Local, regional and monographic approaches to *Cyrtandra* (Gesneriaceae)

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DECLARATION

I hereby declare that the work contained within this thesis is my own, unless otherwise acknowledged and cited, and that this thesis is my own composition. This thesis has not in whole or in part been previously presented for any other degree.

ABSTRACT

A local revision reviewed collections of *Cyrtandra* from Mount Kerinci, Sumatra, recognising thirteen species, three of which are newly described: *C. aureotincta*, *C. patentiserrata*, and *C. stenoptera.* In a regional approach covering species from Peninsular Malaysia, nine species of *Cyrtandra* (Gesneriaceae) were recognised. Three [*C. cupulata*, *C. pendula*, *C. wallichii*] are common and occur more or less throughout the area; four [*C. dispar*, *C. gimlettei*, *C. patula*, *C. suffruticosa*] have more restricted distributions, and two [*C. lanceolata*, *C. stonei*] are local endemics. Three species and one variety are reduced to synonymy: *C. barbata* (= *C. cupulata*), *C. falcata* (= *C. suffruticosa*), *C. rotundifolia* (= *C. pendula*), and *C. cupulata* var. *minor* (= *C. cupulata*). A phylogenetic approach involved a monographic revision of *Cyrtandra* section *Dissimiles.* Eleven species were reviewed, one of which is newly described (*C. fulvisericea*); one species, *C. producta* (= *C. trisepala*) is reduced to synonymy.

Phylogenetic analyses of sequences of the internal transcribed spacer (ITS) region of 18-26S nuclear ribosomal DNA of *Cyrtandra* species from one community on Mount Kerinci, Sumatra, suggest that this community is an assembly of three distinct phyletic lineages, resulting from a gradual accumulation of diversity through time, although one lineage shows evidence of more recent, continuing speciation than the other two. Phylogenetic analyses of a second, larger sample of *Cyrtandra* ITS sequences suggest that Peninsular Malaysian *Cyrtandra* species have affinities with Sumatran and Bornean species, following previously recognised floristic patterns. These affinities can be explained historically, as periods of lower sea levels in the Pleistocene exposed land bridges between the Malay Peninsula, Sumatra and Borneo. A smaller sample of *Cyrtandra* species was sequenced for the *trn*L-F region of the chloroplast genome, and phylogenetic analyses recognised major groups represented in the ITS phylogeny, suggesting congruence between the ITS and *trn*L-F data, and that the ITS phylogeny is an approximation of true evolutionary history.

Large genera such as *Cyrtandra* have the potential to provide answers to critical biological questions concerned with ecology, conservation, evolution and biogeography. A taxonomic framework is a critical first step: to achieve monographs of large genera demands their division into groups of species treatable in short periods. Genera can be divided geographically or phylogenetically, and the resulting taxonomic revisions have different merits. A local approach to *Cyrtandra* monography, such as the Kerinci revision, is not entirely suitable because the genus is species-rich with a large distribution, making local revisions too repetitive and time consuming to cover the whole genus. However, local revisions are useful as indicators of the species richness of areas and provide an introduction to the genus for those who are new to it. A monographic approach is hampered by the lack of an infrageneric classification for *Cyrtandra*. It requires a well-sampled molecular and morphological phylogeny, so that molecular data can corroborate morphologically defined groups as shown for section *Dissimiles*. Such a phylogeny could be produced using ITS and *trn*L-F sequences, with the addition of key morphological characters.

A regional approach is most suitable for *Cyrtandra* because of its distribution across the islands of SE Asia and its high degree of local endemism. Larger islands, with high species richness, could be further divided or worked on by a team of taxonomists. Regional approaches are the most efficient way to achieve the much-needed increase in collections of *Cyrtandra*, vital for the completion of accurate revisionary work and a molecular phylogeny of the genus. Regional approaches may not be as suitable for other large genera as for *Cyrtandra*, as they are distributed in different areas and have different patterns of endemism. Local and regional approaches are most suitable for considering which areas, species or habitats should be prioritised for conservation, when assessing the species diversity of areas, and also for local botanists and ecologists.

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OBJECTIVES

Cyrtandra J.R. & G.Forst. is the largest genus in the Gesneriaceae, containing over 600 species. It occurs throughout the primary rain forests of SE Asia, and is also present on the islands of the Pacific and Hawaii. It is poorly known and many species are undescribed. There is no modern monograph of *Cyrtandra*, due to its huge size: all recent revisions have been regional.

