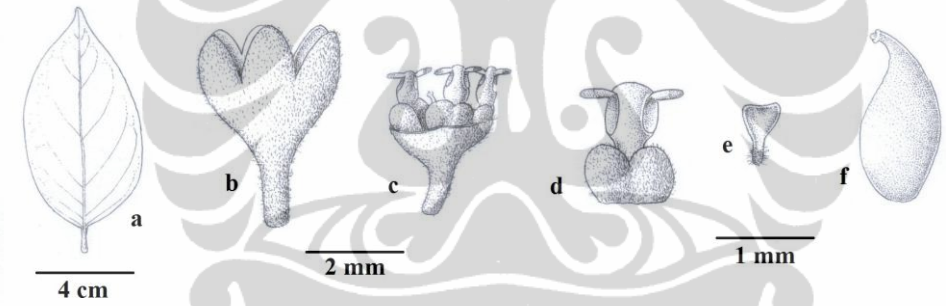

Figure 1.27. *Endiandra invasorium* Kosterm. a. leaves, b. intact flower, c. open flower, d. stamen with a pair of glands, e. staminodia, f. pistil (*Eddows NGF13129*)

29. Endiandra kassamensis Arifiani, *spec. nov.* – Figure 1.26, 1.28.

Endiandra kassamensis Arifiani – Type: *Womersley & Vandenberg 37195* (holo BO; iso SING), Kassam Pass, Kainantu, Eastern Highlands District, PNG.

Tree up to 43 m high, 90 cm in diameter. *Twigs* solid, dark brown, glabrous. *Terminal buds* conical, big, with dense short hairs. *Leaves* alternate; petiole thin, canaliculate above, ca. 1 cm long, glabrous; blade coriaceous**,** narrowly elliptic to elliptic, 11-14 x 3-6 cm, glabrous on both surfaces, apex acuminate, base cuneate; midrib flat to slightly impressed above, raised below, both surfaces glabrous; lateral veins diverging, 10-11 pairs, slightly raised, glabrous on both surfaces; minor venation coarsely reticulate, prominent. *Inflorescences* paniculate, bear many flowers, up to 12 cm long, terminal or axillary, with sparse short hairs; bracts caducous; pedicels slender, ca. 3 mm long, with dense curly hairs**.** *Flowers* brown (fresh), erect, 2 mm in diameter; tepals thin, soft, subequal (inner ones smaller), narrowly ovate, 1.2-1.5 x 1-1.2 mm, with sparse long curly hairs outside, same inside especially basal part at anthers attachment; glands none; stamens 3; anthers somewhat triangular, 1 x 0.6 mm, glabrous; filament short, 0.1 mm long; locules small, roundish; staminodia 3, pentagonal, 0.4 x 0.3 mm, with curly hairs; receptacles deep, with curly hairs; ovary ovoid, 0.6-0.9 mm long, glabrous; style ca. 0.3 mm long; stigma inconspicuous. *Fruits* unknown.

Distribution – Eastern Highlands District (PNG).

Habitat & Ecology – Rain forest, on hillside, subcanopy; alt. 1280-1372 m.

Specimens examined (3 sheets) – Coode & Dockrill 32655; Womersley & Vandenberg 37195.

Notes – *Endiandra kassamensis* Arifiani is different from other species of *Endiandra* in New Guinea because of specific composition of flowers. The species bears no glands but interestingly staminodia are present. The only species that has similar floral composition is *E. crassitepala* Arifiani but *E. kassamensis* can be recognized by thinner and softer tepals. Vegetatively, *E. kassamensis* is similar to *E. fulva* Teschner but bears more lateral veins and coarser reticulation.

Figure 1.28. *Endiandra kassamensis* Arifiani. a. habit; b. intact flower; c. flower with 2 tepals removed; d. anther; e. staminode; f. pistil (*Womersley & Vandenberg NGF 37195*)

30. Endiandra lanata Arifiani, *spec. nov.* – Figure 1.26, 1.29.

Endiandra lanata Arifiani – Type: *Croft 68764* (holo BO; iso BO, SING), Ferguson Island, Milne Bay, PNG.

Tree up to 20 m tall, 50 cm in diameter. *Twigs* solid, dark brown, with dense curly hairs, sparser downward. *Terminal buds* conical, 3-5 mm long, with dense curly hairs. *Leaves* alternate; petiole thin, terete, 0.8-1.5 cm long, flat above, curly pubescent; blade chartaceous, elliptic or subobovate, 7.5-13.5 x 4-6.5 cm, glabrous above, with curly hairs, whitish or glaucous below, apex acute, base attenuate; midrib slightly impressed, with sparse curly hairs above, raised, with dense curly hairs below; lateral veins diverging, 5-7 pairs, slightly impressed or flat, with sparse curly hairs above, raised with dense curly hairs below; minor venation finely reticulate. *Inflorescences* paniculate, length up to 17 cm or more, axillary or subterminal, many-flowered, rusty brown, densely curly pubescent; bracts linear or lanceolate, 1-2 mm long; pedicels slender, 2.5-3 mm long, with dense curly hairs. *Flowers* yellow (fresh), spreading, up to 8 mm in diameter; tepals subequal where inner ones smaller, ovate or broadly ovate, 2.2-2.5 x 1.5-2.5 mm, glabrous inside, with dense curly hairs outside; glands united to form a disc-like appendage; stamens 3; anthers ovate, protruding from fused glands, glabrous; locules roundish, small; staminodia none; receptacle deep, pubescent; ovary ellipsoid, 0.5 mm long, glabrous; style short; stigma inconspicuous. *Fruits* unknown.

Distribution – Milne Bay, Morobe (PNG)

Habitat & Ecology – Mid-montane forest, alt. 150-823 m.

Local name – Kovitiomatanga (Middle Waria)

Specimen examined (5 sheets) – Craven & Schodde LAE947; Croft LAE68764; Streimann & Kairo NGF26160.

Notes – The species has inflorescences with very dense curly hairs similar to *E. papuana* Lauterb. but *E. lanata* is distinct from *E. papuana* in bearing fewer flowers and having smaller leaf size. Additionally, minor leaf veins of *E. lanata* is fine, prominent on the upper surface vs obscure, smooth in *E. papuana*.

Endiandra lanata also shows affinity to *E. gemopsis* Kosterm. but *E. lanata* has more hairs on the twigs and inflorescences compared to *E. gemopsis*.

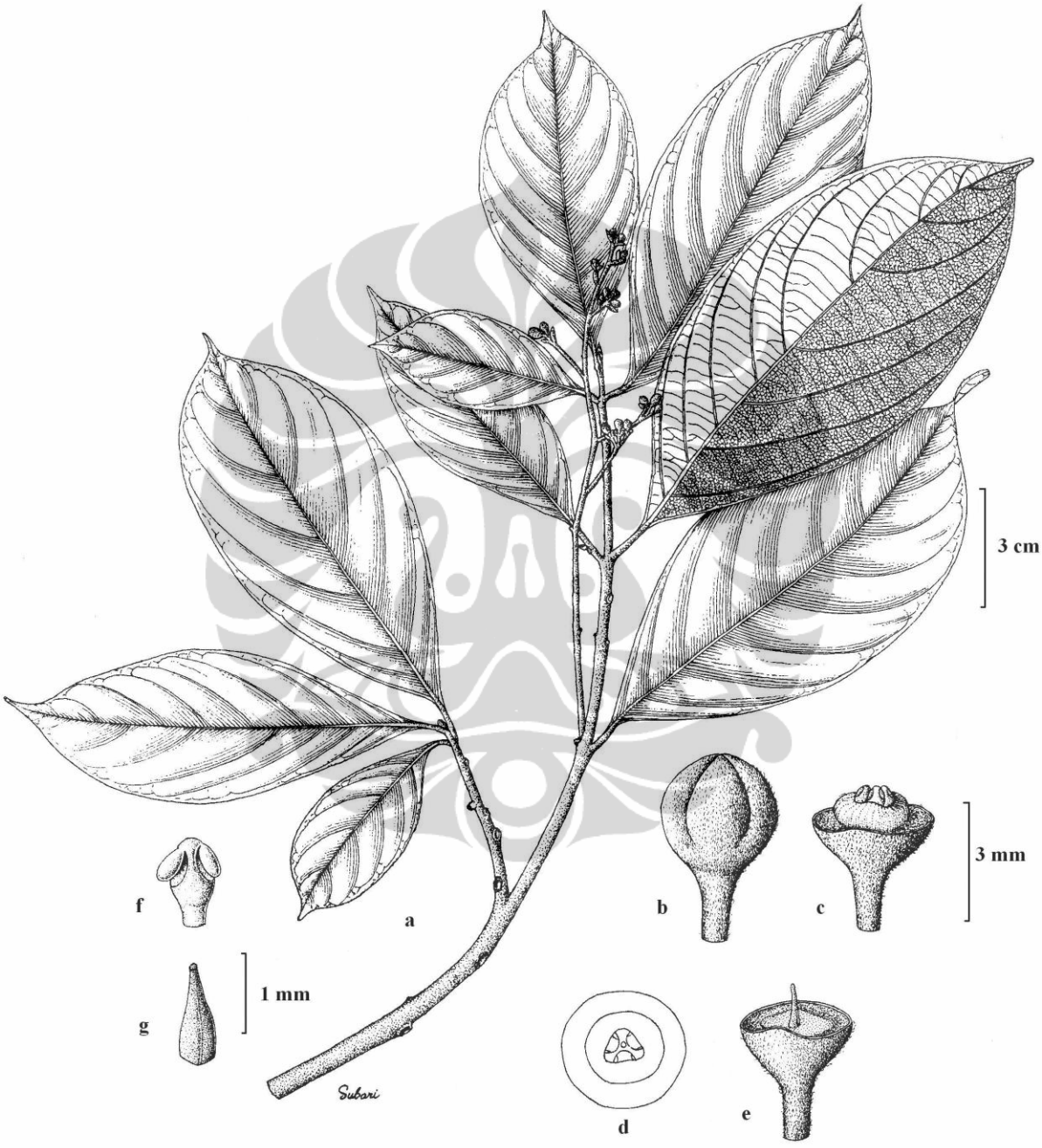

Figure 1.29. *Endiandra lanata* Arifiani. a. habit; b. intact flower; c. flower with tepals removed; d. flower diagram (top view); e. receptacle showing style; f. anther; g. pistil (*Croft LAE 68764*)

31. Endiandra latifolia Kosterm. – Figure 1.26.

Endiandra latifolia Kosterm., Reinwardtia 7 (1969) 487. –Type: *Hoogland 4585* (holo BM; iso L), Tufi sub-district, Northern District, PNG.

Tree up to 46 m tall, 30-60 cm in diameter. *Twigs* brown, with dense short curly hairs, sparser downward. *Terminal buds* elliptic or conical, up to 10 mm long, with very dense short curly hairs**.** *Leaves* alternate; petiole stout, 1.5-2 cm long, flat above, with dense short curly hairs**;** blade coriaceous, rounded, 15-22 x 12-17 cm, glabrous above, below with dense short curly hairs**,** apex and base rounded; midrib broad at the base, flat above, raised below, with dense short curly hairs on both sides; lateral veins spreading, 8-9 pairs, slightly impressed or flat above, raised below, with dense short curly hairs on both sides; minor venation finely reticulate, obscure above, prominent below. *Inflorescences* paniculate, length up to 21 cm, axillary, rusty-brown, many-flowered, with dense curly hairs; bracts ovate, very small, indument same as inflorescence; pedicels thin, 3-5 mm long, indument same as inflorescence. *Flowers* pale green (fresh), erect, 2 mm in diameter; tepals thin, ovate, 1.5 -2 mm, with sparse long erect hairs outside; glands separate, basal, 3 pairs, each pair flanks filament, subglobose, small, sessile; stamens 3; anthers ovate, pointed tip, glabrous; locules roundish, rather large; filament distinct, as long as the anthers; staminodia unknown; receptacles shallow; ovary ovoid, glabrous; style short; stigma inconspicuous. *Fruits* ovoid, 4-4.5 x 2.5-2.8 cm; pedicel 6 cm long.

Distribution – Sidoarsi Mts. (W Papua); Anjura and Siurane areas, Morobe, Milne Bay, and Northern Districts (PNG).

Habitat & Ecology – Lowland, mid-montane forest, by river, on rocky clay; alt. 6-1250 m.

Local name – Kainen (Onjob, Koreaf), Coranga (Biaru), Siepmem (Manikiong).

Specimens examined (8 sheets) – Croft LAE68722; Havel & Kairo NGF15500; Hoogland 4585; Iwanggin BW9047; Pullen 5568; Smith NGF1103.

Notes – The species can easily be distinguished by its large, obtuse leaves with dense short curly hairs underside. Vegetatively, it is similar to *E. grandifolia*

Teschner but the latter has acuminate leaf apex and conspicuous flower bracts, in constrast to rounded leaf apex and minute bracts.

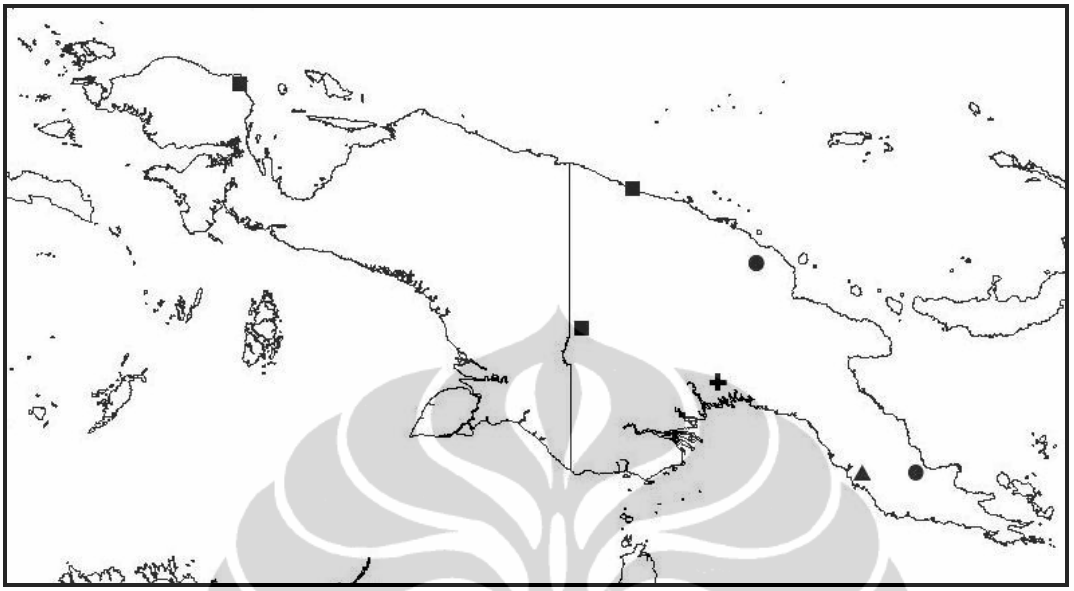

Figure 1.30. Species distribution of *E. magnilimba* (●), *E. macrostemon* (▲), *E. ledermannii* (■) and *E. minutiflora* (✚)

32. Endiandra ledermannii Teschner – Figure 1.30, 1.31.

Endiandra ledermannii Teschner, Engl. Bot. Jahrb. Syst. 58 (1923) 419. – Type: *Ledermann 9626*, Sepik-Gebiet, PNG.

Tree 15-20 m tall. *Twigs* solid, dark-brown, glabrous. *Terminal buds* thin, triangular 2-3 mm long, densely appressed pubescent. *Leaves* alternate; petiole thin, 0.8-1.2 cm long, canaliculate above, glabrous; blade coriaceous, elliptic, 6-8 x 2.5-5 cm, glabrous on both surfaces; apex apiculate, base cuneate; midrib slightly impressed to flat above, raised below, both surfaces glabrous; lateral veins spreading, obscure, 4-8 pairs, slightly raised and glabrous on both surfaces, as prominent as minor veins; minor venation coarsely reticulate, prominent. *Inflorescences* paniculate, few-flowered, length up to 5 cm, axillary, with sparse short hairs, almost glabrous; bracts caducous; pedicels thin, ca. 1 mm long, glabrous. *Flowers* half-erect, 1.5-2 mm in diameter; tepals nearly equal, ovate, 1 x 0.7 mm**,** with dense curly hairs (anther attachment part) inside, with sparse short

hairs outside; glands separate, basal, 3 pairs, each pair flanks filament, reniform, 0.3 x 0.3 mm; stamens 3; anthers ovate, 0.5-0.6 x 0.4-0.5 mm, glabrous; filament short, 0.2 mm long, pubescent; locules large, roundish; staminodia 3, cordate; receptacles shallow, with dense curly hairs; ovary ovoid, 0.7 mm long, glabrous; style short, 0.2 mm long; stigma inconspicuous. *Fruits* unknown.

Distribution – Sepik (PNG).

Habitat & Ecology – Forest, alt. 1000 m.

Specimens examined (5 sheets) – Koster BW11824; Ledermann 6679, 9782; Streimann LAE51864.

Notes – *Endiandra ledermannii* Teschner is closely related to *E. schlechteri* Teschner, but the two can be distinguished by leaf texture, pedicel surface and staminodia shape (coriaceous, glabrous and cordate, in *E. ledermannii*, respectively vs chartaceous, with sparse short hairs and globose in *E. schlechteri*).

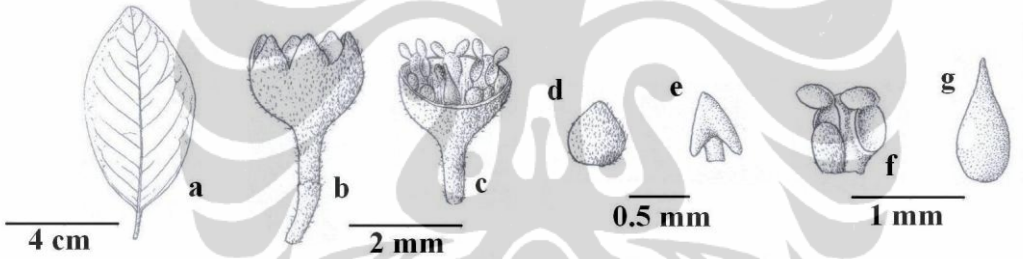

Figure 1.31. *Endiandra ledermannii* Teschner, a. leaves, b. intact flower, c. open flower, d. gland, e. staminode, f. stamen with gland, f. pistil (*Ledermann 6679*)

33. Endiandra macrostemon Kosterm. – Figure 1.30.

Endiandra macrostemon Kosterm., Reinwardtia 8 (1970) 82. – Type: *Havel NGF17375* (holo BO; iso A, BRI, CANB, K, L, LAE), Brown River Station, Central Division, PNG.

Tree up to 20 m high, 50 cm in diameter. *Twigs* solid, thin, brown, with minute scales, striate at the upper part, glabrous. *Leaves* subopposite; petiole thin, canaliculate above, 0.5-1 x 0.1 cm, with sparse appressed hairs to glabrous; blade chartaceous, narrowly elliptic to elliptic, 10-21 x 3-6.2 cm, glabrous above, papillose below, apex acuminate (0.5-1 cm acumen), base attenuate; midrib flat above, raised below; lateral veins spreading, thin, 8-10 pairs, slightly raised

above, prominent below, nerves in between lateral veins as nearly long as venation; minor venation coarsely reticulate, prominent; domatia absent. *Inflorescences* paniculate, short, 2-7 cm long, axillary, few-flowered, dense appressed pubescent; bracts caducous; pedicels slender, 3 mm. *Flowers* cream yellow (fresh), small (young), spreading, 0.7-0.8 mm in diameter; tepals elliptic to ovate, 1 mm long; glands none; stamens 3; anthers sessile, sparsely pubescent; locules roundish, large; staminodes absent; ovary ovoid. *Fruits* unknown.

Distribution – Brown River Station, Central Division (PNG).

Habitat & Ecology – Monsoon rain forest; alt. 90 m.

Specimens examined (3 sheets) – Havel NGF17375.

Notes – *Endiandra macrostemon* Kosterm. can be recognized from its attenuate leaf base and coarse reticulation of leaves.

34. Endiandra magnilimba Kosterm. – Figure 1.30.

Endiandra magnilimba Kosterm., Reinwardtia 7 (1965) 29. – Type: *White NGF 10270* (holo BO ; iso BO, L), Josephstaal, PNG.

Tree up to 33 m high, 75 cm in diameter. *Twigs* solid, stout, light brown, smooth or with longitudinal lines, lenticellate, with dense short appressed hairs. *Terminal buds* small, thin, acute, with dense short hairs. *Leaves* alternate; petiole stout, canaliculate above, ca. 3 cm long, glabrous; blade chartaceous, broadly elliptic to rounded, 12-30 x 7-16 cm, glabrous above, glabrous with reddish dots or slightly papillose below, apex acuminate, base rounded; midrib flat or slightly impressed above, raised below, both surfaces glabrous; lateral veins erect, 7-8 pairs, slightly impressed above, prominent below**,** both surfaces glabrous; slightly arcuate; minor venation coarsely reticulate, prominent. *Inflorescences* unknown. *Flowers* pale green (fresh), parts unknown. *Fruits* black (fresh), ellipsoid, 5.5-6.5 x 4-5 cm, glaucous.

Distribution – Josephstaal (PNG).

Habitat & Ecology – Forest; alt. 80 m.

Specimens examined (7 sheets) – Pullen 5905; White NGF10270, 10283.

Notes – The species is characterized by rounded leaves, which is similar to *E. latifolia* Kosterm., however the presence of short curly hairs in *E. latifolia*, makes it easy to differentiate the two species.

35. Endiandra minutiflora Kosterm. – Figure 1.30.

Endiandra minutiflora Kosterm., Reinwardtia 7: 342 (1968). – Type: *Floyd, Gray & Middleton NGF8073* (holo A; iso BO, L), Middletown, PNG.

Tree 10 m tall, 15 cm in diameter. *Twigs* dark-colored, rectangular, hollow rather swollen at the branching point, glabrous. *Terminal buds* 6-7 mm long, with dense short erect hairs. *Leaves* alternate; petiole thin, terete**,** canaliculate above, 1.2-1.5 x 0.1-0.15 cm, glabrous; blade chartaceous, rounded, 12.5-17.5 x 6.4-7.7 cm, glabrous both surfaces, apex acuminate (0.5 cm acumen), base cuneate; midrib flat above, raised below, glaborus; lateral veins diverging, 7-8 pairs, slightly impressed above, raised below, glabrous both sides; minor venation coarsely reticulate, smooth somewhat immersed above, prominent below. *Inflorescences* paniculate, 2-2.5 cm long, axillary, many-flowered, rusty brown, sparsely curly pubescent; bracts small, elliptic, 0.8 x 0.5 mm, with sparse short erect hairs; pedicels slender, 3 mm long, with sparse short erect hairs**.** *Flowers* yellow (fresh), half-erect, 1.5-1.8 mm in diameter (not fully open); tepals almost equal, elliptic, 1.2 x 0.8 mm, with dense long hairs inside, sparsely pubescent to glabrescent outside; glands separate, basal, 3 pairs, each pair flanks stamen, reniform, 0.35 x 0.3 mm; stamens 3, anthers broadly triangular, ca. 0.5 mm long, glabrous; locules roundish, large covering most of anther space; staminodia 3, sagitate, 0.30 x 0.25 mm; receptacles shallow; ovary immature, ca. 0.5 mm long, glabrous. *Fruits* unknown.

Distribution – Seribi River, Middletown (PNG)

Habitat & Ecology – Forest.

Local names – Tagidi, Sosopa (Kiwai).

Specimens examined (6 sheets) – Floyd, Gray & Middleton NGF8065, 8073.

Notes – A special character possessed by *E. minutiflora* is the hollow twigs. Hollow twig is not commonly encountered in other *Endiandra* species. The

species is also characterized by rectangular twigs (upper shoot), rather swollen at the branching point.

36. Endiandra montana C. White – Figure 1.32.

Endiandra montana C. White. Contr. Arnold Arbor. 4 (1933) 36. – Type: *Kajewski 1497*

Brassiodendron fragrans Allen, J. Arnold Arbor. 23 (1942)153. – Type: *Brass 7465* (holo A; iso BO, BRI, L), Lake Daviumbu, Middle Fly River, PNG.

Endiandra fragrans (Allen) Kosterm., J. Sci. Res. 1 (1952)151. – Type: *Brass 7465* (holo A; iso BO, BRI, L), Lake Daviumbu, Middle Fly River, PNG.

Tree 10 to 30 m tall, 20 to 80 cm in diameter. *Twigs* solid, brown, angular or terete, slightly with grooves, glabrous or with straight, appressed hairs when young. *Terminal buds* pointed, slender, straight, 3 mm long, with straight appressed hairs. *Leaves* subopposite; petiole thin, flat or slightly canaliculate above, 0.6-1.6 cm long, glabrous; blade subcoriaceaous, narrowly elliptic to elliptic**,** 7-17 x 3-6 cm, glabrous both surfaces, apex acuminate, base attenuate; midrib immersed above, raised below, glaborus; lateral veins spreading, 9-10 pairs, obscure to slightly impressed, glabrous above, slightly raised below, disappearing toward margin; minor venation coarsely reticulate. *Inflorescences* paniculate, 3-5 cm long, terminal or axillary, many-flowered, with sparse short, appressed hairs or almost glabrous in main axis, and with straight, short, erect hairs in secondary axis; bracts caducous; pedicels very short, with hairs same as secondary inflorescence axis. *Flowers* white or cream (fresh), nice fragrant (fresh), 5-7 mm in diameter, spreading; tepals subequal, outer tepals broadly elliptic, 2.5-4 x 1.9-2.7 mm, inner tepals elliptic, 2.3-4 x 1.9-2.7 mm, with sparse, short, erect hairs inside where stamens attached, glabrous or rarely sparsely pubescent outside; glands separate, basal, small; stamens 6; anthers triangular, 1.5-1.8 x 0.8-1.3 mm, sessile, pubescent; locules slit-like; staminodia none; ovary subglobose, ca. 0.7-1 x 0.6-1 mm, glabrous; style short, ca. 0.1-0.4 mm long; stigma inconspicuous; receptacles deep, glabrous or rarely sparsely pubescent outside, pubescent inside. *Fruits* shiny green to purple-red when mature (fresh), globose or ellipsoid, 3-5.2 x 2-4.1 cm.

Distribution – Western District, Lake Daviumbu, Tamoorik (PNG); Queensland.

Habitat & Ecology – Rain forest, subcanopy; alt. up to 1300 m.

Local name – Ake'me.

Specimens examined (12 sheets) – Anta 235; Branderhorst 19; Brass 7465; Hyland 9343, 13329; Kostermans s.n.; Reksodihardjo 191, Pullen 7169.

Notes – The species has 6 stamens and previously was described for a new genus *Brassiodendron fragrans* Allen. The new genus was merged to *Endiandra* based on the position of its stamens, which reside on the third and fourth whorls. Apart from the number of stamens, the species can be distinguished from other *Endiandra* by its big and glabrous flowers.

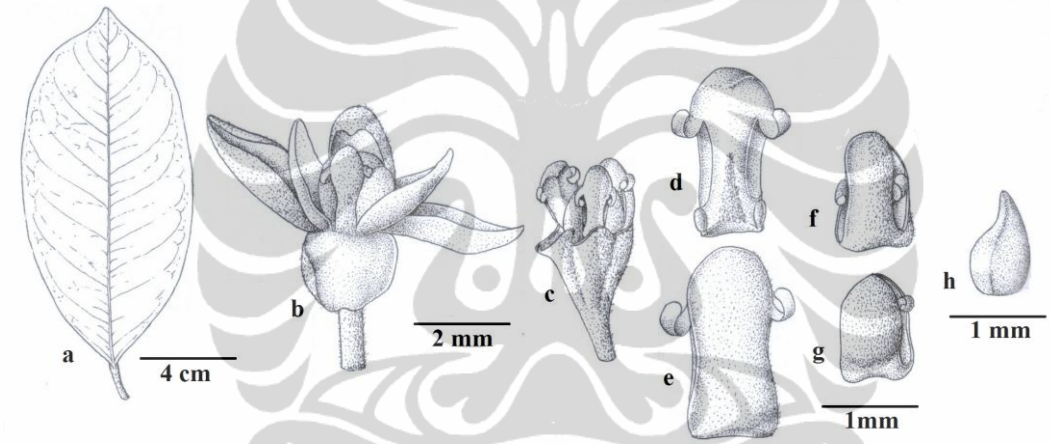

Figure 1.32. *Endiandra montana* C.White, a. leaves, b. intact flower, c. open flower, d-e. outer stamen with a pair of small glands, f-g. inner stamens staminodia, h. pistil (*Kostermans s.n.*)

37. Endiandra multiflora Teschner

Endiandra multiflora Teschner, Engl. Bot. Jahrb. 58 (1923) 419. – Type: *Ledermann 8015* (holo, A; iso BO), Sepik-Gebiet, PNG.

Tree 17-25 m, up to 55 cm in diameter, buttress up to 1.8 m high. *Twigs* solid, dark brown to black, smooth, glabrous. *Terminal buds* narrowly elliptic, 4 mm long, with dense long appressed hairs. *Leaves* alternate; petiole thin, slightly canaliculate, appressed pubescent, 1.2-1.3 x 0.1 cm; blade coriaceous, elliptic,

7.7-9.5 x 3.7-4.7 cm, glabrous above, with sparse minute hairs below, apex acute, base cuneate; midrib glabrous, flat to slightly impressed above, raised below; lateral veins obscure, spreading, c. 11 pairs, slightly raised, glabrous on both surfaces, as prominent as minor veins; minor venation coarsely reticulate, prominent. *Inflorescences* paniculate, axillary, compact, 5-6 cm long, bear many flowers, densely appressed to curly pubescent especially on young shoots; bracts caducous; pedicels thin, short, with dense curly hairs. *Flowers* yellow, erect, ca. 1.5 mm in diameter**;** tepals narrowly elliptic, 1.25 x 0.3-0.8 mm**,** with dense short curly hairs; glands separate, basal, 3 pairs, each pair flanks stamen, spherical or reniform, 0.2 mm in diameter; stamens 3; anthers rounded, 0.2 x 0.3 mm, glabrous; locules roundish; filament ca. 0.3-0.4 mm; staminodia 3; receptacles shallow**;** ovary ovoid, 0.5 x 0.3 mm, glabrous; style 0.3 mm long, stigma inconspicuous. *Fruits* unknown.

Distribution – Sepik-Gebiet (PNG); Woriki (W Papua).

Habitat & Ecology – Forest; alt. 10-100 m.

Specimens examined (2 sheets) – Koster BW6976; Ledermann 8015.

Notes – *Endiandra multiflora* is similar to *E. engleriana* from the coriaceous leaf and obscure lateral veins but it differs in minor leaf vein (coarsely reticulate in *E. multiflora* vs fine in *E. engleriana*).

38. Endiandra oviformis Kosterm.

Endiandra oviformis Kosterm., Reinwardtia 10 (1988) 461. – Type: *Streimann NGF47811* (holo BO; iso L), Wau, Bulolo, PNG.

Tree up to 20 m high, up to 30 cm in diameter. *Twigs* solid, dark grey, fine fissures, glabrous. *Terminal buds* lanceolate, straight or curved, 5 mm long, with sparse short hairs sometimes glabrous. *Leaves* alternate**;** petiole flat above, 0.8-1.2 cm long, glabrous; blade stiffly coriaceous, elliptic, 10.2-17 x 4.4-7.8 cm, glabrous on both surfaces, apex acute, base cuneate; midrib flat or slightly impressed above, raised below, both surfaces glabrous; lateral veins thread-like, obscure, ca. 11 pairs, slightly raised above, immersed, obscure below, both surfaces glabrous; minor venation coarsely reticulate, prominent. *Inflorescences*

unknown. *Flowers* unknown. *Infructescences* up to 10 cm long, glabrous; peduncle woody, 1.5-2 cm, glabrous. *Fruits* bluish green (fresh), broadly ellipsoid or subglobose, 4.5-5 x 3.1-3.8 cm, glabrous.

Distribution – Wau (PNG).

Habitat & Ecology – Ridge forest; alt. 1159 m.

Specimen examined (4) – Streimann NGF47811.

Notes – The species has very coriaceous leaves and globose fuits. Leaf buds are only covered with sparse short hairs even sometimes glabrous, whereas most of *Endiandra* leaf buds are densely pubescent.

39. Endiandra papuana Lauterb. – Figure 1.33.

Endiandra papuana Lauterb., Nova Guinea, Bot. 8 (1912) 819. – Type: *Branderhorst 263* (BO, K, L), PNG.

Tree up to 30 m. *Twigs* solid, dark brown or rusty colored, terete, sometimes flaky, densely pilose. *Terminal buds* rusty colored, 2-5 mm in diameter, densely pubescent, smooth. *Leaves* alternate; petiole stout, terete, flat, 1-2 x 0.2-0.25 cm, densely pubescent; blade subcoriaceous, elliptic to broadly elliptic, 10-19 x 7-10 cm, glabrous, shiny above, slightly shiny or glaucous, sparsely to densely pilose below, apex apiculate, base obtuse; midrib flat or slightly impressed above, raised below, pubescent on both surfaces; lateral veins spreading, 7-8 pairs, flat slightly impressed above, raised below, arcuate towards margin; minor venation finely reticulate, obscure above, prominent below. *Inflorescences* paniculate, 18-30 cm long, axillary, many-flowered, densely pubescent; bracts caducous; pedicels slender, 2-3 mm long, dense pubescent. *Flowers* white or creamy (fresh), 6-8 mm in diameter, spreading; tepals subequal where inner ones smaller, ovate or broadly elliptic, 2.5-3 x 2.3-2.5 mm, with sparse minute curly hairs to glabrescent inside, with dense curly long hairs outside; glands fused, united to form a disc-like appendage; stamens 3; anthers orange-yellow (fresh), glabrous; locules roundish; staminodes none; receptacle

deep, pubescent; ovary ellipsoid, 1.5-2.5 mm long, glabrous, style and stigma inconspicuous. *Fruits* globose to ellipsoid, 1-2 cm long.

Distribution – Raja Ampat (W Papua); Kokoda, Lae, Wareo (PNG).

Habitat & Ecology – Lowland forest, stream banks on alluvial; alt. 50-458 m.

Local name – Tomara (Orokaiva, Mumuni, Kokoda).

Specimens examined (22 sheets) – Branderhorst 263; Clemens 1782; Mirmanto & Ruskandi 09304; Hoogland 3955; Havel & Kairo NGF11197; van Leeuwen 9016; White NGF10487; Wommersley NGF 43919.

Notes – The species is recognized by densely pubescent of lower leaf surface with smooth upper leaf surface and fused glands. *Endiandra papuana* is more commonly encountered in the forests of Papua New Guinea, around Morobe District than in Indonesian part of New Guinea.

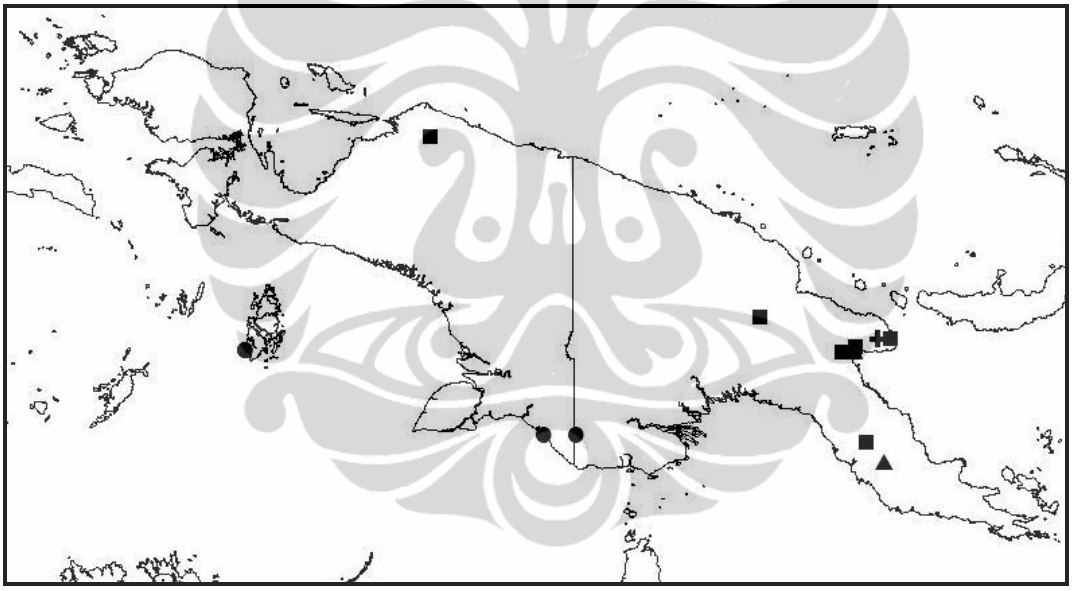

Figure 1.33. Species distribution of *E. rifaiana* (●), *E. pilosa* (▲), *E. papuana* (■) and *E. schlechteri* (✚)

40. Endiandra pilosa Kosterm. – Figure 1.33, 1.34.

Endiandra pilosa Kosterm., Reinwardtia 7 (1969) 490. – Type: *Carr 14538* (holo L), Boridi, PNG.

Tree up to 23 m high. *Twigs* solid, rather thick, rusty brown, not lenticellate, with dense long straight to slightly wavy hairs. *Terminal buds* conical

or elliptic, 4-10 mm, with dense long straight to slightly wavy hairs**.** *Leaves* alternate; petiole thick, 2-2.2 cm, with hairs same as twigs; blade chartaceous, elliptic, 11-22.5 x 6-10 cm, glabrous above, with hairs same as twigs below, apex acuminate, base cuneate; midrib slightly raised above, raised below, both surfaces with hairs same as leaf blade; lateral veins diverging, 5-6 pairs, slightly impressed above, prominent below, both sides with hairs same as midrib, arcuate towards margin; minor venation coarsely reticulate, prominent. *Inflorescences* paniculate, up to 24 cm long, terminal or axillary, many-flowered, rusty-brown, with hairs same as twigs; bracts ovate, acute, 1 mm long; pedicels 2-4 mm, with dense curly hairs. *Flowers* yellowish green (fresh), half-erect, 3 mm in diameter; tepals unequal, ovate, 0.75 mm, with straight to slightly wavy hairs, sparser and shorter than other parts; glands separate, basal, 3 pairs, each pair flanks stamen, globose to reniform, 0.4 mm; stamens 3; anthers oblong, 0.6-0.7 mm, glabrous; filament 0.2 mm; locules roundish, large; staminodia 3, cordate, with short hairy stalked, 0.2 mm long; ovary subglobose, 0.7 mm, glabrous; style 0.5 mm long; stigma inconspicuous. *Fruits* unknown.

Distribution – Boridi (PNG).

Habitat & Ecology – Forest, alt. 1433-1525 m.

Specimens examined (3 sheets) – Carr 14538, 13037; Kairo NGF44085.

Notes – *Endiandra pilosa* is characterized by coarse reticulation and wavy indument on the surface.

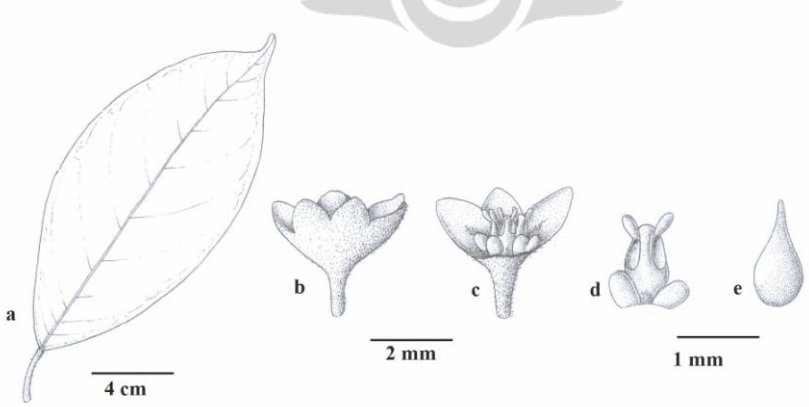

Figure 1.34. *Endiandra pilosa* Kosterm. a. leaf, b. intact flower, c. open flower, d. stamen with a pair of glands, e. pistil (*Kairo NGF44085*)

41. Endiandra rifaiana Arifiani, *spec. nov.* – Figure 1.33, 1.35.

Endiandra rifaiana Arifiani, Type: *Reksodihardjo 238* (holo, BO), Bajampa, Merauke District, W Papua.

Tree up to 28 m, up to 53 cm in diameter. *Twigs* solid, dark brown towards black, finely fissured, with sparsely appressed indument when young to glabrescent. *Terminal buds* narrowly elliptic, 4 mm long, with dense long appressed hairs. *Leaves* slightly clustered; petiole thin, slightly canaliculate above, 8-10 x 0.8 mm, appressed pubescent; blade subcoriaceous, elliptic, 6-9 x 1.7-3.1 cm, glabrous with minute hairs (near base) above, glaucous with sparsely short or erect hairs below, apex acuminate (0.5 cm acumen), base deeply cuneate or attenuate; midrib flat to slightly impressed above, raised below, with appressed hairs; lateral veins spreading, 3-4 pairs, flat above, raised below, rather erect towards margin; minor venation finely reticulate, slightly raised. *Inflorescences* paniculate, axillary or terminal, 5-7 cm long, bear many flowers, densely pubescent; bracts caducous; pedicel slender, 2-5 mm long. *Flowers* dirty yellow (fresh), spreading, ca. 4 mm in diameter; tepals narrowly elliptic, 1.7 x 1.3 mm, dense pubescent on both surfaces; glands separate, basal, 3 pairs, each pair flanks stamen, ovate 0.2-0.4 x 0.2-0.4 mm, glabrous; stamens 3; anthers obtriangular to rounded, 0.5 x 0.5 mm, glabrous; filament 0.5 mm long, with dense appressed hairs; locule roundish; staminodes 3, cordate, 0.3 mm, pubescent at the basal part; receptacles slightly deep, dense pubescent; ovary ovoid, 0.4 x 0.4 mm, glabrous; style 0.6 mm long, stigma inconspicous. *Fruits* green, ellipsoid, ca. 1-2 cm long.

Distribution – Ngaibor (Aru Island), Bajampa (W Papua); Werevea (PNG).

Habitat & Ecology – Closed savana forest; alt. 20-30 m.

Specimens examined (10 sheets) – Buwalda 5396, 401; Reksodihardjo 238; Ridsdale & Galore NGF33478.