The lack of monographs of large genera such as *Cyrtandra* is a problem in angiosperm taxonomy: genera with more than 400 species account for 23% of angiosperm species (R. Scotland, pers. comm.). Without monographs, the potential of large genera such as *Cyrtandra* to provide answers to critical biological questions concerned with ecology, conservation, evolution and biogeography is diminished. A taxonomic framework is a critical first step: to achieve monographs of large genera demands their division into groups of species treatable in short periods. Genera can be divided geographically or phylogenetically, and the resulting taxonomic revisions are likely to have different merits.

This thesis has the following objectives:

a) to discuss the problem of large genera: their reality, their use, and strategies that have been taken towards dividing them for taxonomic treatment;

b) to investigate the relative merits of different taxonomic approaches to large genera by taking three taxonomic approaches to *Cyrtandra*:

- i) a local approach, revising the *Cyrtandra* species of Mount Kerinci, Sumatra;
- ii) a regional approach, revising the *Cyrtandra* species of Peninsular Malaysia;
- iii) a phylogenetic/monographic approach, revising *Cyrtandra* Section *Dissimiles* C.B.Clarke;

c) to evaluate the suitability of the taxonomic approaches to *Cyrtandra* and suggest a future strategy for *Cyrtandra* taxonomy.

d) to assess the suitability of the taxonomic approaches to other large genera

e) to demonstrate the utility of molecular phylogenies in evolutionary biology and biogeography by carrying out molecular phylogenetic analyses of nuclear ribosomal internal transcribed spacer (ITS) sequences to:

  i) examine the assembly of plant diversity on a local scale, using the example of the *Cyrtandra* community of Mount Kerinci, Sumatra;

  ii) elucidate the geographic affinities of Peninsular Malaysian *Cyrtandra*;

  iii) confirm the monophyly of section *Dissimiles*;

e) to examine confidence in the use of ITS to estimate true evolutionary history by sequencing a small sample of *Cyrtandra* species for the chloroplast *trn*L-F region.

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1 CHAPTER ONE

1.1 THE NEED FOR TAXONOMIC MONOGRAPHS

Systematics is faced with the problem of large genera. In many such groups, determining the exact boundaries of hundreds of species is not possible in short-term research periods; in many cases, such genera lack monographic revisions entirely. Monographs are comprehensive treatments of all species in a genus or higher taxonomic group, which provide descriptions, keys for identification, distribution maps, citations of representative specimens, and further information such as taxonomic history, phytogeography, ecology, anatomy, cytology or chemistry. Monographic studies have high significance for systematics (Stuessy, 1993) and are the ultimate goal of the taxonomist when studying a genus. Following Stuessy (1975), monographs are beneficial as a source of classification, an aid to identification, a source of biological data and as stimulus for further study.

As a source of classification, monographs are of great relevance to society: they permit easy retrieval of information about species, and this can enable relationships between species to be inferred and the prediction of unknown attributes of taxa (Stuessy, 1975). Monographs are invaluable as an aid to identification for the many types of people who need to name plants.

The descriptions, information on distributions and comments on phenology and ecology of species can be a source of biological information for other scientists. Monographs of large genera, often with a wide range of morphological form, can give us a sound basis for hypotheses on evolutionary processes (Mabberley, 1997). Monographs of such genera can also be a source of evidence for biogeographical, ecological and conservation work.

Finally, monographs are important because they act as a stimulus and basis for further study (Stuessy, 1975): evolutionary studies depend on monographs for hypotheses of relationships to test; ecological, conservation and cytological studies can add to the information on the species revised, and in addition, specific problems may be emphasised in the monograph, inviting further investigation.

We therefore need to consider how we might divide large genera up into manageable portions so that taxonomists are able to revise them in a reasonable period. This chapter is in two parts: the first part introduces the problem of large genera and discusses ways in which we might divide them, and the second part focuses on *Cyrtandra* (Gesneriaceae), an example of a large genus, on which this thesis is based.