Notes – *Endiandra rifaiana* was described based on several specimens previously presumed as *E. microphylla* Teschner by Kostermans (based on the Teschner's protolog) and other additional specimens. Teschner mentioned that *E. microphylla* bears no glands, but he actually meant that *E. microphylla* has fused

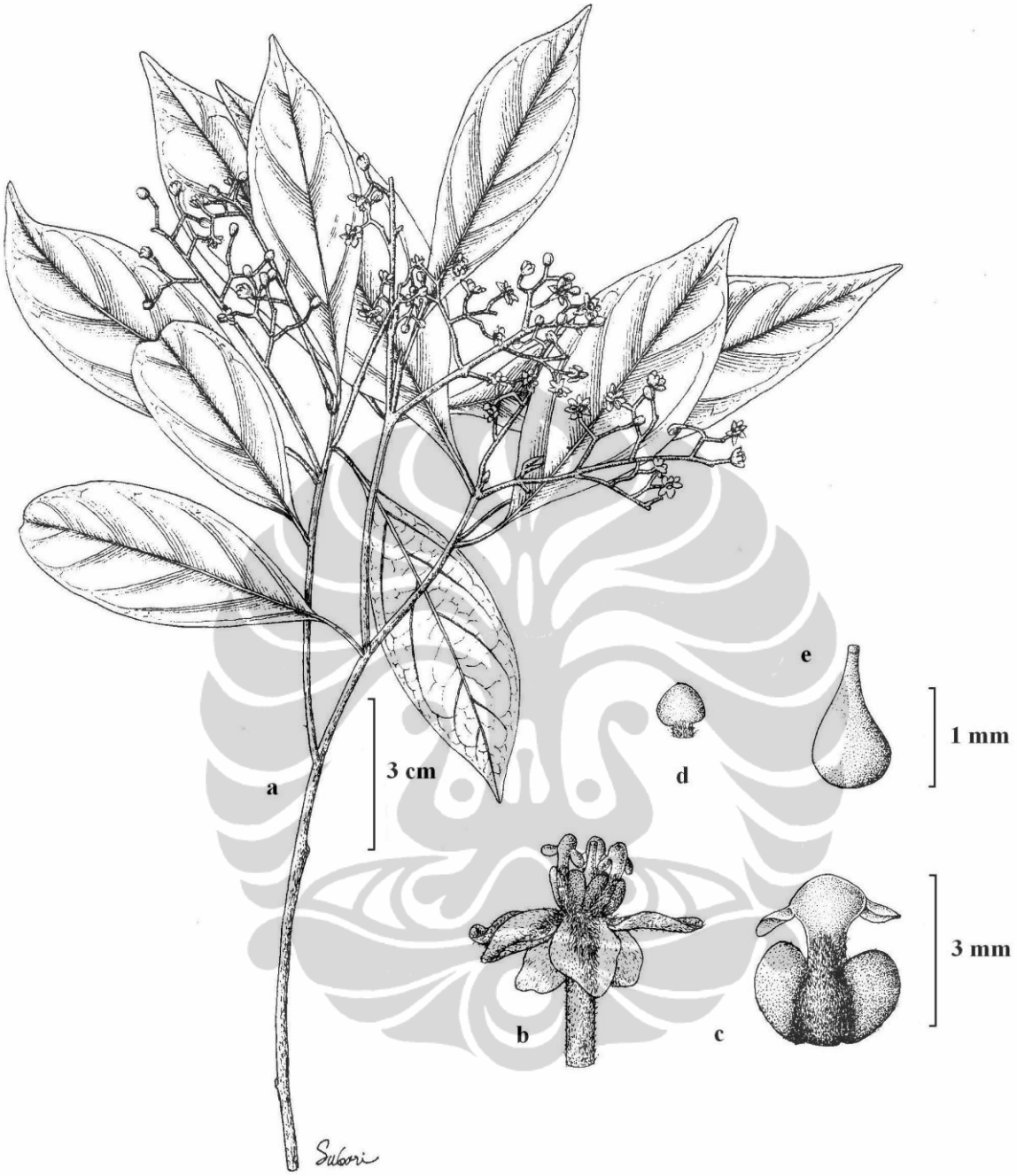

Figure 1.35. *Endiandra rifaiana* Arifiani. a. habit; b. intact flower (spreading); c. stamens with a pair of glands still attached; d. staminode; e. pistil (*Reksodihardjo 238*)

gland (as in *E. flavinervis* Teschner, which he said to bear no glands, but infact it bears fused ones). Therefore, these specimens presumed as *E. microphylla* cannot be the species that Teschner has described, because it has 3 pairs of separate

glands which flank the three stamens. Therefore, it was described it as a new species, *E. rifaiana*. The species is similar to *E. glauca* R.Br., the leaf characters are similar but the flowers are different in the presence of basal glands not the fused one.

42. Endiandra schlechteri Teschner – Figure 1.33.

Endiandra schlechteri Teschner, Engl. Bot. Jahrb. Syst. 58 (1923) 419. – Type: *Schlechter 17693*, PNG.

Tree up to 36 m tall, 36 cm in diameter. *Twigs* solid, brown, thin, glabrous. *Terminal buds* conical, sparse short appressed. *Leaves* alternate; petiole 1-1.5 cm long, canaliculate above, glabrous; blade chartaceous, elliptic, 10-13 x 3.4-5.5 cm, glabrous both sides, apex acuminate (long acumen), base cuneate**;** midrib flat above, raised below, glabrous on both surfaces; lateral veins diverging, thin, thread-like, 5-6 pairs, slightly raised or flat above, raised below, glabrous; domatia minute, 0.5 mm; minor venation coarsely reticulate, prominent. *Inflorescences* paniculate, thin, length ca. 1.5 cm, axillary, few-flowered, with sparse short erect hairs; bracts acute, 0.5 mm, with sparse short erect hairs; pedicels thin, 1.5-2.2 mm long, indument same as inflorescence. *Flowers* greenish (fresh), erect, 1.8 mm in diameter; tepals subequal, elliptic, with sparse short hairs outside; glands separate, basal, 3 pairs, each pair flanks filament, reniform; stamens 3; anthers 3, glabrous; locules roundish; filament with dense long straight hairs; staminodia 3, globose, sparsely pilose; receptacles shallow; ovary ovoid, glabrous. *Fruits* unknown.

Distribution – Morobe (PNG).

Habitat & Ecology – Rain forest; alt. 1000 m.

Specimens examined (6 sheets) – Hoogland 8947; Schlechter 17693.

Notes – The species is characterized by thin glabrous twigs and the presence of minute domatia under leaf surface. Several floral character states following Teschner (1923).

43. Endiandra sericea Kosterm. – Figure 1.36.

Endiandra sericea Kosterm., Reinwardtia 7: 491 (1969) – Type: *van Royen NGF 20161* (holo BO; iso K), Markham Point (PNG).

Tree up to 30 m tall, 40 cm in diameter. *Twigs* solid, brown, densely sericeous, sparser downward. *Terminal buds* conical, 4-6 mm long, densely sericeous. *Leaves* alternate; petiole thick, 1-1.5 cm long, canaliculate above, sparsely or densely sericeous; blade subcoriaceous, elliptic, 11.5-14 x 5.8-7.5 cm, with dense short hairs to glabrescent above, below densely sericeous with short hairs to glabrescent, apex apiculate, base cuneate; midrib slightly impressed or flat, with dense or sparse short hairs above, raised, with dense short hairs below; lateral veins diverging, 8 pairs, slightly impressed or flat, with dense or sparse short hairs above, raised with dense short hairs below; minor venation finely reticulate, prominent. *Inflorescences* paniculate, thin, length up to 11 cm, axillary, rusty brown, many-flowered, with dense short wavy hairs; bracts linear, 0.5-0.8 mm long, indument same as inflorescence; pedicels thin, 0.6-1 mm long, indument same as inflorescence. *Flowers* yellow (fresh), half-erect, 2-2.5 mm in diameter; tepals thin, fragile, equal, ovate, 0.8-1.1 x 0.6-0.8 mm, with dense long wavy hairs inside, with dense short wavy hairs outside; glands separate, basal, 3 pairs, each pair flanks filament, reniform, 0.2-0.3 x 0.2-0.3 mm; stamens 3; anthers obovate or rounded, 0.4-0.5 x 0.4-0.5 mm, glabrous; locules roundish, basal closer to filament; filament ca. 0.2 mm long; staminodia 3, triangular, 0.2 mm long, pubescent; receptacles shallow, with dense long wavy hairs; ovary ellipsoid, 0.5 mm long, glabrous; style short, 0.15-0.2 mm long; stigma inconspicuous. *Fruits* black, elongated ellipsoid, 6-7.5 x 2-3.2 cm.

Distribution – Markham Point, Lae, Oomsis (PNG).

Habitat & Ecology – Rain forest, Quercus forest; alt. 300-488 m.

Specimens examined (5 sheets) – Hartley 10510; Henty NGF14808; Streimann NGF27835; van Royen NGF20161.

Notes – *Endiandra sericea* Kosterm. is characterized by sericeous lower leaf surface, the surface clothed with dense short silky hairs. The species is similar *E. invasorium* Kosterm. but the two differ in gland arrangement in their flowers. In

E. sericea, the glands are not adnate to the filaments, each pair sits next to filaments, compared to ones in *E. invasorium*.

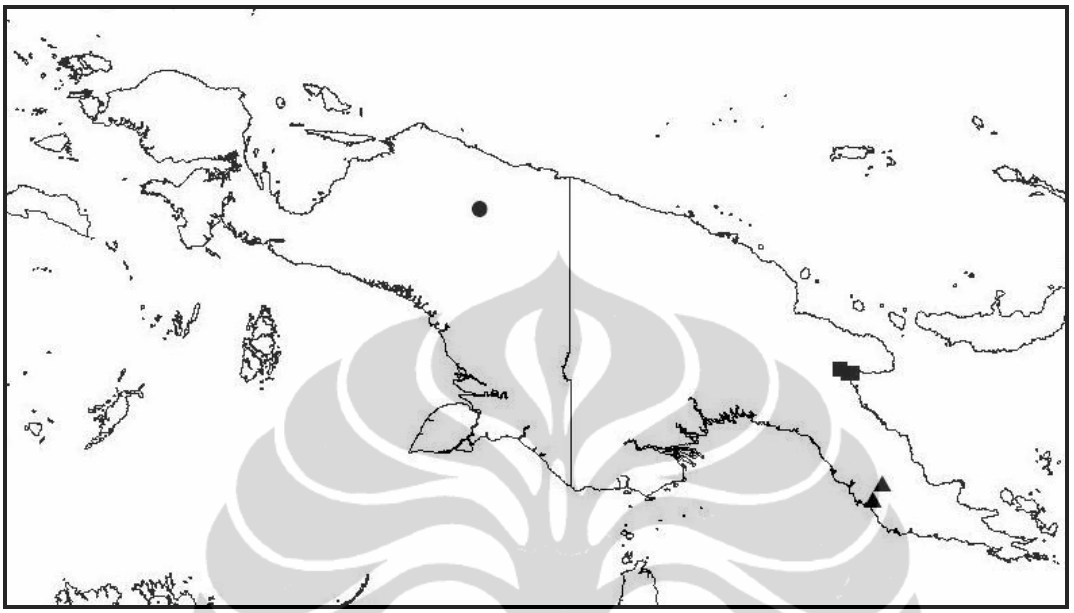

Figure 1.36. Species distribution of *E. versteeghii* (●), *E. xylophylla* (▲) and *E. sericea* (■)

44. Endiandra sleumeri Kosterm.

Endiandra sleumeri Kosterm., Reinwardtia 7 (1969) 492. – Type: *van Royen 7732* (holo BO; iso L), Aiwa R., Sudjak Village, Tamrau Range, Vogelkop Peninsula, W Papua.

Tree up to 25 m tall, 40 cm in diameter. *Twigs* solid, brown, lenticellate, sericeous with sparse short hairs, glabrescent downward. *Terminal buds* up to 10 mm long, with very dense short hairs. *Leaves* alternate; petiole stout, 1.5-1.7 cm long, flat above, with sparse short hairs; blade coriaceous, elliptic or subobovate, 9-19 x 5-12 cm, glabrous above, sericeous below, apex rounded, base cuneate-attenuate; midrib slightly raised above, raised below, glabrous; lateral veins diverging, 6-8 pairs, slightly impressed above, raised below, glabrous; minor venation fine reticulation, slightly immersed. *Inflorescences* paniculate, length up to 17 cm, terminal or axillary, rusty-brown, many-flowered, with dense short wavy hairs; bracts caducous; pedicels thin, 1 mm long, with dense short curly

hairs. *Flowers* white (fresh), half-erect, 3 mm in diameter; tepals thin, ovate, 1.5 - 2 mm, with dense short erect hairs outside, with dense long curly hairs inside; glands separate, basal, 3 pairs, each pair flanks filament, subcordate to reniform, 0.2-0.3 mm; stamens 3; anthers obovate, subglobose, 0.3-0.5 mm, glabrous; locules roundish; filament distinct, 0.3-0.4 mm; staminodia 3, small, pubescent; receptacles shallow, with dense curly hairs; ovary ovoid, 0.6 mm, glabrous; style 0.3-0.4 mm; stigma inconspicuous. *Fruits* unknown.

Distribution – Vogelkop Peninsula (W Papua), Managalase (PNG).

Habitat & Ecology – Forest, on bank; alt. 580-840 m.

Local name – U-Uma (Managalase).

Specimens examined (4 sheets) – Pullen 5782; van Royen & Sleumer NGF7732.

Notes – The species is closely related to *E. sericea* because of similar sericeous lower leaf surface and flowers. *Endiandra sleumeri* can be distinguished by bigger, more coriaceous leaves, rounded apex.

45. Endiandra versteeghii Kosterm. – Figure 1.36.

Endiandra versteeghii Kosterm., Reinwardtia 7 (1969) 494. – Type: *Brass & Versteegh 13198* (holo BO; iso A, BO, BM, L), Bernhard Camp, Idenburg River, W Papua.

Tree up to 22 m high. *Twigs* solid, dark brown, lenticellate, with dense short appressed hairs, glabrous downward. *Terminal buds* conical, 2-4 mm long, with dense short appressed hairs. *Leaves* alternate; petiole flat to slightly canaliculate above, ca. 1.5 cm long, with sparse short erect hairs; blade chartaceous, narrowly elliptic, 8.5-13 x 3.1-5.6 cm, glabrous above, sericeous with short hairs below, apex acuminate, base attenuate; midrib flat (basal part) or slightly impressed above, raised below, both surfaces with sparse short hairs; lateral veins 7-9 pairs, slightly impressed, glabrous above, prominent, with sparse short hairs below; minor venation finely reticulate, immersed above, covered with silky hairs below. *Inflorescences* unknown. *Flowers* unknown. *Infructescences*

axillary, up to 7 cm long, with sparse long straight hairs. *Fruits* ellipsoid, 4.5-4.6 x 2.4-2.5 cm, tepals not persist, glaucous.

Distribution – Bernhard Camp, Idenburg River (W Papua).

Habitat & Ecology – Rain forest, on slopes; alt. 750 m.

Specimen examined (5 sheets) – Brass & Versteegh 13198.

Notes – The species is similar to *E. havelii* Kosterm. but the number of lateral nerves are less. *Endiandra versteeghii* has different fruit shape and tepals are absent from the fruits.

46. Endiandra xylophylla Kosterm. – Figure 1.36.

Endiandra xylophylla Kosterm., Reinwardtia 7 (1969) 495. – Type: *Carr 14610* (holo SING; iso BO, BM, K, L, SING), Boridi, PNG.

Tree up to 30 m tall, 50-100 cm in diameter. *Twigs* solid, stout, rusty-brown to black, with sparse short curly hairs, glabrescent downward. *Terminal buds* stout, conical or oblong, up to 10 mm long, with very dense short curly hairs. *Leaves* subopposite; petiole stout, 1-2 cm long, flat above, with short curly hairs; blade coriaceous, obovate, 8.5-11 x 4.5-9 cm, glabrous above, with sparse short curly hairs below, apex rounded, base cuneate or attenuate; midrib slightly raise to flat**,** with short curly hairs (near petiole), glabrous above, raised, with curly hairs below; lateral veins diverging, 6-7 pairs, slightly impressed, glabrous above, raised, with curly hairs below; minor venation fine reticulation, obscure, slightly immersed above, raised below. *Inflorescences* paniculate, ca. 10 cm long, terminal, rusty-brown, few-flowered, with dense short curly hairs; bracts caducous; pedicels thin, 1 mm long, with dense short curly hairs. *Flowers* green (fresh), half-erect, 1.8 mm in diameter (still in bud); tepals ovate, with dense short curly hairs; glands separate, basal, 3 pairs, each pair flanks filament, reniform, 0.4 x 0.3 mm; stamens 3; anthers globose, 0.5 mm, glabrous; locules roundish; filament distinct, flattened, 0.3 mm long; staminodia 3, cordate, 0.3 mm, stalked ca. 0.1 mm, glabrous; receptacles shallow, with curly hairs; ovary ovoid,

0.5 mm, glabrous; style 0.3 mm; stigma inconspicuous. *Fruits* green (immature, fresh), ellipsoid, 2-2.5 x 1-1.3 cm.

Distribution – Boridi, Central Districts (PNG).

Habitat & Ecology – Lower montane & submontane forests, near stream; alt. 550-1900 m.

Specimens examined (7 sheets) – Carr 14610, 15722; Croft & Lelean LAE60506; Streimann NGF26182.

Notes – *Endiandra xylophylla* Kosterm. is closely related to *E. carri* but they can be distinguished by hairs on lower leaf surfaces and minor veins. Lower leaf surfaces of *E. xylophylla* bear curly hairs and prominent minor veins, but glabrous and immersed minor veins in *E. carrii*.

3.6 Imperfectly known species

1. Endiandra albiramea Kosterm.

Endiandra albiramea Kosterm., Reinwardtia 7 (1969) 472. – Type: *Kostermans 2006* (holo BO; iso BO, K, L), Vogelkop Peninsula, W Papua, elev. 1700 m.

2. Endiandra spathulata Kosterm.

Endiandra spathulata Kosterm., Reinwardtia 7 (1969) 494. – Type: *Brass & Versteegh 11954* (holo BO; iso A), Bernhard Camp, Idenburg River, W Papua.

Endiandra albiramea Kosterm. and *Endiandra spathulata* Kosterm. were each described based on a single sterile specimen. Determining identity of species in *Endiandra* without any flowers will lead to wrong genera. *Endiandra* and *Beilschmiedia* are two genera that are similar vegetatively, so that it is frequently misidentified. When more specimens (flowering) become available, it will be further studied.

3. Endiandra teschneriana Allen

Endiandra teschneriana Allen, J. Arnold Arb. 23 (1942) 152. – Type: Schlechter 18908 (holo A; iso L), PNG.

The species is placed as an imperfectly known species for the time being because there are not a single specimen available for study at the time.

4. Endiandra oblonga Teschner

Endiandra oblonga Teschner, Engl. Bot. Jahrb. Syst. 58 (1923) 419. – Type: *Ledermann 9476*, Sepik, PNG.

The species is similar to *E. gemopsis* Kosterm. but differs in gland shape (based the Teschner's protolog). *Endiandra oblonga* Teschner has separate basal glands, on the other hands *E. gemopsis* Kosterm. has fused glands. There is no specimen available for observation, the only one available is the image of an isotype from L, but it is suspected that the isotype actually consists of two specimens. For the time being, this species is placed as imperfectly known species until more specimens are available for observation.

5. Endiandra ferruginea Teschner

Endiandra ferruginea Teschner, Engl. Bot. Jahrb. 58 (1923) 416. – Type: *Ledermann 807*, Sepik-Gebiet, PNG.

Coarse reticulation together with obovate leaf are good characters to recognize the species. Other specimens cited on Teschner (1923) were Ledermann 10801 and 10895 but they are not available for observation. The only specimen available consists of one leaf fragment, which is not sufficient for study.

4. DISCUSSION

4.1 Morphological characteristics of New Guinean *Endiandra*

The New Guinean species of *Endiandra* are vegetatively more or less similar with the species in Borneo and Malay Peninsula. The vegetative characters such as indument type and density, texture of leaf blade, fine or coarse minor venation, prominence of the venation shaped the species in New Guinea, Borneo (Arifiani 2001) and Malay Peninsula (Kochummen 1989). However, the floral characters are more variable in New Guinean species. The species of *Endiandra* in Borneo and Malay Peninsula are uniform in floral structure by having a pistil and three triangular, sessile stamens (Arifiani 2001, Kochummen 1989). Whereas, the floral structure of the species in New Guinea is more complex by consisting a pistil, three stamens (rarely 6 stamens) combined with or without staminal glands and staminodes. The staminal glands are 3 pairs, each pair positioned at the base of each stamen or the glands can be fused to form a disc-like appendages surrounding the three stamens.

The presence of staminal glands and staminodes in *Endiandra* species provide reward for pollinators (Endress 2011). Due to high diversity of insects in New Guinea, the flowers develop an effort to attract pollinators by providing nectar produced by the staminal glands and staminodes. Therefore, staminal glands and staminodes are maintained for increasing the survival chances. According to Walker-Larsen & Harder (2000), staminodes had evolved from fertile stamens and they also help avoiding self-pollination by facilitating pollen removal and receipt. The small size of staminodes probably provided more open space inside the flowers so that pollinators can have open access to penetrate the flowers to remove nectar and pollen which later they will transfer them to the other flowers when they repeat their pollination activities.

4.2 Species enumeration, distribution, habitat and ecology

The species of *Endiandra* in New Guinea are distributed from the Northwest part in Raja Ampat islands, Indonesia to the Southwest part in Kokoda village area of Papua New Guinea (PNG, Figure 1.2), with some species are distributed further West in Celebes (*E. papuana*) and up to the Southeast in Australia (*E. glauca, E. hypotephra, E. impressicosta, E. dielsiana* and *E. montana*). The number of *Endiandra* species in Indonesian part of New Guinea (West Papua) is 19 species, only 50 % the number of *Endiandra* species occurred in PNG, which is 38 species. Eleven species occurred in both Indonesia and PNG. The high number of species found in PNG is due to more intensive explorations done in the country than in West Papua (Indonesia). Explorations in western New Guinea are probably disadvantaged by lack of service infrastructures over the Indonesia provinces, such as no comprehensive forest mapping system like in PNG (Takeuchi pers. comm.). Additionally, limited explorations in Indonesian New Guinea are mainly caused by limited budget for such explorations. Travel to West Papua is very costly and logistics are often difficult to manage when targetting the remote and uninhabited areas of surveys.

The number of *Endiandra* in New Guinea was 46 species and is much higher compared to the number of *Endiandra* species in Java (1 species, Backer & Bakhuizen 1963), Malay Peninsula (10 species, Kochummen 1989) and Borneo (8 species, Arifiani 2001). Higher number of *Endiandra* species occurred in New Guinea compared to other islands is in accordance with high number of plant species in New Guinea reported by Welzen *et al*. (2005) and related to the Island theory (MacArthur and Wilson 1967) that predicts there is a positive correlation between island size and the number of species. Additionally, high number of plant species in New Guinea can also be explained by the geological history of the island formation, in which the original southern part of New Guinea merged together with island arcs, continental fragments and pieces of sea floors, therefore different origins of New Guinea have made the island rich in biodiversity (Welzen *et al*. 2005).

The species of *Endiandra* in New Guinea are mainly endemic to the region except *E. papuana*, *E. glauca*, *E. hypotephra*, *E. impressicosta*, *E. dielsiana* and *E. montana* with several other species (*E. asymmetrica*, *E. beccariana*, *E. forbesii*, and *E. rifaiana*) that distributed up to Moluccas and Aru Island. High number of *Endiandra* endemic species in New Guinea is in agreement with Welzen *et al*. (2005) that reported New Guinea housed highest endemic plant species in Malesian regions. Geological activities in New Guinea has caused high number of species endemicity in New Guinea (Welzen 1997) in which there is a correlation between mountain formation and number of endemic species (Welzen *et al* . 2005).

This study showed that the New Guinean *Endiandra* species occurred in primary or secondary rain forest from lowland to montane forests, or in riverine forests. The species can usually grow on loam soil, alluvial or clay. The species occurred generally in lowland forests, from 0 – 600 m above sea level and the number of species will decrease at higher altitude in montane forests, above 1000 m (Figure 1.3). According to Rohwer (1993), the diversity of Lauraceae species are higher in lowland forests, therefore it is in agreement with the distribution of New Guinean *Endiandra* shown by the present study.

4.3 Detection of new species of *Endiandra* from New Guinea

This study detected the presence of six novel species of *Endiandra* in New Guinea. The discovery of six species of *Endiandra* in New Guinea showed that 13 % of the total *Endiandra* species in New Guinea were undescribed, which indicated the possibility to find new taxa in New Guinea. Hyland (1989) described 17 species out of 38 species occurred in Australia which accounted about 45 % of the total Australian *Endiandra* species, therefore it is possible that more species of *Endiandra* are awaiting to be discovered in New Guinea.

Six new species discovered in this study were described based on the combination of characters that were different with previously described species.

Endiandra areolata is a newly described species and is different from other species of *Endiandra* in New Guinea because of its stiffly coriaceous leaf, lateral veins obscured by coarsely areolate minor veins, and small, erect flowers. Its coriaceous leaf is similar to that of *E. oviformis* Kosterm., but their leaf color and surface texture are distinct (dark-colored and prominent surface in *E. areolata* vs pale-colored and smooth in *E. oviformis*). The specific epithet *areolata* refers to the prominent areolate minor venation.

Endiandra crassitepala Arifiani and *E. kassamensis* Arifiani are different from other species of *Endiandra* in New Guinea because of specific flower composition. The two species bear no staminal glands in their flowers but the staminodes are present. This condition is uncommon in other *Endiandra* species, therefore it is a good character to recognize the species. *Endiandra crassitepala* and *E. kassamensis* are vegetatively similar but the former has unequal, erect, very thick and hard tepals. Tepals of *E. crassitepala* are difficult to crush, the inner ones much smaller, however, *E. kassamensis* has thinner and softer tepals. Moreover, *E. crassitepala* was named after its thick tepals and *E. kassamensis* was named after the locality where the type specimen was collected, i.e. in Kassam area, Kainantu subdistrict of Papua New Guinea.

Endiandra cupulata Arifiani was described based on the oblong anthers which sparsely covered by curly hairs, other species generally have triangular or ovate anthers. The epithet *cupulata* was given after its cup-shaped flower tube. The new species of *E. lanata* Arifiani has inflorescences with very dense curly hairs similar to *E. papuana* Lauterb. but *E. lanata* is distinct from *E. papuana* in bearing fewer flowers and having smaller leaf size. Additionally, minor leaf veins of *E. lanata* is fine, prominent on the upper surface vs obscure, smooth in *E. papuana*. *Endiandra lanata* also shows affinity to *E. gemopsis* Kosterm. but *E. lanata* has more hairs on the twigs and inflorescences compared to *E. gemopsis*. The epithet *lanata* refers to its dense curly indument, wool-like, inflorescence axis.

Endiandra rifaiana was described based on several specimens previously presumed as *E. microphylla* Teschner by Kostermans (based on the Teschner's

protolog) and other additional specimens. Teschner mentioned that *E. microphylla* bears no glands, but he actually meant that *E. microphylla* has fused gland (as in *E. flavinervis* Teschner, which he said to bear no glands, but infact it bears fused ones). Therefore, these specimens presumed as *E. microphylla* cannot be the species that Teschner has described, because it has 3 pairs of separate glands which flank the three stamens. Therefore I described it as a new species, *E. rifaiana*. The epithet is named after Prof. Mien A. Rifai to honor his invaluable contribution to the plant taxonomy in Indonesia. The species is similar to *E. glauca* R.Br., the leaf characters are similar but the flowers are different in the presence of basal glands not the fused one.

5. CONCLUSION

New Guinea housed high number of *Endiandra* species with 46 species of *Endiandra* were recorded from the island, including six new species (*E. areolata* Arifiani, *E. crassitepala* Arifiani, *E. cupulata* Arifiani, *E. kassamensis* Arifiani, *E. lanata* Arifiani and *E. rifaiana* Arifiani). The species of *Endiandra* in New Guinea are distributed from the Northwest part in Raja Ampat island, Indonesia to the Southwest part in Kokoda village area of Papua New Guinea. There are 5 species that are currently placed in imperfectly known species because flowering materials were not available for the study. New Guinea has also high endemicity of *Endiandra* species with 36 endemic species were recorded from the island. The flowers of *Endiandra* species in New Guinea have more complex structure with staminal glands and staminodes are present in most species.

6. RECOMMENDATION

The exploration of *Endiandra* in New Guinea are needed to improve the collections of herbarium specimens, especially in Indonesian part of New Guinea,

which were less explored compared to the areas in Papua New Guinea. Additionally, with the high number of species that are endemic to New Guinea it is important to study in more detail the endemic species and the area where they are occurred. This study later can be used as basis for decision makers in allocating conservation efforts.

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TOPIC 2

THE PHYLOGENETIC RELATIONSHIPS OF NEW GUINEAN SPECIES OF *ENDIANDRA* AND *BEILSCHMIEDIA* (*LAURACEAE*) BASED ON MORPHOLOGICAL CHARACTERS

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ABSTRACT

Endiandra species from New Guinea consist of species which vary in vegetative and reproductive characters. Staminal glands are present in 34 species out of 46 species of *Endiandra* in New Guinea, in constrast to the Bornean and Malay Peninsular species that lack staminal glands. *Beilschmiedia* is a genus that often confused with *Endiandra* vegetatively, only flower characters can differentiate the two genera. This study was aimed to understand relationships of *Endiandra* species in New Guinea and to know the importance of staminal glands in grouping the New Guinean species of *Endiandra*. Moreover, the relationships between *Endiandra* and *Beilschmiedia* based on the morphological characters will also be discussed. A phylogenetic analysis was performed to 47 morphological characters from 50 taxa, consisted of 41 species of *Endiandra* and 6 species of *Beilschmiedia* (as in-groups) with 3 species of *Cryptocarya* (as outgroups). Phylogenetic tree was constructed by using Maximum Parsimony method. Phylogenetic tree showed that 47 in-groups taxa were grouped into five clades however with low bootstrap support. The species with and without glands are not separated from each other. The grouping within *Endiandra* based on the presence and absence of staminal glands was not well supported phylogenetically. The two genera, *Endiandra* and *Beilschmiedia* are separated, forming their own clades, suggesting that the two are monophyletic. Phylogenetic analysis with more species of *Endiandra* and more characters are suggested to be done in the future.

Keywords: *Beilschmiedia*, clade, *Endiandra*, New Guinea, staminal glands

1. INTRODUCTION

Endiandra R.Br. is a member of *Lauraceae*, a family of about 50 genera with 2500-3500 species (Rohwer 1993). The generic delimitation in the family are mainly based on the floral morphology (Nees 1836, Meissner 1864, Mez 1889, Kostermans 1957). *Endiandra* is a genus consists of over 100 species which was first described by Robert Brown in 1810 from a single species from New South Wales (Australia), *Endiandra glauca*. The species can be characterized by paniculate inflorescence in which the ultimate cyme is not strictly oppposite, bisexual flowers, stamens 3 (rarely 2 or more than 3) with 2 locules of anthers and fruits are free on receptacles. *Endiandra* is grouped together with the genera *Beilschmiedia*, *Potameia*, *Cryptocarya* and *Triadodaphne* based on the inflorescence type above in the tribe *Cryptocaryeae* (Werff & Richter 1996). *Endiandra* is very close to *Beilschmiedia* vegetatively, and both can only be separated by observing flowering specimens. Typical flowers of *Endiandra* has 3 stamens, whereas *Beilschmiedia* has 9 stamens (Figure 2.1). Therefore, it is rather difficult to determine the correct genus without a flowering specimen (Werff 2001). Based on sterile specimens, misidentification frequently occurred and lead to critical problems for further research. Misidentification will lead to wrong interpretation of the respective research results. A correct species name is required for further research such as research on species bioprospectings for medicines and study on species relationships.

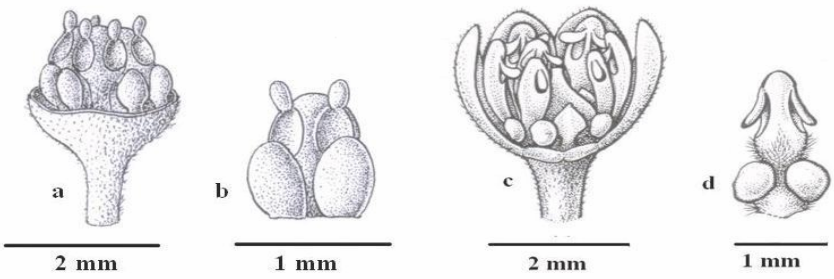

Figure 2.1. Flowers of *Endiandra* and *Beilschmiedia*, a. flower with 3 stamens, b. a stamen with a pair of glands (*E. grandifolia* from *Hoogland 4919*); c. flower with 9 stamens, 2 stamens were removed, b. a stamen with a pair of glands (*B. recurva* taken from Hyland 1989)

Beilschmiedia is first described by Nees (1831) with type species of *B. roxburghiana* Nees. It has paniculate inflorescence, flowers trimerous, bisexual, stamen 9 or 6, with or without glands, anther 2-locules, and fruits are free on pedicel. The genus consists of about 250 species has pantropical distribution (Rohwer 1993).

Morphologically, variation of vegetative and floral characters within *Endiandra* has created the diversity of the species. Floral characters vary with flower component differences forming the flowers. Basic floral parts are tepals, stamens and a pistil. Some species accommodate extra floral parts such as extra-staminal glands and staminodia. The type species *E. glauca* has fused glands forming skirt-like appendages surrounding stamens. Later, Blume erected a new genus, *Dictyodaphne*, with the type species from Indonesia, *D. rubescens*, with the absence of glands in its flowers (Blume 1850). Blume then realized the similarity between *Endiandra* and *Dictyodaphne* and indicated that *Dictyodaphne* may be a subgenus of *Endiandra*. However, the subdivision within *Endiandra* was not established, instead, *Dictyodaphne* has become synonym of *Endiandra*. It is interesting to find out that through the time, with more species have been described, variation of flowers in *Endiandra* still exists. Most of Australian species have flowers that bear glands (Hyland 1989) and Bornean species have showed the absence of glands in the flowers (Arifiani 2001). These facts have elevated the existence of a group of species that have *Dictyodaphne* characteristics.

Based on the specimens observation and references on *Endiandra* (Kochummen 1989, Hyland 1989, Arifiani 2001), the presence and absence of glands in the flowers of *Endiandra* seem to support the grouping within *Endiandra* by dividing the genus into two groups, i.e.: 1) a group that consists of species that have extra flower parts such as glands and 2) a group with species that bear basic flower parts with no glands or other parts. First group will represent *Endiandra* group as Brown first described the genus and second group will represent species that have *Dictyodaphne* characteristics. It is interesting to know if staminal glands can be used for grouping within *Endiandra*. Up to now, there is no phylogenetic analysis was performed to understand grouping within

Endiandra based on morphological characters, especially to know if staminal gland is an important character for grouping. Therefore, the phylogenetic analysis using morphological characters was carried out in this study with the aims were 1) to understand the relationships of *Endiandra* species in New Guinea; 2) to know the distribution of glandless species and species with glands in the cladogram and 3) to analyze the phylogenetic relationships of two closely related genera *Endiandra* and *Beilschmiedia* based on the morphological characters.

2. MATERIALS AND METHODS

2.1 Materials

There were 50 taxa included in the analysis, consisting of 41 species of *Endiandra* from New Guinea, 6 species of *Beilschmiedia* and 3 species of *Cryptocarya* (Table 2.1). *Cryptocarya* species were selected for outgroups as they were more distantly related to *Endiandra* than *Beilschmiedia* within the tribe *Cryptocaryeae* (Werff & Richter 1996). Additionally, *Cryptocarya* is the closest relative for both *Endiandra* and *Beilschmiedia* (Rohwer 2000, Chanderbali *et al*. 2001).

Table 2.1. Taxa included in the phylogenetic analysis

No.	Species	Distribution	Voucher
1	*E. aggregata*	PNG	Clemens 1421 (BO)
2	*E. archiboldiana*	PNG	Brass 3813 (BO)
3	*E. areolata*	W Papua	Pleyte 733; Brass & Versteegh 13142 (BO)
4	*E. arfakensis*	W Papua	Mayr 184 (BO)
5	*E. asymmetrica*	Moluccas, W Papua, PNG	Brass 6921, 14101, 32429; Clemens 1742, 1848 (BO)
6	*E. aurea*	W Papua	Kostermans 2014 (P); following Kostermans (1950)

Table 2.1. continued

No.	Species	Distribution	Voucher
7	*E. beccariana*	Moluccas, W Papua	Kostermans & Tangkilisan 146 (BO)
8	*E. carrii*	PNG	Carr 13849 (BO)
9	*E. crassipetala*	PNG	Henty NGF29370 (BO)
10	*E. cupulata*	W Papua	Koster BW1344 (BO)
11	*E. cyphellophora*	PNG	Carr 15379, 15380 (L); following Kostermans (1950)
12	*E. dielsiana*	PNG, Queensland	Hyland 13176; Kostermans 2004 (BO)
13	*E. djamuensis*	PNG	Schlecter 17341 (BO)
14	*E. euadenia*	PNG	White NGF10252 (BO)
15	*E. faceta*	PNG	Carr 12195 (BM, L); following Kostermans (1969)
16	*E. flavinervis*	PNG	Gillison NGF25065; Henty NGF27344; Womersley *et al.* NGF5281; Womersley NGF15379 (BO)
17	*E. forbesii*	Moluccas, PNG	Kostermans & Tangkilisan 136; Rastini 190 (BO)
18	*E. fulva*	W Papua, PNG	Royen NGF5124 (BO)
19	*E. gem*	W Papua	Anta 64 (BO)
20	*E. gemopsis*	W Papua	Royen & Sleumer 6877 (BO)
21	*E. glauca*	PNG, Queensland	Brass 8589; Gray 3211; Hyland 11598 (BO)
22	*E. grandifolia*	W Papua, PNG	Clemens 2110; Hoogland 4919; Kairo 426; Katik W2776 (BO)
23	*E. hypotephra*	W Papua, PNG, Queensland	Grey & White NGF 10377; Hyland 12476; Kanehira & Hatusima 13097; Mueller s.n. (BO)
24	*E. impressicosta*	W Papua, PNG, Queensland	Brass 7619; Balgooy & Mamesah 6228 (BO)
25	*E. inaequitepala*	PNG	Carr 16082; Pullen 5556 (BO)
26	*E. invasorium*	PNG	Eddowes & Kumul NGF13129 (BO)
27	*E. kassamensis*	PNG	Coode & Dockrill 32655; Womersley & Vandenberg 37195 (BO)
28	*E. lanata*	PNG	Croft LAE68764 (BO)
29	*E. latifolia*	W Papua, PNG	Hoogland 4585; Iwanggin BW9047; Pullen 5568 (BO)

Table 2.1. continued

No.	Species	Distribution	Voucher
30	*E. ledermannii*	PNG	Ledermann 6679 (BO)
31	*E. macrostemon*	PNG	Havel NGF17375 (BO)
32	*E. minutiflora*	PNG	Floyd, Gray & Middleton NGF8065, 8073 (BO)
33	*E. montana*	PNG, Queensland	Brass 7465; Hyland 9343 (BO)
34	*E. multiflora*	W Papua, PNG	Koster BW6976 (BO)
35	*E. papuana*	Celebes, W Papua, PNG	Branderhorst 263; Clemens 1782 (BO)
36	*E. pilosa*	PNG	Kairo NGF44085 (BO)
37	*E. rifaiana*	Aru island, W Papua, PNG	Buwalda 5396, 401; Reksodihardjo 238 (BO)
38	*E. schlecteri*	PNG	Hoogland 8947 (BO); following Teschner (1923)
39	*E. sericea*	PNG	Hartley 10510; Henty NGF14808; Royen NGF20161 (BO)
40	*E. sleumeri*	W Papua, PNG	Pullen 5782; Royen & Sleumer NGF7732 (BO)
41	*E. xylophylla*	PNG	Carr 14610; Streimann NGF26182 (BO)
42	*B. castrisinensis*	Queensland	Following Hyland (1989)
43	*B. obtusifolia*	Sumatra, Borneo, Java, Celebes, New Guinea	Following Hyland (1989)
44	*B. recurva*	New Guinea and Queensland	Following Hyland (1989)
45	*B. dictyoneura*	Sumatra, Borneo, Java, Celebes, New Guinea	Following Nishida (2008)
46	*B. gemmiflora*	Sumatra, Borneo, Java, Celebes, New Guinea	Following Nishida (2008)
47	*B. kuntsleri*	Malay Peninsula, Sumatra, Borneo, Thailand	Following Nishida (2008)
48	*C. brassii*	New Guinea, Cape York Peninsula (Australia)	Following Hyland (1989)
49	*C. densiflora*	Java to New Guinea, up to Queensland	Following Hyland (1989)
50	*C. mackinnoniana*	The Philippines, New Guinea, Queensland	Following Hyland (1989)

2.2 Methods

2.2.1 Characters used for phylogenetic analysis

A total of 47 characters was chosen for this analysis (Table 2.2) and will be discussed briefly below. The characters were observed during the species enumeration study of *Endiandra* in New Guinea and scored for the cladistic analysis. The characters of *Beilschmiedia* and *Cryptocarya* were obtained from species descriptions in the publication (Hyland 1989).

Twig characters used in this analysis are the surface color of dried twigs, the presence of lenticell and indument, its indument types and orientation of the indument (Character 1-6). The color on dried twig varies from whitish to dark brown, most twigs were brown when dried and whitish twigs are limited to some species only. Three indument types were observed in *Endiandra*, i.e., straight, wavy and curly with different orientation. The straight indument can be appressed to the surface or erect, however the wavy and curly indument were usually erect. Some species of *Endiandra* provide insect (ants) a place for laying eggs and the hollow twigs were created by ants when they penetrated the twig to hide the eggs.

Leaf characters included leaf bud, leaf arrangement, leaf venation, petiole and leaf texture. Indument on leaf surface was also included as in twig characters (Character 7-15). Midrib, lateral vein, and minor venation were quiet variable in *Endiandra* (Character 16-22), leaf domatia (Character 23) as a result of eggs laid by insect was present in *E. chyphellophora* and *E. schlechteri*. Inflorescence (Character 24-26) were scored for inflorescence bract, indument, and flower number. Inflorescence bracts were present in *E. gemopsis* and *E. grandifolia*.