1.2 PART ONE: THE PROBLEM OF LARGE GENERA

1.2.1 Are large genera real?

Plant taxonomists have long observed that the frequency distribution of taxon sizes is very skewed. Willis (1922) showed that when, for example, the number of genera was plotted against the number of species per genus, the result was a hollow curve, which demonstrated a pattern where there were many small genera and very few large genera (figure 1.1). He found that within plants 'this type of grouping into sizes holds for the genera of any single family, with a few trifling variations among the very small families'. It also became obvious to Willis (1922) that the same hollow curve was followed in animals, leading him to conclude that this was a 'perfectly general phenomenon'. Since then this has been confirmed, as hollow curves have been documented in insects, vertebrates and birds (summarised in Dial & Marzluff, 1989).

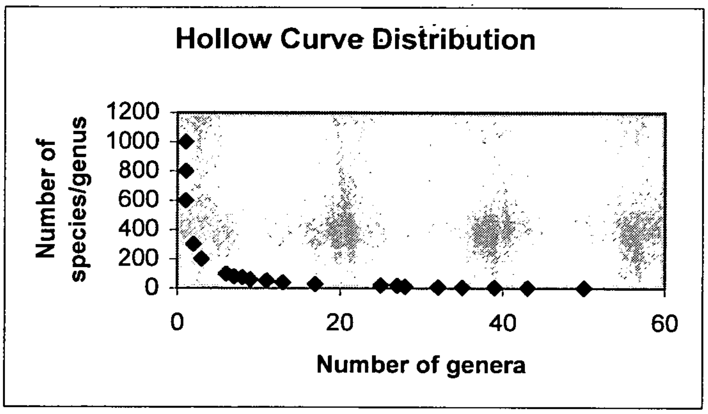


Figure 1.1: Graph illustrating the hollow curve distribution

The fact that the ubiquity of the hollow curve is common to essentially all groups of organisms and is prevalent within major taxa at essentially any level within the hierarchy of classification (Dial & Marzluff, 1989) makes it reasonable to conclude that the curve, and therefore large genera, either represent universal taxonomic artefact, or universal biological phenomena. Determining the validity of either of these explanations has been the source of controversy.

1.2.2 Why are large genera large?

Possible explanations for the hollow curve distribution, considered here in terms of large genera, are discussed under two categories - one concerning the role of taxonomists, and the second the role of biological process.

1.2.2.1 i) Large genera as taxonomic artefacts

One of the main supporters of the idea that the hollow curve is a result of taxonomic artefact and could therefore be explained by what he termed psychological and historical factors was Walters (1961, 1986). He suggested that taxonomists are constrained by previous classifications and therefore that large genera may be likely to result from broad generic concepts dating back to Linnaeus that have not been scrutinised recently. The process known as 'chaining', whereby taxonomists prefer to add to existing genera rather than create new ones (Walters, 1986) could play a substantial role in this. In cases such as these it could be argued that detailed study might result in splitting of large genera.

A further argument explaining large genera could be that they tend to exist in the more understudied areas such as the tropics, and have therefore been avoided by taxonomists. But some genera in the tropics have recently grown via the increased study of previously imperfectly explored tropical areas e.g. *Begonia* (Begoniaceae), *Dendrobium* (Orchidaceae), *Rhododendron* (Ericaceae), (Frodin, 1998). Furthermore, some of the largest genera such as *Euphorbia* (Euphorbiaceae, c. 2000 species), *Carex* (Cyperaceae, c. 2000 species) and *Astragalus* (Leguminosae, c. 1750 species) have predominantly temperate or cosmopolitan distributions.

Although there does seem to be more of a tendency for families commonly represented in Europe, and that have been recognised since the pre-Linnaean folk taxonomies, to be comprised of large numbers of small genera (Walters, 1986), this is somewhat dependent on the family in question. This is shown using the example of the Cyperaceae and Graminae, where differences in importance to the pre-Linnaean communities are reflected in the Linnaean classification, as Linnaeus tended to use the information already available as the basis for his groupings (Walters, 1986). In the Graminae, a family that was extremely useful and important in the community, especially as grazing for livestock, many small genera were recognised (average number of species per genus 15.5). On the other hand, the Cyperaceae, a family not well recognised and of little importance to the community, has a smaller number of large genera (average number of species per genus 44.5).

It could also be argued that genera which include a large number of widely grown ornamentals e.g. *Bulbophyllum* (Orchidaceae) are inflated in size as taxonomic work is largely in the hands of amateurs. Instead of looking for similarities, an undue stress tends to be laid on differences between species, resulting in an extremely narrow species concept (Vermeulen, 1993).

1.2.2.2 ii) Large genera as biological phenomena

There have also been many attempts to explain the hollow curve distribution using biological hypotheses. To explain large genera, the fundamental question is 'why should some groups be so much more diverse than others?' In relation to the hollow curve, Willis (1922) reasoned that the large genera were very ancient and had therefore had time to diversify, and the monotypic genera were nascent. In contrast, Cronk's relict hypothesis (Cronk 1987, 1989) suggested that the monotypic genera were ancient relicts that had been taxonomically and geographically isolated due to widespread extinction, and that large genera were young. In the relict hypothesis, groups go through three periods: one of bloom, i.e. where diversification occurs and groups become large; one of evolutionary stasis, and then a period of extinction at a more or less constant rate. At any one time there will be a few bloom groups with many more depleted groups i.e. the hollow curve distribution. Cronk (1989) also linked this with taxonomic factors, as large diverse groups are more likely to contain more similar, closely related entities and therefore be described as one taxonomic unit, but groups depleted by extinction are likely to have morphological discontinuities, making it easier to draw taxonomic boundaries. He concluded that in this relict hypothesis it is patterns of extinction that are controlling taxonomy.

Scientists have also sought to explain large genera as the result of evolutionary patterns. They have asked why some groups seem to have shifts in diversification rates, with a possible answer the evolution of key morphological or physiological innovations that promote explosive speciation. In a study on *Astragalus*, the goal of Sanderson and Wojciechowski (1996) was to assess whether increases in the diversification rate coincided with the origin of the genus. They hoped that this would allow meaningful discussion of hypotheses about evolutionary innovations that might have been responsible for any shift in diversification rate in *Astragalus*. They acknowledged that the absence of a good fossil record made it difficult to estimate absolute rates of diversification, but they were able to conclude that diversification rates in *Astragalus* itself were not particularly high, but they were high in a larger clade including the genus. This suggested that characteristics common to the entire clade, such as ecological factors or cryptic physiological or biochemical factors might have been responsible for increased diversification.

Gentry (1989) explained the high species richness of the neotropical flora as a result of what he termed 'explosive speciation', often in large genera e.g. *Anthurium* (Araceae), *Piper* (Piperaceae) and *Pleurothallis* (Orchidaceae). In Andean cloud forests, he suggested that factors such as ultrafine niche partioning, founder effect mediated speciation caused by a kaleidoscopically changing landscape, and intricate coevolutionary interactions e.g. with pollinators such as hummingbirds, may have enhanced local speciation rates.

In order to assess the contribution of particular psychological, historical and biological factors to the hollow curve distribution, Cronk (1989) measured the hollowness of curves of different classifications. He concluded that classifications are roughly equal proportions of psychohistorical artefact and biological reality, and moreover that the historical and psychological factors which contribute to the hollow curve probably act by accentuating the biologically produced hollow curve.

Dial & Marzluff (1989) showed that the overdominance of an assemblage (e.g. all genera within a family) by one unit (e.g. a genus) is common whether phylogenetic or traditional classification schemes are used to assemble taxa. They therefore proposed that this overdominance reflects real differences in the evolutionary success of units within an assemblage, implying that large genera are more likely to be large due to biological factors.

Sanderson and Wojciechowski (1996) have a similar opinion: 'the existence of hollow curves in disparate taxa and the persistence of large taxa despite the repeated efforts of taxonomists to dismember them suggests the action of an underlying biological process' but, they go on to say, in agreement with Cronk (1989) that 'the distribution is also strongly dependent on taxonomic practice'. In my opinion this balanced view seems the most justifiable.

Now it has been established that large genera are in part real and some of the possible explanations for their existence have been considered, it is necessary to briefly discuss how a genus is defined. The exact definition of the genus depends on the various methods of classification used. With this is in mind we remember that there is an absence in Nature of any ranking criterion for our higher taxa; the level at which we recognise a particular taxon is a convention (Stevens, 1997) whatever method is used. That is to say that if large genera or indeed 'groups' of plants are recognised as being real, whether it actually matters how they fit into the classification system becomes speculative. But classifications are our means of treating groups in a standard way, allowing communication, so it does seem necessary to briefly introduce the major methods for their production.