Floral characters (Character 27-31) included were floral bract and opening, pedicel and indument on tepal surface. Floral parts including staminal glands, stamens, anthers, staminodes, and ovary were included in character 32-44. Staminal glands, stamens and staminodes were scored based on their position in the staminal whorls. Fruit characters (45-47) used were position of ovary, presence of perianth remnant and presence of floral tube. Some characters were

unknown, in such case missing characters were coded as (?). Each character of each taxon used for the cladistic analysis was scored as shown in Table 2.2 and then a data matrix was created to perform the analysis. The data matrix is shown in Table 2.3.

Table 2.2. Characters and character states used in the phylogenetic analysis

No.	Characters	Character states (scored)
1	Bark color	dark-brown (0), whitish (1)
2	Twigs surface	without lenticell (0), with lenticell (1)
3	Hair on twig surface	glabrous (0), pubescent (1), densely pubescent (2)
4	Hair type on twig surface	glabrous (0), straight (1), wavy (2), curly (3)
5	Hair orientation on twig surface	glabrous (0), appressed (1), erect (2)
6	Twigs	solid (0), hollow (1)
7	Leaf buds	sparsely pubescent (0), densely pubescent (1)
8	Leaf arrangement	alternate (0), subopposite (1), slightly clustered (2)
9	Leaf venation	pinnately-veined (0), tripli-veined (1)
10	Petiole	slender (0), thick (1)
11	Petiole upper surface	flat (0), canal (1)
12	Hair on petiole	glabrous (0), pubescent (1), densely pubescent (2)
13	Leaf texture	chartaceous(0), subcoriaceous (1), coriaceous (2), stiffly coriaceous (3)
14	Lower leaf surface	glabrous (0), pubescent (1), densely pubescent (2)
15	Lower leaf surface	not glaucous (0), glaucous (1)
16	Midrib on upper surface	flat (0), impressed (1), slightly raised (2)
17	Lateral veins orientation	diverging (0), spreading (1)
18	Lateral veins	clear (0), obscure (1)
19	Lateral veins	flat (0), impressed (1), slightly raised (2), obscure (3)
20	Minor venation reticulation	coarse (0), fine (1), obscure (2)
21	Minor venation on upper surface	raised (0), obscure (1)
22	Minor venation on lower surface	raised (0), obscure (1)
23	Leaf domatia	absent (0), present (1)
24	Hair on inflorescence	glabrous (0), pubescent (1), densely pubescent (2)
25	Inflorescence bract	absent (0), present (1)
26	Number of flower in inflorescence	many-flowered (0), few-flowered (1)
27	Floral bract	absent (0), present (1)
28	Pedicel	thin (0), thick (1)
29	Flower opening	erect (0), half-erect (1), spreading (2)
30	Tepal outer surface	glabrous (0), pubescent (1), densely pubescent (2)
31	Staminal glands	absent (0), present (1)
32	Staminal glands separate	absent (0), present (1)
33	Staminal glands adnate to filament	absent (0), present (1)
34	Staminal glands fused (ring-like)	absent (0), present (1)
35	Stamens number	9 (0), 6 (1), 3 (2)
36	Stamens in the 1st whorl	absent (0), present (1)
37	Stamens in the 2nd whorl	absent (0), present (1)
38	Stamens in the 3rd whorl	absent (0), present (1)
39	Anther	glabrous (0), pubescent (1)

Table 2.2. continued

No.	Characters	Character states (scored)
40	Anther locule	roundish (0) slit-like (1)
41	Staminodes	absent (0), 3 (1), 6 (2)
42	Staminodes in 3rd whorl	absent (0), present (1)
43	Staminodes in 4th whorl	absent (0), present (1)
44	Ovary	glabrous (0), pubescent (1)
45	Ovary	inferior (0), superior (1)
46	Fruit tip	with perianth remnant (0), without perianth remnant (1)
47	Fruit	entirely enclosed in enlarged floral tube (0), free on the pedicel (1)

Table 2.3. Data matrix used in the phylogenetic analysis by using Maximum Parsimony method

Taxon/Character number	1111111112222222223333333333444444444 12345678901234567890123456789012345678901234567
E. aggregata	000001100110100000000001001002110020011010101 11
E. archiboldiana	000000110100100000110001010001110020010010101 11
E. areolata	000000120010300011200001000000110020010000001 11
E. arfakensis	001110000011000000000010100?110012001?10000111
E. asymmetrica	000000100010200010010001000011110020011010101 11
E. aurea	012100110101220001321102 0?110211002001000000111
E. beccariana	002120100001110010110001010020100120010000001 11
E. carrii	000000100000210000101002010011110020011010101 11
E. crassipetala	000000100000210000101002010011110020011010101 11
E. cupulata	000000120010100010000002001021110020011010101 11
E. cyphellophora	000000110010200000000011000001000020 01?00000111
E. dielsiana	001110110000211000000000000020110020011010101 11
E. djamuensis	001110000000100200311001010 0?000002001100000111
E. euadenia	100000100110200100111102000122100120010000001 11
E. faceta	100000100000200200001001010020000020011000001 11
E. flavinervis	010000100010111010010002000022100120010000001 11
E. forbesii	001110100110111100110002010022100120010000001 11
E. fulva	000000100000200010010001000011110020010010101 11
E. gem	001110100010000100110001 0?00?111002001?0000?111
E. gemopsis	111110100110000100010002111102100120010000001 11
E. glauca	002110100012011110110002011021100120010000001 11
E. grandifolia	012320100112220010111002101022110020011010101 11
E. hypotephra	000000100012001110110002011021100120010000001 11
E. impressicosta	000000100010200111321101000020000020011100001 11
E. inaequitepala	010000100111000010200001000022000020 01?00001111
E. invasorium	002320100001110000011102001022101020010010101 11
E. kassamensis	000000100010200000200001000001000020010010101 11
E. lanata	002320100001011100010002001022100120010000001 11
E. latifolia	002320100102220010011002001001110020010000001 11
E. ledermannii	000000100010200011200001010011110020010010101 11

Table 2.3. continued

Taxon/Character number	11111111122222222233333333344444444
	12345678901234567890123456789012345678901234567
E. macrostemon	000000?10010010010200002010022000020011000001111
E. minutiflora	00000110001000000010100100101111002001001010111
E. montana	00000011001010001030000100002011001011110000111
E. multiflora	00000010001121001120000200000211002001001010111
E. papuana	00212010010211101001100200002210012001000000111
E. pilosa	00222010012?02020010000200101111002001001010111
E. rifaiana	00111012001111101001000200002211002001001010111
E. schlecteri	00000000001000000000001101100111002001001010111
E. sericea	00111010011112001001000200101211002001001010111
E. sleumeri	01111010010121020011110200001211002001001010111
E. xylophylla	00132011010121000011100201001211002001001010111
B. castrisinensis	00111010000011121000000110000100001110002110111
B. dictyoneura	00111000001010110020010100000000001110002110111
B. gemmiflora	00132012001000010021100110001111000111?1010111
B. kuntsleri	01132010010020010010000100001111000111?1010111
B. obtusifolia	00111010001011021020000110000111000111?1010111
B. recurva	00111010001011121020000110000111000111101010111
C. mackinnoniana	00212010011121111001000100010111000111?1010000
C. brassii	00212010001101110000000110000111000111001010000
C. densiflora	00111010101011111010000100010211000111?1010000

Note: missing characters were coded as "?".

2.2.2 Phylogenetic Analysis

Fifty taxa and 47 characters were used in the phylogenetic analysis. Ingroups consisted of 41 species of *Endiandra* and 6 species of *Beilschmiedia*. *Beilschmiedia* was included in the analysis to clarify its relationships with *Endiandra*. Three species of *Cryptocarya* as the closest relative of *Endiandra* and *Beilschmiedia* were used as outgroups (Rohwer 1993, Werff & Richter 1996, Werff 2001).

Phylogenetic interpretations of the morphological characters were undertaken using PAUP program (Swofford 1998) to perform a maximum parsimony analysis, searching for shortest trees. A heuristic search for most-parsimonious trees was performed with stepwise simple addition and Tree-Bisection-Reconnection (TBR) branch swapping. Characters were treated as unordered and having equal weight. Consistency index (CI) and retention index (RI) were calculated to know the quality of the tree. Consistency index (CI) measured the amount of homoplasy in a character data set in relation to cladogram and RI was calculated to measure the amount of similarity in a character that can be interpreted as synapomorphy on a cladogram (Kitching *et al*. 1998). Bootstrap analysis was performed to test the tree topology stability (Felsenstein 1985).

3. RESULTS

The parsimony analysis produced 86 equally most parsimonious trees, one of the parsimonious trees is shown in Figure 2.2. Their length was 296, CI = 0.220, RI = 0.588. Of 47 characters used, 3 characters were parsimony-uninformative and 44 characters were parsimony-informative. Overall, phylogenetic tree showed low bootstrap support, only two clades of *Endiandra* have bootstrap values higher than 50 %. Two clades consisted of *E. djamuensis* - *E. faceta* and *E. glauca* - *E. hypotephra* were supported with bootstrap values of 59% and 66% respectively.

The phylogenetic analysis was performed to show the relationships of *Endiandra* species occurred in New Guinea and the relationships between *Endiandra* and its closely related genus, *Beilschmiedia*. One of the parsimonious tree showed that *Endiandra* species were grouped into six clades (clades I-VI), and separated from all *Beilschmiedia* species (clade VII). The species of *Endiandra* that have staminal glands were grouped together with the species that do not have staminal glands.

Clade I of the phylogenetic tree consisted of *E. arfakensis*, *E. gem*, *E. glauca*, *E. hypotephra*, *E. euadenia*, *E. gemopsis* and *E. forbesii* and clade II

consisted of *E. invasorium*, *E. lanata*, *E. papuana*, *E. beccariana* and *E. flavinervis.* The characters that unite clades I and II are solid twig; alternate and pinnate leaves; clear lateral vein; absence of domatia; presence of separate, adnate or fused staminal glands; and 3 stamens in the 3rd whorl.

Clade III consists of *E. aurea*, *E. latifolia*, *E. grandifolia*, *E. pilosa*, *E. xylophylla*, *E. sleumeri*, *E. sericea* and *E. rifaiana*. They are grouped together in clade III by characters such as dark brown and solid twig; dense pubescent leaf bud; pinnate leaves; absence of domatia; presence of staminal glands, all are separate; and stamens 3, in the 3rd whorl.

Endiandra dielsiana was placed as a single lineage in the cladogram. There is no unique character observed in *E. dielsiana* to explain such position. Addition of more characters and more taxa may change the placement of *E. dielsiana*.

Clade V consisted of *E. djamuensis*, *E. faceta*, *E. cyphellophora*, *E. impressicosta*, *E. montana*, *E. inaequitepala*, *E. macrostemon*, *E. crassitepala*, *E. kassamensis*, *E. areolata*, *E. multiflora*, *E. ledermannii*, *E. asymmetrica* and *E. fulva*. Some characters shared by the clade are solid twig; pinnate, shiny (not glaucous) leaves; absence of inflorescence and flower bracts; thin pedicel; staminal glands could be absent or present, all separate when present; stamens 3 or 6, in the 3rd whorl or in the 2nd and 3rd whorls, respectively. The clade consisted of both species without and with staminal glands. The upper part from *E. djamuensis* to *E. kassamensis*, consisted of species without staminal glands except for *E. montana*, that has small separate glands with 6 stamens at the 2nd and 3rd whorls. In contrast, lower part of clade V from *E. areolata* to *E. fulva*, consisted of species with staminal glands. *Endiandra montana* was not grouped together in the lower part of clade V probably because of the absence of staminodes that is shared by most of upper clade V members. Other characters shared by *E. montana* with members of upper clade V are subopposite and subcoriaceous leaves; spreading flowers; and roundish anther locules.

Clade VI consists of *E. minutiflora*, *E. schlechteri*, *E. aggregata*, *E. cupulata*, *E. archiboldiana* and *E. carrii*. The shared characters are twig dark brown, without lenticell, glabrous; pinnate leaves; petiole glabrous; lower leaf

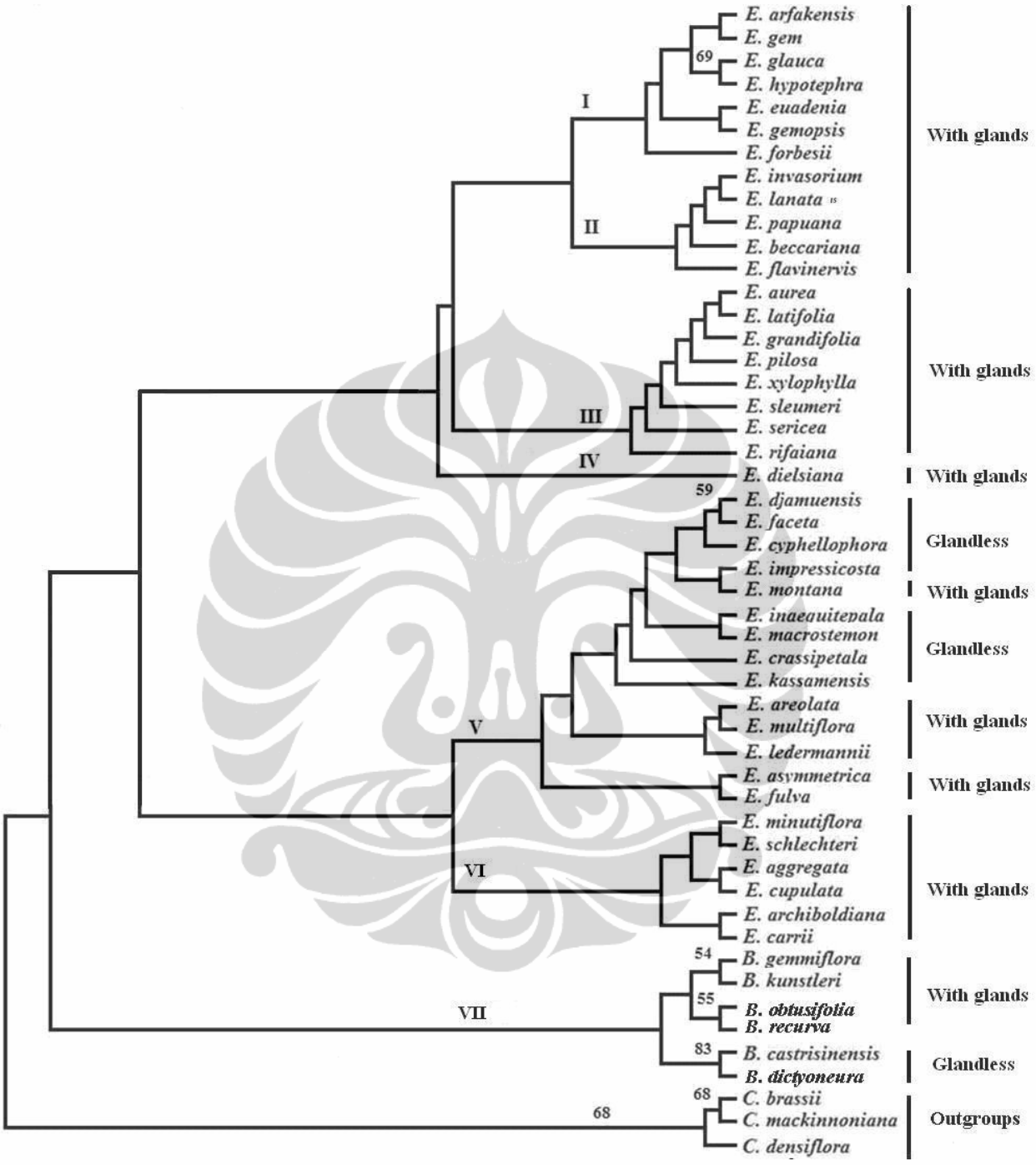

Figure 2.2. One of the 86 most parsimonious trees obtained from parsimony analysis of morphological character using PAUP (length = 296; CI = 0.220; RI = 0.588). Internal support was indicated by bootstrap values that are shown above the branches

surface shiny (not glaucous); midrib flat above; lateral veins raised above; staminal glands separate; stamens 3 reside in the 3rd whorl; anther locule roundish; and staminodes 3, in the 4th whorl.

The phylogenetic tree resulted from the Maximum Parsimony analysis has shown that *Endiandra* and *Beilschmiedia* were separated, indicating that both genera are monophyletic. *Beilschmiedia* was placed in clade VII, separated from all *Endiandra*. Clade VII consists of 6 species of *Beilschmiedia* that shared dark brown, pubescent and solid twig; leaves pinnate; petiole glabrous; domatia absent; inflorescen pubescent; flowers many; floral bract absent; pedicel thin; and ovary glabrous. *Beilschmiedia castrisinensis* and *B. dictyoneura* are grouped together because both have 6 stamens and 6 staminodes, whereas the rest of *Beilschmiedia* in the clade have 9 stamens with 3 staminodes.

4. DISCUSSION

The relationships of *Endiandra* species in New Guinea shown in the phylogenetic tree (Figure 2.2) indicated that *Endiandra* is a monophyletic group. The species of *Endiandra* from New Guinea were grouped in six clades but the relationships are only supported by low bootstrap support. Low bootstrap support was probably due to limited number of characters used in the analysis (Li & Christophel 2000). The number of stamens thought to be important to recognize genera was not separated, *E. montana*, a species with six stamens was in the same group with species of *Endiandra* that have three stamens.

The presence and absence of staminal glands in *Endiandra* species are not grouped well in the phylogenetic tree (Figure 2.2). The species without staminal glands were grouped together with the species with staminal glands in clade V, even though species with glands are grouped together in clade I, II, III, IV and VI, but with low bootstrap support. The species with fused glands are almost nicely grouped together in clade I, but 1 species in the clade has separate glands (*E. gem*). Therefore, grouping based on the gland arrangement is also not well supported. The flowering specimen of *E. gem* however was not available, the

information on the gland arrangement was obtained from the perianth remnant at the base of the fruits (Kostermans 1969). It is interesting to know the floral characters when the flowering specimens are become available.

In this study, *Endiandra* species with glands are greater in number than glandless species. This probably was caused by the union of New Guinea and Australia geologically in the past so that similar to Australian *Endiandra* species that 79 % are with glands (Hyland 1989), New Guinean *Endiandra* with glands were also dominant. Moreover, in accordance with high plant diversity in New Guinea (Welzen *et al*. 2005), the insect diversity is also probably high so that *Endiandra* flowers compete to attract the insects, and flowers with glands are successful because they provide nectar to the insects. According to Armstrong & Irvine (1990) and Rohwer (2009), the glands secrete nectar consisted of sugar that will attract insects to come by the flowers. Attracted insects enable pollination to occur and therefore it guarantees the fruit and seed sets. In other words, the glands are important for plant survival because the glands gives an advantage of increasing fruit set which increases the chances of fruits are being dispersed by birds. Consequently, more species may grow in other places.

The present analysis indicated that *Endiandra* and *Beilschmiedia* are monophyletic groups. Number of stamens is the important character to delimit the genera *Endiandra* and *Beilschmiedia* (Kostermans 1957, Rohwer 1993) but the presence of species that have 6 stamens, intermediate number of stamens between 3 (*Endiandra*) and 6 (*Beilschmiedia*) has created some doubt about the characters. The species with 6 stamens are either recognized as different genus, *Brassiodendron* (Werff 2001) or as either *Endiandra* or *Beilschmiedia* (Hyland 1989). In this present analysis the characters separating *Endiandra* and *Beilschmiedia* are the stamens and staminodes. Their number and position in the floral whorl separate the two genera. *Endiandra* has 3 or 6 stamens in the 3rd whorl or 2nd and 3rd whorls (respectively), versus 9 or 6 stamens in the 1st, 2nd and 3rd whorls or 1st and 2nd whorls (respectively). When a specimen has 6 stamens, it can be assign to the appropriate genus (*Endiandra* or *Beilschmiedia*) by looking at the position of the stamens in the floral whorls. Stamens of *Endiandra* are in the 2nd and 3rd whorls whereas those of *Beilschmiedia* are in the 1st and 2nd whorls.

It is noted that characters selected for creating for phylogenetic analysis were highly subjective. The tree topology is determined largely by characters selected for the analysis. Different characters used for the phylogenetic analysis, the tree topology resulted from the analysis will be different. In this study, *Endiandra* and *Beilschmiedia* were polyphyletic when some characters, position of stamens characters (character 36-38), were excluded. Inclusion of characters indicating position of stamens separated *Endiandra* and *Beilschmiedia*. Similarly, different sets of characters used for grouping will result in different grouping systems depending on the importance of characters chosen. Difficulties in finding a good set of characters for grouping occurred also in the family *Lauraceae* in general, for examples Pax (1889) used the number of anther locules to delimit the subfamilies and it is noted that such character did not have a generic value (Rohwer 1993).

5. CONCLUSION

It is concluded that based on the phylogenetic analysis of morphological characters, that *Endiandra* are grouped in several clades however, the clades of *Endiandra* cannot be determined by particular morphological characters. The grouping within *Endiandra* based on the presence and absence of staminal glands is not well supported, because the species with and without staminal glands are grouped together in the same clade. Moreover, based on morphological characters, *Endiandra* and *Beilschmiedia* are monophyletic groups. Important characters for separating the two genera are number of stamens and position of stamens in the floral whorls. It is noted that character selection for delimiting grouping is important therefore finding a good set of characters for grouping is important.