1.2.3 Defining the genus

The concept of the genus is not modern - the idea that almost all plants belong in genera with two or more species was suggested by Conrad Gessner around the middle of the sixteenth century (Morton, 1981) and similar groupings are evident in folk taxonomies (Berlin, 1973). Early attempts to provide guidelines for describing the genus included that of Joseph Pitton de Tournefort, who in 1694, argued that generic characters should be recognisable in all members of a genus and should be visible (Judd *et al.*, 1999). Before Linnaeus, the genus was not applicable at any particular level: it was Linnaeus who suggested the wider grouping of the basic units (genera) into families, orders, classes and divisions in his hierarchical system.

Hence for centuries the genus has formed part of a classification system, the objectives of which are to be easy to use, stable, an aid to memory, predictive and concise, whilst also reflecting nature (Judd *et al.*, 1999). Since earlier times there has been the development of new systems of classification, most still based on the categorical ranks of Linnaeus, but defining the ranks e.g. the genus, in different ways. Phenetic classifications named groups by producing treelike diagrams that grouped organisms on overall similarity (Sokal & Sneath, 1963). These groupings were never designed to retrieve evolutionary history, but problems arose as they were often interpreted as though they did reflect phylogeny (Judd *et al.*, 1999).

More recently, the formulation of cladistics (e.g. Hennig, 1966) saw the popularisation of cladistic classifications, which name only monophyletic groups and are hence congruent with phylogeny. Since groups are only recognised if monophyletic (containing all descendants of a common ancestor), cladistic classifications are really the only system in which the delimitation of groups can be unambiguously defined (Judd *et al.*, 1999). More traditional were the evolutionary classifications, where the most important criterion for grouping was morphological similarity, and monophyly and paraphyly were secondary, although the groups recognised in such classifications were often called monophyletic.

In the past few years, there has been much controversy regarding the compatibility of the Linnaean naming system and classification using cladistics. Supporters of a new system of phylogenetic taxonomy, where Linnaean ranking is abandoned and replaced by a system where the representation of phylogenetic relationships is the primary goal (de Queiroz & Gauthier, 1992), argue that the current system of cladistic classification remains constrained by the non-evolutionary Linnaean conditions. In their system monophyletic groups would be given unranked names, defined in terms of common ancestry and diagnosed by reference to their defining characters (synapomorphies). This remains controversial and as yet there is no consensus on whether it should be adopted (Stevens, 1997).

At present, the general consensus among taxonomists seems to be that classifications should accurately reflect our best estimate of phylogeny (e.g. Donoghue & Cantino, 1988; Stevens, 1997) whilst continuing to utilise the Linnaean ranking system (e.g. Angiosperm Phylogeny Group, 1998) and therefore that higher taxa (e.g. genera), should be monophyletic groups, although there are opinions to the contrary (e.g. Cronquist, 1987; Brummitt, 1996). Justification for the general consensus is summarised by Stevens (1997) who argued that the easiest way for the work of taxonomists to be integrated with that of other biologists is to ensure our taxa are monophyletic, and to interpret these taxa in an appropriate fashion as we make recommendations about conservation, or discuss biogeography or historical ecology. He continued by saying that if we opt to maintain traditional criteria for group recognition, the groups we recognise will remain unclear, convenience and expedience will continue to play a subversive role in taxon delimitation. The Angiosperm Phylogeny Group (APG) (1998) agreed with this: 'there is a pressing need for names to communicate the knowledge of monophyletic groupings of families'.

From this we can conclude, in agreement with the general consensus among taxonomists, that genera should be monophyletic. But, we still need to be aware of the purpose of classification, and take heed in ensuring that genera are defined so that:

i) they can be readily identified, that is, using easily observed morphological synapomorphies;

ii) there is nomenclatural stability: groups are well supported, using more than one line of evidence if possible;

iii) the classification acts as an aid to memory.
Ultimately, the classification must be accessible as means of communicating information about angiosperms for all users, not just taxonomists.

1.2.4 How large is a large genus?

The size of angiosperm genera ranges from one species, to approximately 2000 species. But how large is a large genus? Perhaps as we are thinking here about size in relation to the feasibility of study in the short time frames that are realistic in today's research funding environment, 'large' should be defined by a size that would not be treatable by the average taxonomist in 3-5 years.