5. RECOMMENDATION

Research in order to find a good set of characters for grouping system is suggested. In groups of problematic genera such as *Endiandra* and *Beilschmiedia*, comprehensive studies on the groups need to be done, by paying attention to the characters other than macromorphology. Ultra structure studies on flower developmental and leaf reticulation are highly suggested to be carried out. Additionally, chemotaxonomy can be assessed to understand the chemical composition of taxa studied by extracting the barks. Subsequently, we can used these new sets of characters to understand the relationships of the genera by performing the phylogenetic analysis.

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TOPIC 3

PHYLOGENETIC RELATIONSHIPS OF *ENDIANDRA* R.BR. (*LAURACEAE*) INFERRED FROM INTERNAL TRANSCRIBED SPACER REGION OF NUCLEAR RIBOSOMAL DNA SEQUENCES

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ABSTRACT

The two genera *Endiandra* and *Beilschmiedia* are morphologically very difficult to distinguish when flowers are unavailable and the phylogenetic relationships of two genera is problematic. Previous scientists showed that phylogenetic analyses of *Lauraceae* using *mat*K and *cp*DNA indicated that *Endiandra* was nested within *Beilschmiedia*, however the studies have only used limited samples of *Endiandra*. This study was the first report on the phylogenetic analysis among *Endiandra* species and between *Endiandra* and *Beilschmiedia* based on ITS region of nrDNA. The present analysis has accommodated more samples of *Endiandra* to confirm the position of *Endiandra*. ITS region of nrDNA of twenty eight samples consisted of *Endiandra* (19 samples), *Beilschmiedia* (3 samples) and *Cryptocarya* (6 samples) were sequenced in this study and total of 31 taxa, consisted of 19 samples of *Endiandra*, 5 samples of *Beilschmiedia* (as in-groups) and 7 samples of *Cryptocarya* (as outgroups) were used for phylogenetic analysis using maximum parsimony method. One of the most parsimonious trees suggested that *Beilschmiedia* cannot be separated from *Endiandra*. The staminal glands distributed in the lower clades of the tree, left the terminal clade with a group of glandless species with an exception of *E. monothyra*. Staminal gland is an important character for practical identification but the grouping based on the present and absence of staminal gland was not supported by ITS data sequence. Improving the resolutions of the cladogram for more reliable interpretations of the species relationships within *Endiandra* is suggested by adding more samples and introducing more suitable markers.

Keyword: *Beilschmiedia*, *Endiandra*, Internal Transcribed Spacer (ITS) region of nrDNA, phylogenetic analysis, sequences, staminal glands

1. INTRODUCTION

Endiandra R.Br. is a member of *Lauraceae*, one of plant families dominated the tropical rain forests. The genus consists of mostly trees and is distributed in Asia and Australia with several species distributed in Pacific Islands (Rohwer 1993). Based on the inflorescence, *Endiandra* is grouped together with the genera *Beilschmiedia*, *Potameia*, *Cryptocarya* and *Triadodaphne* and placed in the tribe *Cryptocaryeae* (Werff & Richter 1996). Vegetatively, *Endiandra* is very close to *Beilschmiedia* and both can only be separated by observing flowering specimens (Werff 2001). Typical flowers of *Endiandra* has 3 stamens, whereas *Beilschmiedia* has 9 stamens. Therefore, it is rather difficult to determine to the correct genus without a flowering specimen.

Based on the observation of New Guinean specimens and comparing with Bornean ones (Arifiani 2001), it is thought that presence and absence of glands in the flowers of *Endiandra* could be use to divide the genus into two groups, i.e.: 1) a group that consists of species that have extra flower parts such as glands and 2) a group with species that bear basic flower parts with no glands or other parts. First group will represent *Endiandra* group as Brown first described the genus and second group will represent species that have *Dictyodaphne* characteristics.

Molecular evidence enrich the range of characters in *Lauraceae* in order to understand intrafamilial relationships (Rohwer 2000, Chanderbali *et al.* 2001) and species relationships in *Litsea* (Fijridiyanto & Murakami 2009), *Neolitsea* (Li *et al*. 2007), *Persea* (Rohwer *et al*. 2009) and *Sassafras* (Nie *et al*. 2007).

Phylogenetic studies of *Lauraceae* using *mat*K gene (Rohwer 2000) and chloroplast genes of *trn*L-F, *psb*A-*trn*H, *trn*T-L, *rpl*16 and 26S nrDNA (Chanderbali *et al.* 2001) showed that *Endiandra* was nested within *Beilschmiedia*. Those studies suggested that phylogenetic relationships of *Endiandra* and *Beilschmiedia* is problematic. In each of the studies above, only one species was included in the phylogenetic analysis, i.e., *E. pubens* (Rohwer 2000) and *E. microneura* (Chanderbali *et al*. 2001). Therefore, it is interesting to know the relationships of *Endiandra* and *Beilschmiedia* when more species of

Endiandra were included and different gene was sequenced for the phylogenetic analysis.

Protein-coding gene sequences have been widely used in phylogenetic analyses as molecular data resources and about the same time the non-coding DNA sequences have also provided information predominantly applied for similar purposes. The current popular non-coding regions used in the phylogenetic reconstruction are plastid *trn*L-F regions and ITS region of nrDNA (Calonje *et al.* 2009).

Internal Transcribed Spacer (ITS) is a rapidly evolving genomic non-coding region that possesses a higher degree of variation than regions of cpDNA. Region of ITS nrDNA has been proven to be useful in resolving phylogenetic relationships of closely related species and genera in plants (Baldwin *et al*. 1995; Chanderbali *et al.* 2001) and problematic taxa such as in *Oleaceae* (Besnard *et al.* 2009) and *Isatis* **(**Moazzeni *et al*. 2010). Additionally, ITS sequences have been used previously for inferring phylogenetic relationships in other genera of *Lauraceae* such as *Litsea* (Li *et al*. 2004), *Neolitsea* (Li *et al*. 2007), *Persea* (Rohwer *et al*. 2009), therefore it is expected that this region will also be informative for inferring phylogenetic relationships in *Endiandra*.

Molecular study in *Endiandra* using ITS region of nrDNA sequences was never been done before. The fact that there seems to be a morphological division within *Endiandra* based on differences in floral part, it is important to further explore the molecular characters in these species involved. It is expected that phylogenetic relationships inferred from ITS region of nrDNA sequences will provide knowledge that later can be compared with that of morphological data to confirm further division within *Endiandra*. Therefore, the aims of this research are 1) to analyze phylogenetic relationships of *Endiandra* based on ITS region of nrDNA sequence data for a better understanding of the relationships among *Endiandra* species and 2) to understand relationships between *Endiandra* with *Beilschmiedia*.

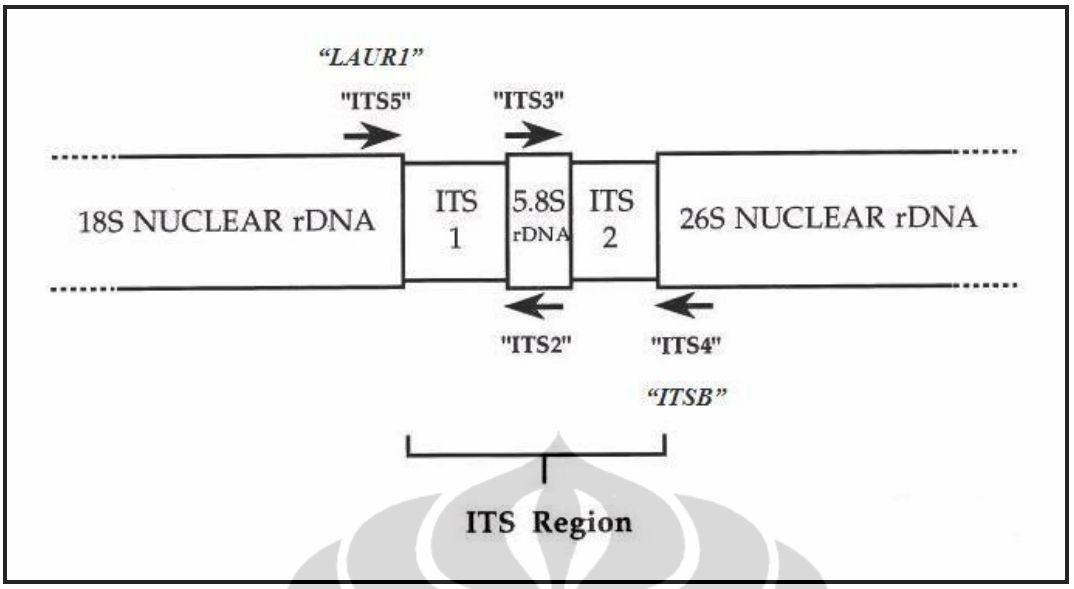

Figure 3.1. Organization of the ITS region of nrDNA. Primer names in quotation marks with arrows indicate orientation of the primers and approximate position of primer sites (modified from Baldwin 1995)

2. MATERIALS AND METHODS

2.1 Materials

Nineteen samples of *Endiandra*, 3 samples of *Beilschmiedia* and 7 samples of *Cryptocarya* were successfully sequenced. A total of 31 samples, representing 30 species were included in the phylogenetic analysis. Nineteen species of *Endiandra* and 4 species of *Beilschmiedia* were analyzed as in-group species and 7 species *Cryptocarya* were incorporated as the outgroups. ITS sequence data of three species, i.e., *Beilschmiedia fordii* (EF538710), *B. robusta* (GU082363) and *Cryptocarya metcalfiana* (GU082367) were obtained from the GenBank. Table 3.1 provides information for all samples used in this study.

Table 3.1. Taxa used in the phylogenetic study

No.	Species	Provenance	Voucher	Accession Number**
1	*Beilschmiedia fordii**	China	Scau 00456 (CANT)	EF538710
2	*Beilschmiedia robusta**	China	Wang 08063 (HITBC)	GU082363
3	*Cryptocarya metcalfiana**	China	Wang 08067 (HITBC)	GU082367

Table 3.1. continued

No.	Species	Provenance	Voucher	Accession Number**
4	*Beilschmiedia kuntsleri*	Kalimantan	DA1164 (BO)	will be deposited in GenBank
5	*Beilschmiedia roxburghiana*1	Sumatra	DA1174 (BO)	will be deposited in GenBank
6	*Beilschmiedia roxburghiana*2	Java	DA1171 (BO)	will be deposited in GenBank
7	*Cryptocarya crassinervia*	Kalimantan	DA1159 (BO)	will be deposited in GenBank
8	*Cryptocarya densiflora*	Java	DA1172 (BO)	will be deposited in GenBank
9	*Cryptocarya ferrea*	Java	DA1180 (BO)	will be deposited in GenBank
10	*Cryptocarya laevigata*	Java	DA1169 (BO)	will be deposited in GenBank
11	*Cryptocarya massoy*	New Guinea	DA1170 (BO)	will be deposited in GenBank
12	*Cryptocarya pulchrinervia*	Kalimantan	DA1165 (BO)	will be deposited in GenBank
13	*Endiandra beccariana*	New Guinea	DA652 (BO)	will be deposited in GenBank
14	*Endiandra compressa*	Queensland	Hyland 13696 (BO)	will be deposited in GenBank
15	*Endiandra coriacea*	Taiwan	Kuo Fang s.n.	will be deposited in GenBank
16	*Endiandra dielsiana*	New Guinea	WT21916 (BO)	will be deposited in GenBank
17	*Endiandra glauca*	Queensland	MVDM630 (NSW)	will be deposited in GenBank
18	*Endiandra globosa*	Queensland	MVDM643 (NSW)	will be deposited in GenBank
19	*Endiandra impressicosta*	Queensland	MVDM552 (NSW)	will be deposited in GenBank
20	*Endiandra kingiana*	Kalimantan	Insya s.n. (WAN)	will be deposited in GenBank
21	*Endiandra macrophylla*	Java	DA1162 (BO)	will be deposited in GenBank
22	*Endiandra monothyra*	Queensland	MVDM602 (NSW)	will be deposited in GenBank
23	*Endiandra montana*	Queensland	BG9307 (NSW)	will be deposited in GenBank
24	*Endiandra neocaledonica*	New Caledonia	Lowry 6807 (MO)	will be deposited in GenBank
25	*Endiandra palmerstonii*	Queensland	MVDM513 (NSW)	will be deposited in GenBank
26	*Endiandra pouenboensis*	New Caledonia	McPherson 18988 (MO)	will be deposited in GenBank
27	*Endiandra rubescens*	Sumatra	DA1158 (BO)	will be deposited in GenBank
28	*Endiandra* sp.	Sumatra	DA1176 (BO)	will be deposited in GenBank
29	*Endiandra firma*	Sumatra	DA1175 (BO)	will be deposited in GenBank

Table 3.1. continued

No.	Species	Provenance	Voucher	Accession Number**
30	*Endiandra arborea*	Java	DA1178 (BO)	will be deposited in GenBank
31	*Endiandra xanthocarpa*	Queensland	Werff 17046 (MO)	will be deposited in GenBank

Note: *) Sequences were obtained from GenBank
**) Sequence data obtained from this study will be deposited in GenBank

2.2 Methods

2.2.1 DNA extraction

Total genomic DNA was extracted from silica-gel dried leaves or herbarium using CTAB method (Doyle & Doyle 1987) and DNeasy Plant Minikit (Qiagen Inc.). CTAB method (Doyle & Doyle 1987) was used with a slight modification (Makino Laboratory). Firstly, dried 5 mm × 5 mm tissue (stored in silica gel) was prepared in 2 ml centrifuge tube with an almina ball and ground it to a fine powder with mechanical mill (Retsch MM300; 3 min, 25/sec). We modified a method by adding 1 ml HEPES buffer to each tube to remove polysaccharide from each sample and mixed samples by using mechanical mill (3 min, 25/sec). Then, samples were spinned in a table-top centrifuge for 10 min at 12000-15000 rpm at 4°C. After the supernatant was discarded, we added 500 µl CTAB buffer (2% Cetyl trimethyl ammonium bromide, 0.1 M Tris-HCl (pH 8.0), 1.4 M NaCl, 1% PVP, 0.5% 2-mercaptoethanol; e.g. with 10 ml CTAB buffer, we added 0.2 g of PVP and 20µl of β-mercaptoethanol). Then, we incubated at 55-66°C for 20-60 min in a heat block. After removing tubes from heat block, we added 500µl of chloroform/isoamyl alcohol (24:1) and mixed for 20 min by mixer (Taiyo Kagaku, RT-50) or with Vortex. After that, we centrifuged at 12000-15000 rpm for 10 min at 20°C and then transferred the upper aqueous carefully to a new 1.5 ml tube. Then, 300µl of 100% isopropanol was added and mixed gently. After that we centrifuged at 12000-15000 rpm for 20 min at 4°C and the supernatant was discarded and 500µl 70% ethanol was added. Then, we

centrifuged at 12000-15000 rpm for 3 min at 4°C, discarded the supernatant and added 500µl 70% ethanol. After that, we centrifuged again at 12000-15000 rpm for 3 min at 4°C. To dry off ethanol completely from samples we put the samples in desiccator for 10 min. Finally, we diluted the samples with 50µl – 100µl of TE buffer and store at 4°C.

The protocol used for DNA extraction using DNeasy Plant Minikit (Qiagen Inc.) was adopted from DNeasy Plant Handbook (2006). Firstly, we placed the sample material (20 mg dried tissue) into a mortar, ground the sample into fine powder and placed it into 1.5 ml tube. Then, we added 400 µl Buffer AP1 and 4 µl RNase A stock solution (100 mg/ml) and vortexed vigorously. After that, we incubated the mixture for 10 min at 65°C by mixing 2 or 3 times during incubation by inverting tube. We added 130 µl Buffer AP2 to the lysate, mixed, and incubated for 5 min on ice. Then, we centrifuged the lysate for 5 min at 20,000 x g (14,000 rpm) and poured the lysate into the QIAshredder Mini spin column (lilac) placed in a 2 ml collection tube, and centrifuged for 2 min at 20,000 x g (14,000 rpm). After that, we transferred the flow-through fraction into a new tube without disturbing the cell-debris pellet and added 1.5 volumes of Buffer AP3/E to the cleared lysate, and mixed by pipetting. We took 650 µl of the mixture, including any precipitate that may have formed, into the DNeasy Mini spin column placed in a 2 ml collection tube and centrifuged for 1 min at 6000 x g (8000 rpm), and discarded the flow-through. We reused the collection tube to repeat the step for the remaining sample. We discarded flow-through and collection tube. We placed the DNeasy Mini spin column into a new 2 ml collection tube, added 500 µl Buffer AW, and centrifuged for 1 min at 6000 x g (8000 rpm). Then, we discarded the flow-through, reused the collection tube and added 500 µl Buffer AW to the DNeasy Mini spin column. We centrifuged for 2 min at 20,000 x g (14,000 rpm) to dry the membrane and transferred the DNeasy Mini spin column to a 1.5 ml tube, and added 100 µl Buffer AE directly onto the DNeasy membrane. We incubated for 5 min at room temperature (15–25°C), and then centrifuged for 1 min at 6000 x g (8000 rpm) to elute.

2.2.2 DNA amplification

Internal Transcribed Spacer (ITS) region of nrDNA were amplified by the Polymerase Chain Reaction (PCR) using a Thermal Cycler machine. Primers used to amplify the ITS region consisted of universal primers of ITS 5 and ITS 4 and specific forward primer LAUR 1 and ITS B (Table 3.2). First attempts using LAUR 1 and ITS B was performed following the success of amplifying *Laureae* and *Perseae* tribes of *Lauraceae* (Chanderbali *et al*. 2001) but were not successful for this study and universal ITS primers were tried and worked better than former primers.

PCR reactions were performed using a 25 ul mixture of variable volume of ddH_2O, 2.5 ul AmpliTaq Gold Buffer 10x, 2 – 3.5 ul 25 mM $MgCl_2$, 2.5 ul GC Enhancer, 0.5 ul dNTP mix, 0.5 ul ITS 5, 0.5 ul ITS 4, 1 unit of AmpliTaq Gold DNA Polymerase and 0.5 – 2 ul of DNA template.

Table 3.2. Primers used for amplification of ITS region:

Primer name	Sequence (5' -- 3')	Reference
Forward		
ITS5	GGAAGTAAAAGTCGTAACAAGG	White *et al*. 1990
LAUR 1	ACC ACC ACC GGC AAC CA	Chanderbali *et al*. 2001
Reverse		
ITS4	TCC TCC GCT TAT TGA TAT GC	White *et al*. 1990
ITSB	CTT TTC CTC CGC TTA TTG ATA TG	Blattner 1999

PCR reactions were performed in following conditions: 2 minutes of initiation step at 94°C, followed by 35 cycles of denaturation at 94°C for 30 seconds, annealing at 54°C for 30 seconds, and extension at 72°C for 1 minute, then ends with final extension at 72°C for 5 minutes and final holds at 4°C. PCR products then were electrophoresized on 2% agarose, stained with ethidium bromide and visualized under UV to see the result. The PCR reactions of each sample were repeated until clear bands on the visualized agarose gel were obtained.

2.2.3 DNA Sequencing

Good PCR products were then sent to Macrogen Sequencing Service in Korea or 1st BASE in Singapore for direct sequencing. The sequencing procedure was first performed by purifying the PCR fragment and then sequence reactions were performed to produce single stranded DNA in both directions to get overlapping sequences. Sequence reactions were performed in a PCR tube, using 2 ul of ITS 5 and ITS 4, 2 ul DNA template, 4 ul Big Dye, and 4 ul Big Dye Buffer, using ddH_2O to make up final reaction volume of 20 ul. Then the reactions were carried out on PCR machine for 25 cycles with conditions of 96°C for 30 seconds, 50°C for 15 seconds, and 60°C for 4 minutes. Purified products were then directly sequenced using DNA automated sequencer. This machine analyzed DNA fragments produced using lasers within it, which stimulated the fluorescent dyes added to the reactions. The fluorescent emissions detected were collected according to the wavelengths and that output will later constitute the DNA sequence.

2.2.4 Phylogenetic analysis

Sequence data obtained were checked and edited using BioEdit software. After editing and generating consensus sequences for all taxa, different sequence fragments were aligned manually and/or with ClustalX (Thompson *et al*. 1997) to produce a data matrix. Furthermore the data matrix was analyzed to infer the phylogenetic relationships of all taxa analyzed. Sequence data sets were analyzed as heuristic search for most parsimonious trees with TBR branch swapping using PAUP* version 4.0b10 (Swofford 1998). Both 'MulTrees' and 'Collapse' options were in effect but 'Steepest descent' option was not in effect. Characters were assumed to be unordered, equally weighted, and gaps were treated as missing data. Bootstrapping (Felsenstein 1985) with 1000 replications was performed with above heuristic search settings but MaxTrees set to 5000.

3. RESULTS

3.1 DNA extraction, amplification and sequencing

Extraction and amplification of ITS region of nrDNA from *Endiandra* species are not easy. *Endiandra* contains a lot of polysaccharides and secondary metabolites that impair DNA isolation. Several DNA isolation protocol were used to obtain good quality of DNA. CTAB methods were used with several modifications (Doyle & Doyle 1987). Modifications were done by adding incubation time in the water bath to 1 hour at 65º C; washing with 70% cold ethanol twice; cleaning DNA using 3M Sodium acetate and 99% cold ethanol; or adding HEPES buffer to remove polysaccharides from each samples. CTAB modification protocols did not show significant different in the results, only adding HEPES buffer showed better result but it still not sufficient enough to be able to amplify. Another protocol used was DNeasy Plant Minikit (Qiagen) and this protocol has yielded better results.