In the nineteenth century, a taxonomist may have revised 250 species per year (Heywood, 2001), but the size of a genus treatable by taxonomists within a certain period may have gone down in modern times due to an increased amount of literature to cover, more specimens to examine and because of our ability to study in much greater depth, covering all aspects from DNA sequencing to palynology and other detailed microscopy. This reduction in output was suggested by Van Steenis (1979), who gave a figure of 15-20 species per taxonomist per year, and De Wolf (1963), who was more optimistic with an estimate of 30-60 species per taxonomist per year. Therefore for a period of five years, using these estimates, the average taxonomist might be expected to revise 75-300 species. Perhaps then, a large genus should be defined as one containing over 300 species. This is lower than other estimates: Forrest (2000), in a PhD thesis on *Begonia*, defined large genera as being over 400 species, and Mabberley (1997) lists those over 500 species. Appendix 1 lists genera of angiosperms containing over 300 species modified from Minelli (1993).

1.2.5 Large genera and evolutionary biology

Corner (e.g. 1985) recognised the potential of large genera in providing answers to biological questions and inspiration to evolutionary biologists. Using *Ficus* (Moraceae) as an example, he said 'if biological questions could not be addressed with a genus of such outstanding variety, it seemed it could never be done'.

However, despite their fundamental evolutionary interest, large genera are not being studied or used to their full potential because these critical biological questions cannot be answered in the absence of a taxonomic framework. This section highlights some examples of cases where large genera have contributed to evolutionary biology and biogeography.

Large genera often have widespread distributions, their species either occurring in the same habitat across a wide area, or in many different habitats; the example of *Carex* (Catling *et al.*, 1990), one of the largest genera of angiosperms with c. 2000 species, avoided by systematists because of its size and complexity, shows how increased work on a genus, even on one part of its range, can provide useful information. Catling *et al.* (1990) suggested that the increase in study of the genus, after a long period of neglect, was because as knowledge of other groups increased, the lack of information on *Carex* became more and more evident, with the result that many botanists decided that it was a high priority for research. Now the increased taxonomic output on the genus has become useful in completing floras and surveying the current status of rare species (e.g. Ball *et al.*, 1982), and in phytogeographical work, such as explaining disjunct bipolar distributions (Ball, 1990). In addition, there have been ecological studies such as the documentation of decreasing ecological diversity (De Brujn, 1980). De Brujn analysed changes in the distribution frequencies of *Carex* species in the Netherlands, and showed that the impoverishment of the *Carex* flora was indicative of recent changes in the Dutch flora as a whole.

Distributional data gathered from the study of large genera can aid the identification of 'hotspots' that are more species rich than other areas, crucial when considering prioritisation of areas for conservation (Myers *et al.*, 2000). In addition, where large genera are restricted to primary vegetation we can use them as indicators as to the state of the habitat. Work on *Psychotria* (Rubiaceae), another large genus with c. 2000 species, has highlighted its potential for describing species diversity in tropical angiosperms as a whole (Hamilton, 1989). In the introduction to his revision of Mesoamerican *Psychotria* subg. *Psychotria*, Hamilton explains how the diversity pattern of subg. *Psychotria* is representative of many species rich taxa and may therefore be of value as an index of regional diversity for tropical flowering plants. The primary value of this work would be in pinpointing areas to which we should devote conservation effort in order to preserve the maximum diversity of life. He stated that the systematic understanding of species-rich taxa such as *Psychotria*, *Miconia* (Melastomataceae, 1000 species) *Piper* (2000 species) and *Anthurium* (900 species) is critical towards understanding geographical patterns of diversity and processes of diversification in the tropics.

Molecular phylogenetic analyses of large genera, because of the extent of their morphological variation, can be important tools with which to pose hypotheses about the evolution of key morphological characters within genera. For example, Jaramillo & Manos (2001) carried out a phylogenetic analysis of a sample of *Piper*, and found that patterns of floral and inflorescence evolution appeared to generally support the derived status of several of the traditionally recognised groups, and that certain species characters such as umbellate and solitary axillary inflorescences had multiple origins. Similarly, Manos *et al.* (2001) used an *Ipomoea* (Convolvulaceae) phylogeny to demonstrate that the common morphological form of *Ipomoea* is widely distributed and has given rise to a number of specialised forms, many of which have arisen repeatedly. These specialised forms are the result of variation in characters such as corolla shape and colour, habit, and leaf and stem morphology.

In addition, since large genera often show blanket coverage of entire biogeographical areas, phylogenies can provoke the consideration of questions such as 'where do the geographical affinities of a specific flora lie?' or 'how and when was a flora constructed?'. For example, using phylogenies of *Inga* (Leguminosae), Richardson *et al.* (2001) estimated that the genus had diversified recently and rapidly, with speciation concentrated in the past 10 million years and with many species arising as recently as two million years ago. They suggested that in this pattern of speciation, *Inga* may be representative of other similar neotropical genera.