DNA isolation using DNeasy Plant Minikit produced better quality of DNA because the kit provides columns for cell destruction. These columns are good to help removing mucus. The effectiveness of DNA isolation in *Endiandra* depended on how the samples were stored and how old were the samples. Samples that are dried in silica gel yield better DNA quality than ones obtained from herbarium specimen. DNA of *Endiandra* is rarely recovered from herbarium specimens because the specimens were usually preserved in 70% alcohol for several weeks in the field before drying. This will preserve the specimens from rotten but it may break down the DNA so that it is difficult to recover. Occasionally, herbarium specimens were dried without alcohol treatment, the DNA of such herbarium may not be broken down so that it is easier to recover the DNA. Additionally, chemical treatment such as corrosive sublimate (mercuric chloride) might be added to the herbarium specimens to send the insects away. This treatment may also break down the DNA.

Age of leaf samples from silica-dried material and herbarium influences the successfulness of DNA isolation. The longer we kept leaf sample from the

time it was collected, the smaller is the chance to recover its DNA. Therefore, DNA extractions of fresh leaf samples are successful most of the time but in *Endiandra*, it is difficult to get fresh samples because the samples are usually collected in the forest far from the Laboratory.

Visualization of total DNA is shown in Figure 3.2. Samples number 1-9 showed clear bands that indicate good recovery of DNA. The thickness of the band indicates the quantity of DNA recovered, the thicker the band, the larger amount of DNA recovered. However, in the case of *Endiandra*, the absence of bands did not necessarily mean that no DNA was recovered from DNA isolation. Samples number 10-12 did not show any band for total DNA but these samples were amplified well in the PCR reactions.

Figure 3.2. Visualization of genomic DNA: 1. 100bp Plus DNA Ladder, 2. *Endiandra rubescens*, 3. *E. macrophylla*, 4. *E. macrophylla*, 5. *Cryptocarya tomentosa*, 6. *C. laevigata*, 7. *C. laevigata*, 8. *C. massoy*, 9. *Beilschmiedia roxburghiana*, 10. *Beilschmiedia* sp., 11. *B. gemmiflora*, 12. *B. kuntsleri*, 13. *E. dielsiana*

DNA amplification was carried out using PCR method. PCR reactions for each sample were carried until clear bands were visualized in the agarose gel. DNA templates from *Endiandra* samples were difficult to amplify, so that PCR reactions were carried out repeatedly until good PCR products were obtained. There is currently no established recipe for PCR reaction mix and PCR conditions available. PCR reactions were done many times with different the concentrations and volumes of reagents in the reaction mix, such as the $MgCl_2$, primers, and DNA templates. Additionally, PCR conditions were tried in different temperatures and time length, especially the temperatures of annealing, extension and number of cycles ran. Figure 3.3 showed that samples of *Endiandra*

sankeyana, *E. glauca*, *E. montana*, and *E. xanthocarpa* were not amplified yet, no bands appeared on the gel. PCR reactions were repeated for those samples with different reaction mix composition and PCR condition until PCR product were obtained for *E. sankeyana*, *E. glauca*, *E. montana*, and *E. xanthocarpa* samples.

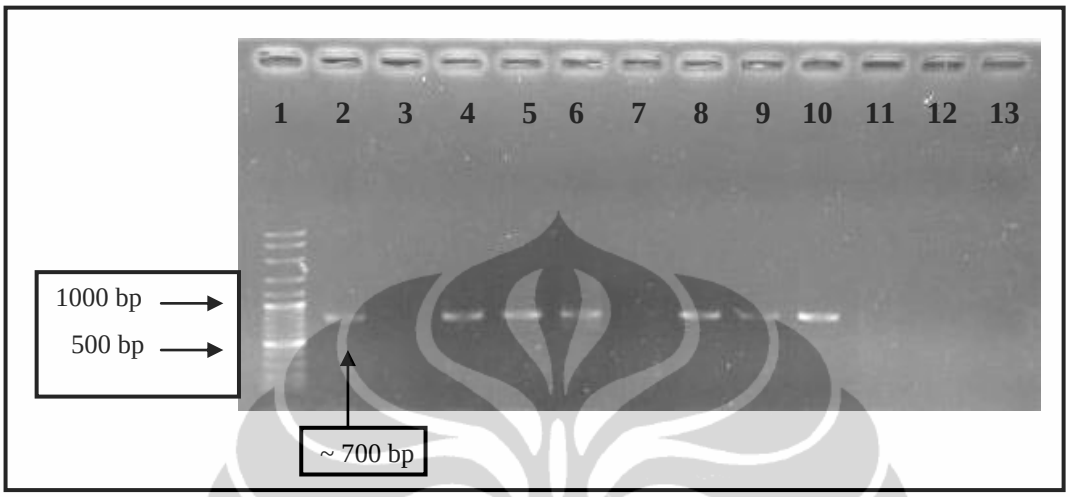

Figure 3.3. Visualization of PCR products from 1. 100bp Plus DNA Ladder, 2. *Endiandra palmerstonii*, 3. *E. sankeyana*, 4. *E. impressicosta*, 5, 6. *E. monothyra*, 7. *E. glauca*, 8-10. *E. globosa*, 11, 12. *E. montana* and 13. *E. xanthocarpa*

Figure 3.4 showed that band positions of *E. coriacea*, *E. dielsiana* and *E. papuana* were different from *E. formicaria, E. elongata*. Different band positions indicated that the length of ITS sequences were variable in *Endiandra*, the length of base pairs ranged from 600-700bp.

The PCR products of samples from *E. monothyra* and *E. kingiana* showed double bands which indicated that sequences of ITS matched at those two positions at the two species (Figure 3.5). In such condition, gel extraction were performed by cutting the gel which contained the bands, then the purified product was rerun for PCR. The band selected for cutting was the one at the same position as other samples with single bands. The succesful rerun PCR products were then sequenced.

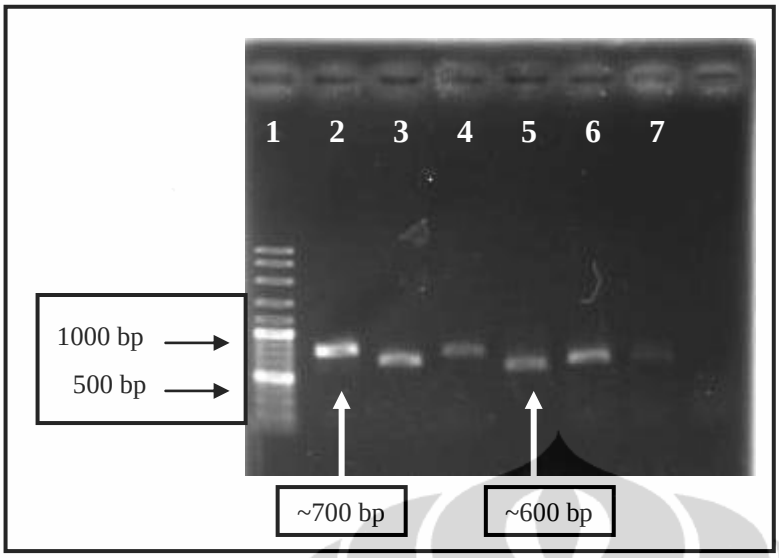

Figure 3.4. Visualization of PCR products: 1. 100bp Plus DNA Ladder, 2. *Endiandra coriacea*, 3. *E. formicaria*, 4. *E. dielsiana*, 5. *E. elongata*, 6. *E. papuana* and 7. *E. anthropophagorum*

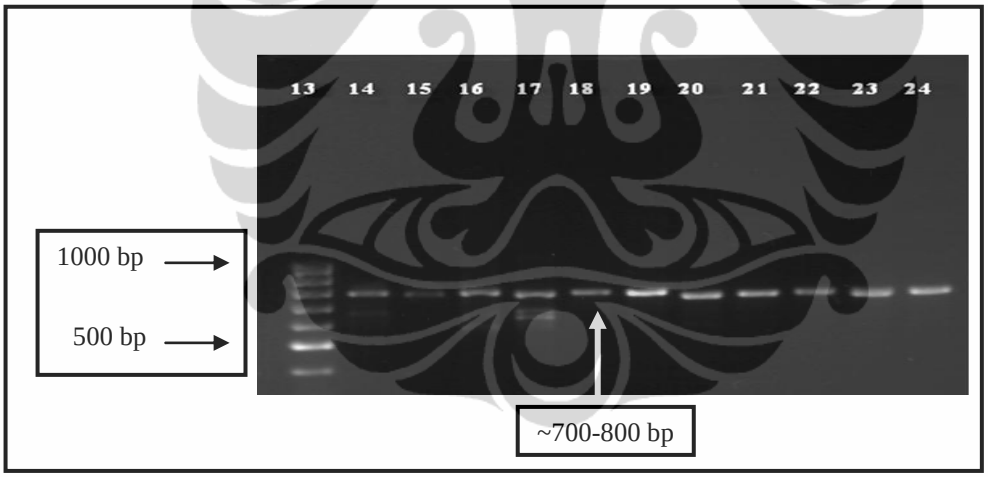

Figure 3.5. Visualization of PCR products: 13. DNA Ladder, 14. *Endiandra monothyra*, 15. *E. dielsiana*, 16, 17. *E. kingiana*, 18. *Beilschmiedia lucidula*, 19. *E. macrophylla*, 20. *Cryptocarya laevigata*, 21. *C. massoy*, 22. *B. roxburghiana*, 23. *Beilschmiedia* sp. and 24 *B. gemmiflora*

3.2 Nucleotide sequences of ITS region of nrDNA and phylogenetic analysis

The ITS sequence data set contained ITS1, 5.8S and ITS2 sites in which the total length of the aligned ITS region of nrDNA sequences was 634 base pairs (bp). The length of ITS sequences of *Endiandra* ranged from 638 to 754 bp and length of *Beilschmiedia* ranged from 655 to 694 bp (Table 3.3). Among the non-excluded 593 bp that constitute the ITS sequences, 329 (55 %) characters were constant, 143 (24 %) variable characters were parsimony-uninformative and 121 (20 %) were parsimony-informative characters.

Table 3.3 Sequence length variation of ITS region of nrDNA in *Endiandra* and *Beilschmiedia*

No.	Species	Sequence length (bp)	No.	Species	Sequence length (bp)
1	*Endiandra pouenboensis*	638	1	*Beilschmiedia fordii**	655
2	*Endiandra rubescens*	656	2	*Beilschmiedia roxburghiana*2	656
3	*Endiandra palmerstonii*	658	3	*Beilschmiedia kuntsleri*	682
4	*Endiandra coriacea*	668	4	*Beilschmiedia roxburghiana*1	693
5	*Endiandra glauca*	670	5	*Beilschmiedia robusta**	694
6	*Endiandra compressa*	677			
7	*Endiandra dielsiana*	684			
8	*Endiandra monothyra*	687			
9	*Endiandra beccariana*	697			
10	*Endiandra montana*	700			
11	*Endiandra macrophylla*	702			
12	*Endiandra xanthocarpa*	711			
13	*Endiandra impressicosta*	717			
14	*Endiandra globosa*	718			
15	*Endiandra firma*	724			
16	*Endiandra* sp.	740			
17	*Endiandra neocaledonica*	741			
18	*Endiandra arborea*	748			
19	*Endiandra kingiana*	754			

Note: *) the sequences were obtained from GenBank

Figure 3.6 showed the ITS sequence variations, showing the conserved region of 5.8S nr DNA in which the sequences of all species are the same except *E. monothyra*. Figure 3.7 showed ITS sequence variation among *Endiandra* species. Among *E. montana*, *E. rubescens*, *Endiandra* sp., *E. macrophylla*, *E. coriacea*, *E. firma*, *E. arborea* and *E. kingiana*, the sequence variations is very low at nucleotide positions of 540 – 634. The variations are shown only at nucleotide position of 585, 590 and 591. Sequence variation of *Endiandra* were also occurred in base pair positions of 560, 568, 569, 571, 574, 578, 581-582, 585, 589-592, 595 and 622 (Figure 3.7 shown by black boxes).

The maximum parsimony analysis of 31 taxa has resulted in 108 most parsimonious trees with a length of 439 steps; consistency index [CI] of 0.736; retention index [RI] of 0.835; homoplasy index [HI] of 0.264. One of the parsimonious trees showed that *E. dielsiana* and *E. impressicosta* are sister to *Beilschmiedia* and *Endiandra* (Figure 3.8). The next clades consist of *Beilschmiedia* species (clade V) and *Endiandra palmerstonii* which is sister to the rest of *Endiandra*. The clades at the upper part of the tree consisted of three clades of *Endiandra* species, i.e., clade I consisted of seven glandless *Endiandra* species and one species with staminal glands, *E. monothyra*; clade II consisted of five species with glands; and clade III consisted of three species with glands.

The type of genus *Endiandra* is *E. glauca* and it positioned in clade II together with *Endiandra beccariana*, *E. xanthocarpa*, *E. globosa* and *E. montana*.

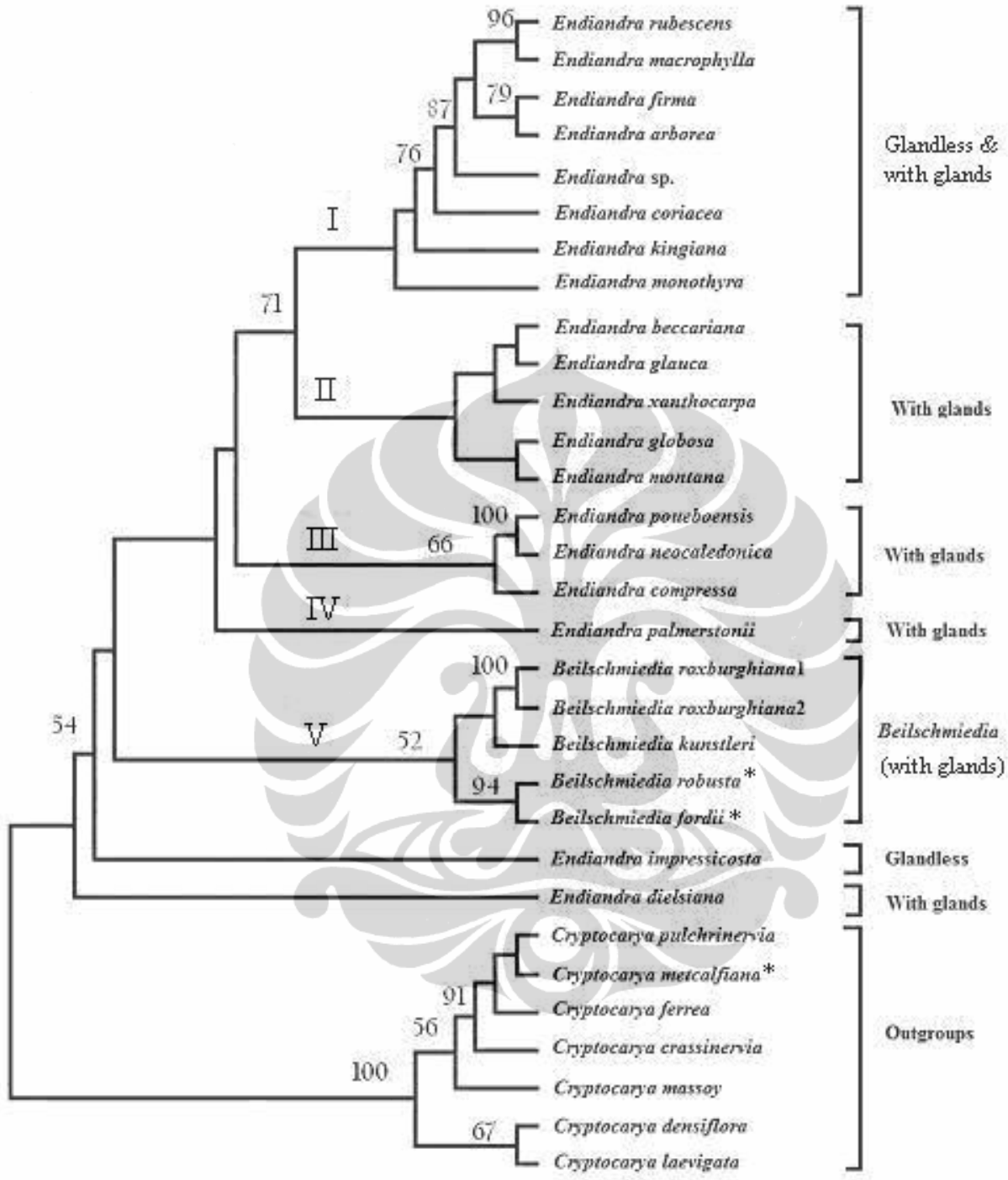

Figure 3.8. One of the 108 most parsimonious trees derived from analysis of ITS sequences (length = 439; CI = 0.736; RI = 0.835). Internal support was examined by bootstrap analysis of 1,000 replicates. Bootstrap values are shown above the branches. All taxa were sequenced in this study except for *B. robusta**, *B. fordii** and *C. metcalfiana** were obtained from GenBank

4. DISCUSSION

4.1 Sequence length variation of the ITS region of nrDNA

There is a sequence length variation within the species of *Endiandra* that ranged from 638 to 754 base pairs. Table 3.3 showed that the shortest was *E. pouenboensis* (638 bp), followed by *E. rubescens* (656 bp), *E. palmerstonii* (658 bp) and *E. coriacea* (668 bp). The longest sequence length was *E. kingiana* (754 bp) followed by *E. arborea* (748 bp) and *E. neocaledonica* (741 bp). Within the species of *Beilschmiedia*, sequence length varied from 655 bp in *B. fordii* to 694 bp in *B. robusta*. Sequence length of ITS region of nrDNA of *Beilschmiedia* species were within range of sequence length of *Endiandra* species, therefore there is no clear differences in sequence length of ITS region of nrDNA from *Endiandra* and *Beilschmiedia*.

4.2 Phylogenetic analysis

Phylogenetic study of *Endiandra* using molecular data of ITS region of nrDNA sequences was carried out for the first time in the present research, therefore information on the relationships among the species of *Endiandra* is newly contributed. The present analysis does yield significant information about the phylogenetic position of several clades and individual taxa even though only limited samples of *Endiandra* were analyzed and low resolution among several taxa occurred.

Cryptocarya was chosen as the outgroup because it is the closest relative to *Endiandra* and *Beilschmiedia* according to analysis of *mat*K sequences (Rohwer 2000) and *trn*L-F, *psb*A-*trn*H sequences (Chanderbali *et al*. 2001).

The phylogenetic tree from ITS sequence has showed that there are three identifiable clades of *Endiandra* on the upper part of the tree. Clades I and II were not well supported, with less than 50 % bootstrap values, but clade III were supported with 66 % bootstrap value (Figure 3.8). Clade I consisted of *E.*

rubescens, *E. macrophylla*, *E. firma*, *E. arborea*, *Endiandra* sp., *E. coriacea*, *E. kingiana* and *E. monothyra*. Six first species in clade I are mostly distributed in the western part of Malesian regions, such as Malay Peninsula, Sumatra, Java, Borneo, and the Philippines and are characterized by the absence of glands in the flowers. On the other hands, *E. monothyra* is distributed in Australia and the flowers bear staminal glands, like most of Australian *Endiandra*. *Endiandra monothyra* is also the only species in *Endiandra* with 1-locular anthers whereas anthers of the remainder of *Endiandra* have two locules. *Endiandra beccariana*, *E. glauca*, *E. xanthocarpa*, *E. globosa*, and *E. montana* are positioned in clade II and all species were characterized by flowers that bear staminal glands. *Endiandra globosa* and *E. montana* are the species of *Endiandra* that have 6 stamens and they are grouped together in this analysis. Therefore, based on this phylogenetic analysis the staminal glands and number of stamens are not a good character to recognize grouping within *Endiandra*.

Clade III, consisted of *E. poueboensis*, *E. neocaledonica* and *E. compressa*, is characterized by species with staminal glands, including its sister lineage, *E. palmerstonii*. These species are distributed in the eastern part of Malesian regions, i.e., New Guinea and Australia to New Caledonia.

The phylogenetic tree also showed that *E. dielsiana* is sister to the rest of *Endiandra* and *Beilschmiedia*, however the relationships was only supported by bootstrap value of 54 %. The next sister to the *Beilschmiedia* and *Endiandra* is *E. impressicosta* but it was not supported by bootstrap value. *Endiandra dielsiana* and *E. impressicosta* are separated from the rest of *Endiandra* in the upper clades by a clade consisting of *Beilschmiedia* species. Both *E. dielsiana* and *E. impressicosta* are occurred in New Guinea and Australia but the two are different in the presence of staminal glands, *E. dielsiana* is with staminal glands and *E. impressicosta* is without staminal glands.

Relationships within *Endiandra* are relatively poor resolved in this study, therefore wider range of sampled taxa are needed to be employed in further studies to resolve the relationships within *Endiandra* and to understand the morphological characters important in the genus classification.

4.3 Is *Endiandra* monophyletic?

The present phylogenetic analysis showed that *Endiandra* was not a monophyletic group because *Beilschmiedia* was nested within *Endiandra*.