But the recognition that evolutionary research on these large genera is a priority misses the first step. For these studies we need a taxonomic framework in which to set the work. To achieve the revision requires a way of dividing the genera up into manageable portions so we can systematically work our way through them. This is summarised by Doorenbos *et al.* (1998) in their book on *Begonia*, another large genus with c. 1400 species: 'when dealing with a genus the size of *Begonia*, it is inevitable that one feels the need of a system to survey this multitude of species, preferably one which gives an insight into their natural relationships.'

1.2.6 Practical considerations: how do we divide large genera up?

A survey of the taxonomic publications on the large genera listed in Appendix 1 shows that revisions are either based on geography (by region, for example by country) or are phylogenetic (based on an infrageneric classification), or a combination of both (e.g. revision of a section in a particular country).

1.2.6.1 Geographic revisions

Geographic revisions can be on a variety of different scales, and are categorised below. The categories are continuous and overlapping, for example some countries may be equal in size to a state or even a national park.

a) phytogeographical region: Neotropics, Old World, Mesoamerica, Malesiana.
Examples: Old world *Artemisia* (Compositae) (Ling, 1992); *Dioscorea* (Dioscoreaceae) for Flora Malesiana (Burkill, 1951)
b) continental: *Impatiens* (Balsaminaceae) of Africa (Grey-Wilson, 1980)
d) country: *Acacia* (Leguminosae) in India (Chakrabarty & Gangopadhyay, 1996)
e) small scale regional or within country: state, district
Example: *Impatiens* of Sumatra (Grey-Wilson, 1989)
f) local: national park, mountain
Example: *Ilex* (Aquifoliaceae) on Mount Kinabalu (Andrews, 1994).

It appears that most geographical revisions are carried out as part of floras. Floras tend to sketch relationships among the included taxa, and are therefore not best suited for helping us to understand phylogenetic and phytogeographic relationships of the groups concerned, unlike monographs which examine taxa in a far greater amount of detail (Stuessy, 1993). However, floras can still provide a good starting point for monographic work, but it is important not to rely on the treatment of genera in floras too heavily when carrying out monographic work. Floras have also been suggested to overestimate rates of synonymy (Mabberley, 1991). The effectiveness of monographs in highlighting synonymy was shown recently by Scotland & Wortley (2003) who showed that for a small sample of monographed genera, rates of synonymy ranged from 67-88%, with a mean value of 78%.

Phylogenetic analysis of molecular data on geographical scales can be particularly useful for inferring biogeographical histories of large genera such as African *Begonia*, Plana (2002) and Australian *Acacia* (Miller *et al.*, 2003). In addition, perhaps more relevant on a local scale, analyses can form the basis of evolutionary hypotheses, for example, relating to the evolution of rain forest communities (e.g. chapter three of this thesis).

There have been numerous criticisms of geographical approaches. In his account '*Impatiens* of Africa', Grey-Wilson (1980) stated that 'regional revisions and floras do little towards a better and more meaningful understanding of the genus as a whole'. Similarly, Graham (1988) commented that the regional nature of most studies in *Justicia* (Acanthaceae) has led to a confusing situation whereby segregate genera are recognised in the geographical area, but not in adjacent regions.

1.2.6.2 Phylogenetic revisions

a) *where there is no satisfactory infrageneric classification*

Dividing the genus geographically may seem the only method of revision if no satisfactory infrageneric classification exists. However, perhaps an alternative is to attempt to create a provisional synopsis of the genus, entailing a minimal statement about relationships within the genus, therefore providing the basis for further work. This can be done using all currently available knowledge of the genus, which may be morphological or in the form of molecular phylogenies. This was the approach taken, for example, by Graham (1988) for *Justicia*, Doorenbos *et al.* (1998) for *Begonia*, Webster (1993) for *Croton* (Euphorbiaceae) and Child & Lester (2001) for *Solanum* (Solanaceae). In these examples, only morphological information was used to create synopses.