Previous phylogenetic analyses of *Lauraceae* using *mat*K and *trn*L-*trn*F, *psb*A-*trn*H, *trn*T-L, *rpl*16 and 26S nrDNA have also suggested that the two genera are problematic (Rohwer 2000, Chanderbali *et al.* 2001). Rohwer (2000) included *Endiandra pubens* in his analysis and the species fell in the same clade with *Beilschmiedia berteroana, B. mexicana, B. roxburghiana* and *B. tawa*. Similarly, Chanderbali *et al.* (2001), in the phylogenetic study of *Lauraceae* using *trn*L-*trn*F, *psb*A-*trn*H, *trn*T-L, *rpl*16 and 26S nrDNA sequences, showed that *E. microneura* fell within a clade consisting of *B. brenesii*, *B. sary*, *B. velutina* and *B. madagascariensis*. Therefore, both studies indicated that *Endiandra* and *Beilschmiedia* were not monophyletic, however only one sample of *Endiandra* was included in the phylogenetic analysis. Therefore, in the present study we included more samples of *Endiandra* (19 samples) phylogenetic analysis (Table 3.1).

Figure 3.8 showed one of the parsimonious trees that demonstrated *Endiandra* was not a monophyletic group with *Beilschmiedia* was nested within it. Most of the *Endiandra* species positioned at the upper clades (clades I-IV) and *Beilschmiedia* is grouped in one clade supported by 52% of bootstrap value, separating basal *Endiandra*, i.e., *E. dielsiana* and *E. impressicosta* with the rest of *Endiandra* in clades I-IV.

Based on the ITS sequence alignment data, *Endiandra* and *Beilschmiedia* can not be separated, because there was no single position in the ITS sequence data that differentiate the two genera. Therefore, ITS sequences were not variable enough to separate *Endiandra* and *Beilschmiedia*.

Based on the present study, the separation *Endiandra* and *Beilschmiedia* based on the number of stamens and their position in the flower whorls was not supported. Therefore, the relationships between *Endiandra* and *Beilschmiedia* is still problematic. However, it is too early to take action on merging the two genera based on the previous and present studies, considering large number of

species are at stake, *Endiandra* consists of more than a hundred species and *Beilschmiedia* is approximately 250 species (Rohwer 1993). More importantly, phylogenetic study with better resolution is needed to resolve the relationships between *Endiandra* and *Beilschmiedia*. Further research on finding good characters through floral developmental study and chemotaxonomic study are also necessary as effort to solve the relationships of *Endiandra* and *Beilschmiedia*. Similarly, more samples of both genera are needed for better resolution of phylogenetic analysis.

5. CONCLUSION

The separation of *Beilschmiedia* and *Endiandra* as distinct genera was not supported by the ITS region of nrDNA sequences data, the two genera were not phylogenetically separated. Therefore, phylogenetic analysis using ITS region of nrDNA cannot clarify the problematic relationships of *Beilschmiedia* and *Endiandra*. The phylogenetic tree obtained from parsimony analysis using ITS region of nrDNA sequences showed that species of *Endiandra* with and without staminal glands were grouped together and the species of *Endiandra* with 6 stamens were nested within *Endiandra* species with 3 stamens. Therefore, based on this study, staminal gland and number of stamens are not good character for grouping within *Endiandra*.

6. RECOMMENDATION

This study is still a preliminary one but the result of the present phylogenetic analysis is very useful to define what is needed to be done in further research. It is necessary to improve the resolutions of the cladogram by involving samples as wide range as possible of *Endiandra* and *Beilschmiedia*. An improved support for the cladogram will result in more reliable interpretations of the species relationships within *Endiandra*. Moreover, in more resolved phylogeny, the

grouping within the genus *Endiandra* and the characters defined the grouping may be recognized and can be useful for practical purposes. It is also suggested to perform phylogenetic analysis by using multi genes, such as External Transcribed Spacer (ETS), Intergenic Spacers (IGS) or performing complete genome analysis to clarify relationships of problematic genera such as *Endiandra* and *Beilschmiedia*.

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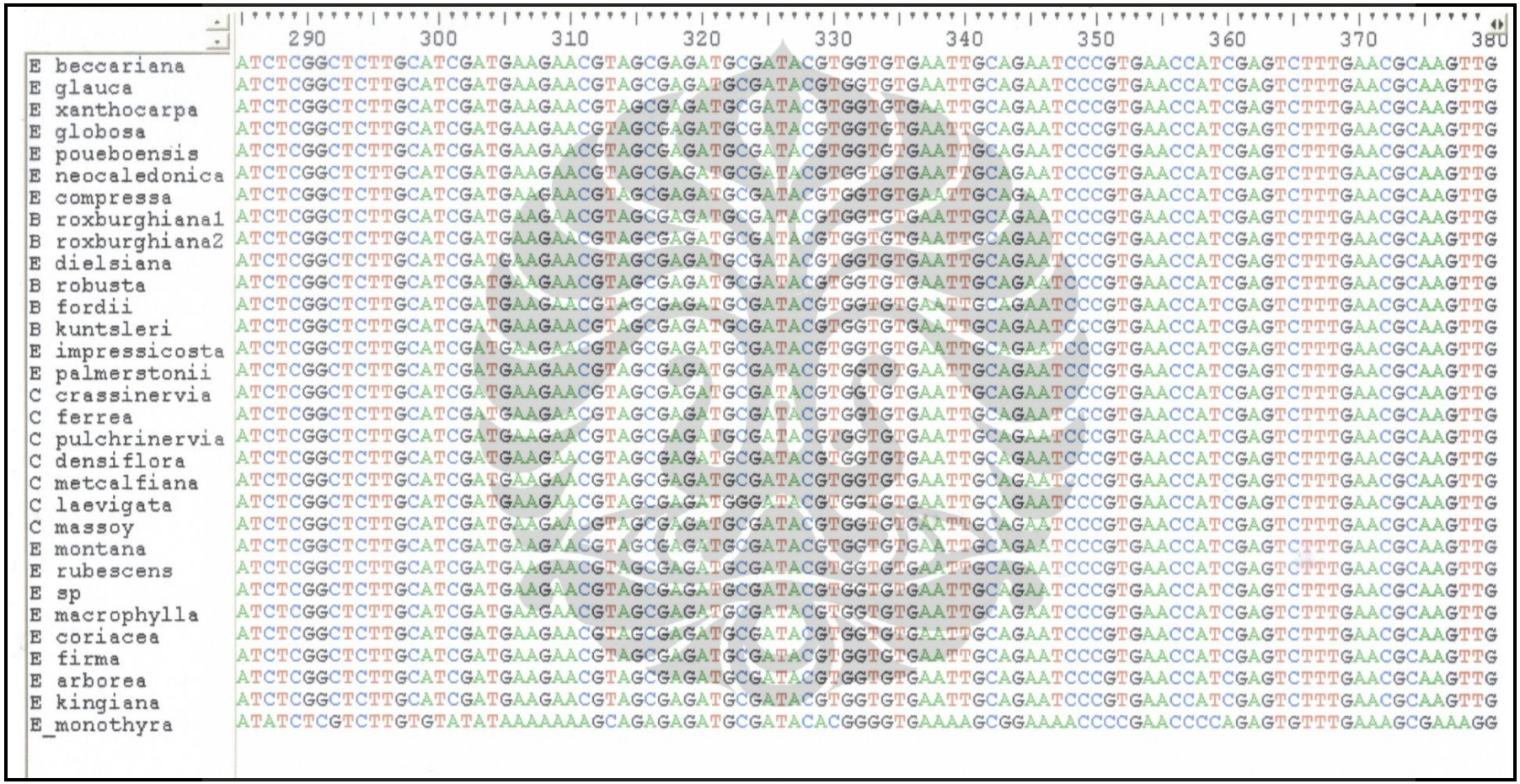

Figure 3.6. The ITS region of nrDNA sequence alignment from position 285 to 380

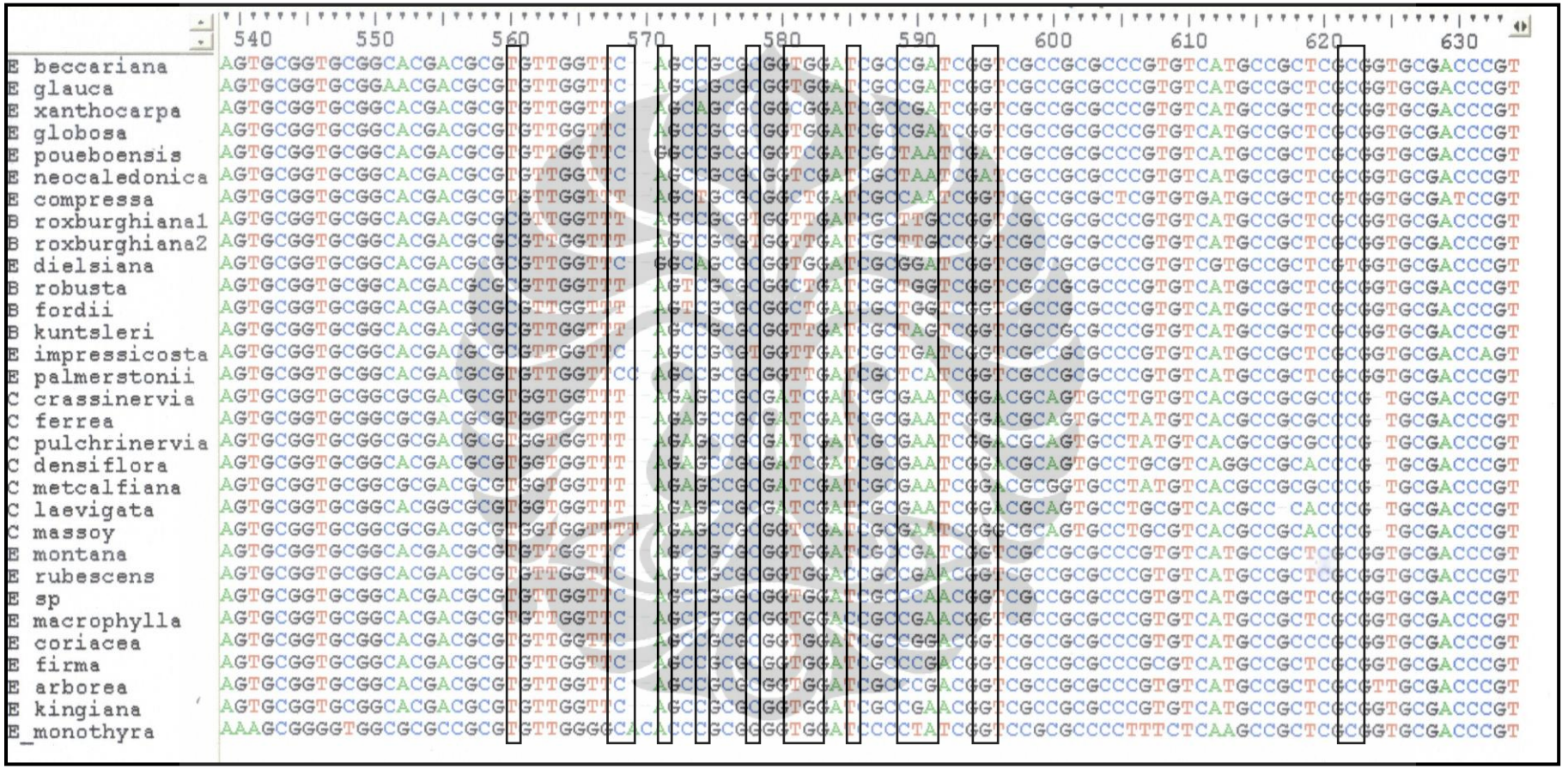

Figure 3.7. The ITS region of nrDNA sequence alignment from position 539 to 634

GENERAL DISCUSSION

The biosystematic study of *Endiandra* (*Lauraceae*) species was carried out in this research. The study consisted of three related topics, namely species enumeration of *Endiandra* in New Guinea, phylogenetic relationships of New Guinean *Endiandra* and *Beilschmiedia* based on morphological characters and phylogenetic relationships of *Endiandra* using ITS region of nrDNA sequences. Species enumeration of *Endiandra* in New Guinea was aimed to record the species occurred in New Guinea, to understand their morphological variation and to provide species descriptions and key identification. Phylogenetic relationships of New Guinean *Endiandra* and *Beilschmiedia* based on morphological characters was carried out to understand the relationships of *Endiandra* in New Guinea, distribution of species with and without staminal glands in the cladogram and the relationships between *Endiandra* and *Beilschmiedia*. Phylogenetic analysis using ITS regions of nrDNA sequences were also carried out to understand the relationships of *Endiandra* species and relationships between *Endiandra* and *Beilschmiedia*.

Species enumeration showed that there are 46 species of *Endiandra* in New Guinea, which distributed in West Papua and Papua New Guinea, with ten species are distributed further West in Celebes, Moluccas and up to the Southeast in Australia (*E. asymmetrica, E. beccariana, E. dielsiana, E. forbesii, E. glauca, E. hypotephra, E. impressicosta, E. montana, E. papuana* and *E. rifaiana*). High number of *Endiandra* species occurred in New Guinea compared to other islands is in accordance with high number of plant species in New Guinea reported by Welzen *et al*. (2005) and related to the Island theory (MacArthur and Wilson 1967) which predicted that there is a positive correlation between island size and the number of species. Additionally, New Guinea was formed by union of its southern part with island arcs, continental fragments and pieces of sea floors, therefore different origins of the island have made New Guinea in biodiversity (Welzen *et al*. 2005).

Thirty six species of *Endiandra* in New Guinea are recorded as endemic to the island. High number of *Endiandra* endemic species in New Guinea is in

agreement with Welzen *et al*. (2005) that reported New Guinea housed highest endemic plant species in Malesian regions. According to Welzen (1997), geological activities in New Guinea has caused high number of species endemicity in New Guinea and Welzen *et al*. (2005) reported that there is a correlation between mountain formation and number of endemic species.

Six new species of *Endiandra* described from New Guinea are *E. areolata, E. crassipetala, E. cupulata, E. lanata, E. kassamensis* and *E. rifaiana*. These species are different from other species based on the vegetative characters, such as leaf texture, lateral and minor venation. Floral characters are also important in determining the new species, such as flower opening, texture of tepals, indument on the inflorescences and glands arrangement. In this study, 13 % of the total species found in New Guinea were undescribed, which indicated that there are possibly many species are awaiting to be found.

The species of *Endiandra* grow at sea level, lowland up to montane forests. Almost half of species in New Guinea can be found in up to 1000 m above sea level or more, such as *E. carrii, E. engleriana, E. fulva, E. aurea, E. dielsiana, E. latifolia, E. ledermannii, E. pilosa, E. schlechteri, E. xylophylla, E. arfakensis, E. flavinervis, E. forbesii, E. hypotephra, E. cyphellophora, E. inaequitepala, E. montana, E. kassamensis, E. crassitepala, E. havelii* and *E. oviformis*.

Observation on the morphology of each species in this study enables the selection of characters important for species delimition and identification. Indument is one of the important characters for delimiting and identifying species of *Endiandra*, including its type, density and orientation. The presence or absence of hairs on the vegetative parts, inflorescences and floral parts may be used to recognized the species. The inflorescences of the New Guinean *Endiandra* species are not only paniculate inflorescences, but *E. gemopsis* has spicate inflorescence and racemose inflorescence were also found in *E. hypotephra* and *E. montana*. The flowers of *Endiandra* are small ranges from 1.5 mm to 8 mm in diameter with tepals can be erect, half-erect, or spreading. Compared to the species from Borneo and Malay Peninsula, the flowers of New Guinean species have more complex structure by consisting of a pistil, three stamens (rarely 6

stamens) with or without staminal glands and staminodes. The species in Borneo and Malay Peninsula did not have any staminal glands or staminodes (Arifiani 2001, Kochummen 1989). High number of species with staminal glands in New Guinea is probably due to high diversity of insects in New Guinea that the flowers develop an effort to attract pollinators by providing nectar produced by the staminal glands.

Phylogenetic analysis was carried out show the relationships of *Endiandra* species occurred in New Guinea based on morphological characters. It is interesting to know the grouping of New Guinean species in the cladogram and find out what characters united the group of species. The phylogenetic tree showed that species of *Endiandra* in New Guinea were monophyletic but with low bootstrap support. Species with glands were grouped together with species without glands. This result suggested that staminal gland cannot be used for grouping the species in New Guinea. Similarly, the number of stamens did not separate species with 3 stamens and 6 stamens. This suggested that it is danger to use number of stamens for grouping. Interestingly, *Endiandra* and *Beilschmiedia* are characterized by the number of stamens, in which *Endiandra* with 3 or 6 stamens, whereas *Beilschmiedia* with 9 or 6 stamens (Kostermans 1957, Rohwer 1993, Hyland 1989) and the two genera are difficult to distinguish based on vegetative and fruiting specimens (Rohwer 1993, Werff 2001). In this study, *Endiandra* and *Beilschmiedia* were separated based on the number of stamens combined with stamen position. Previous attempt in the phylogentic analysis without including character of stamen position, *Beilschmiedia* was nested within *Endiandra*. Therefore, tree topology is determined largely by characters selected for the analysis. Different characters used for the phylogenetic analysis, the tree topology resulted from the analysis will be different.

The same purposes were also targeted for phylogenetic analysis of selected *Endiandra* species using the ITS sequences of nrDNA.

The presence and absence of staminal glands was not distributed well in the phylogenetic trees reconstructed based on both morphological characters and ITS sequences. The species with and without staminal glands are still grouped

together in 1 clade, therefore natural infrageneric grouping within *Endiandra* based on the presence and absence of staminal glands are not suggested.

The phylogenetic analyses have suggested different conclusion about the relationships between *Endiandra* and *Beilschmiedia*. Analysis based on the morphological characters suggested that *Endiandra* and *Beilschmiedia* are good monophyletic genera with the two reside in different clades, however this result was not supported by the analysis based on the ITS sequences of nrDNA, where *Beilschmiedia* is nested within *Endiandra*. Based on these results it is more confident to take into account the phylogenetic analysis based on ITS sequences as this result also supported previous studies (Rohwer 2000, Charderbali *et al.* 2001). Difficulties in distinguishing *Endiandra* and *Beilschmiedia* based on morphological characters may be caused by the close affinity of the two genera in their ITS region of nrDNA sequences. There was no single position in the ITS sequence data that differentiate the two genera. Therefore, ITS sequences were not variable enough to separate *Endiandra* and *Beilschmiedia*.

This study has pointed out that the morphological characters used for delimiting *Endiandra* and *Beilschmiedia* was problematic, therefore the relationships between the two genera are also problematic. Therefore, research for finding new characters that are good for grouping systems are necessary. Ultra structure studies and chemotaxonomy are suggested to explore new characters that later can be tested by phylogenetic analysis using multi genes, such as External Transcribed Spacer (ETS), Intergenic Spacers (IGS) or performing complete genome analysis.

GENERAL CONCLUSION

The species of *Endiandra* in New Guinea were enumerated by observing their morphological characters. There are currently 46 species of *Endiandra* in the region, six of which are newly described. Most of the species are endemic in New Guinea, i.e., 36 species. Additionally, there are 5 species that are placed as imperfectly known species until more materials are available for thorough study.

The *Endiandra* species in New Guinea are characterized by the presence and absence of staminal glands in their flowers. Staminal glands occured more often in the flowers of New Guinean species, with 34 species bear glands in the flowers.

Phylogenetic analysis of New Guinean species of *Endiandra* based on morphological characters to understand the relationships of *Endiandra* species and relationships between *Endiandra* and *Beilschmiedia* was carried out. The results suggested that *Beilschmiedia* is separated from *Endiandra* and the character that separates the two genera are number of stamens and their position in the floral whorls. *Endiandra* has 3 stamens in the third whorl, whereas *Beilschmiedia* has 9 stamens in the first, second and third whorls. When 6 stamens are present in each flower, it could be *Endiandra* or *Beilschmiedia*. If the stamens are in the second and third whorls, it will be *Endiandra* and will be *Beilschmiedia* if the stamens are in the first and second whorls.

The phylogenetic analysis using ITS nrDNA sequences showed that *Endiandra* species with staminal glands were grouped together with species that did not have staminal glands. This result supported the phylogenetic analysis based on the morphological characters. However, separation of *Endiandra* and *Beilschmiedia* was not supported the study using ITS nrDNA sequences, in which *Beilschmiedia* was nested within *Endiandra*. Therefore, phylogenetic analysis using ITS region of nrDNA sequences cannot clarified the relationships between *Endiandra* and *Beilschmiedia*.

RECOMMENDATIONS

High number of endemic species of *Endiandra* is important for the basis in allocating conservation efforts in New Guinea. Additonally, the exploration of *Endiandra* in Indonesian part of New Guinea is important to improve the collections of herbarium specimens.

Phylogenetic analysis based on morphological characters with more species and better characters is suggested to be done in the future. However, it is important to find good characters that can be used for grouping within *Endiandra*

and to separate *Endiandra* and *Beilschmiedia*. Ultra structure studies on flower development and leaf anatomy is suggested to explore new characters in *Endiandra* and *Beilschmiedia*.

It is suggested to keep *Endiandra* and *Beilschmiedia* as separate genera for practical purposes.

Phylogenetic analysis based on ITS nrDNA sequences was perfomed for the first time and further research is needed to be done with more samples of *Endiandra* and *Beilschmiedia* to improve the internal support for each branches in the phylogenetic trees. It is also suggested to perform phylogenetic analysis by using multi genes, such as External Transcribed Spacer (ETS), Intergenic Spacers (IGS) or performing complete genome analysis to clarify relationships of problematic genera such as *Endiandra* and *Beilschmiedia*. Combined data sets is also expected to produce a robust phylogeny needed reliable interpretations of the species relationships within *Endiandra*.

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