Due to the size of the genera and limitations such as time, such synopses are often based on a sample of species from the genus. Doorenbos *et al.* (1998) commented that an exhaustive study of all existing herbarium material of *Begonia* was impossible. This is likely to mean that the synopsis cannot be expected to accommodate all species into groups, as not all the species will have been examined. Indeed, in a later work on *Croton*, Webster (2001) admitted that more detailed study showed modifications to be necessary, but the original synopsis nevertheless provided a good basis, facilitating research. Child & Lester (2001), using initial morphological information, hoped to corroborate their synopsis of *Solanum* with DNA evidence.

A similar approach, applicable where the classification of a genus is in question, is the creation of a list of 'critical species', that represent each of the currently recognised major subgroups, bearing in mind that the delimitation of many of these groups may still be uncertain (Maslin & Stirton, 1997 [for *Acacia*]). This can form the basis for comparative studies, ensuring all significant morphological variation is included. One difficulty with this approach is deciding which species are critical, where the non-critical species fit, and which morphological characters are important. To do this a detailed knowledge of the genus is surely necessary.

Problems can arise if these classifications are unsatisfactory - again in regard to *Croton*, Webster (1993) described how the previous unintelligible classification by Müller (1866, 1873) which was highly artificial, largely due to the a priori weighting of inappropriate characters, greatly impeded progression in understanding relationships between species and species groups. This resulted in taxonomists abandoning the classification, and instead of providing a new system, they used their own informal groups.

A further method of achieving an overview of a genus, with a view to possible infrageneric classifications, is through the use of molecular data. Attempts are numerous: *Psychotria* (Nepokroeff *et al.*, 1999; Andersson, 2002); *Solanum* (Bohs & Olmstead, 1997; Olmstead & Palmer, 1997); *Piper* (Jaramillo & Manos, 2001); *Acacia* (Robinson & Harris, 2000). However, it is difficult to find any examples of where this has led to subsequent formal recognition of infrageneric limits and divisions. This is likely to reflect that in most cases, even though phylogenies may recognise monophyletic groups, they only include a small sample of species. To keep classifications accessible to all users, molecular data must be integrated with morphological data, preferably in the form of easily observable characters, in order to formalise suggested modifications to classifications.

b) *where a satisfactory infrageneric classification exists*

Large genera with an infrageneric classification do not seem as formidable to the taxonomist as those that are lacking in one, assuming that the classification is representing our best estimate of phylogeny. Revisions can be undertaken by treating the appropriate infrageneric group, be it subgenus or section, either in full or, if size is still an impediment, on a particular geographical scale.

However, the act of revising an extremely speciose genus, even by section, demands seeking a balance between speed and thoroughness (Vermeulen, 1993; on *Bulbophyllum*). It could be suggested that a team of taxonomists working together would enable monographic work to be carried out faster and also more thoroughly.

Part One highlighted the problem of large genera and suggested ways in which we might go about dividing them in order to revise them successfully. Now we focus on *Cyrtandra* (Gesneriaceae). This will be the exemplar taxon used in this thesis to examine the utility of different approaches to tackling the taxonomy of large angiosperm genera.

1.3 PART TWO: *Cyrtandra* (Gesneriaceae): a problematically large genus

1.3.1 Gesneriaceae

The Gesneriaceae (African violet family) was first recognised by Dumortier in 1822. There are approximately 2,500-3,500 species in 120-130 genera, distributed primarily in the tropics with a few temperate species in Europe and Japan (Smith *et al.*, 1997). The family is generally considered to consist of three well-differentiated subfamilies (Burtt & Wiehler, 1995):

a) Coronantheroideae Wiehler; 1 tribe with 9 genera and c. 20 species (southern Chile, southern Pacific Islands and Australia);

b) Gesnerioideae Dumort.; 5 tribes, 56 genera, over 1800 species (nearly restricted to the Neotropics);

c) Cyrtandroideae Endl., 5 tribes, 82 genera, over 1900 species (chiefly distributed in the Old World tropics with one species in the Neotropics).

The Cyrtandroideae are separated from the Gesnerioideae and Coronantheroideae by having anisocotylous rather than isocotylous seedling leaves, and the Gesnerioideae are separated from the Coronantheroideae by having a nectary free from the ovary rather than embedded in the basal part of the ovary.

1.3.2 *Cyrtandra*

Cyrtandra J.R.Forst. & G.Forst. (subfam. Cyrtandroideae) is the largest genus in the Gesneriaceae, probably consisting of over 600 species (Burtt, 2001a). The name is derived from the Greek *kyrtos*, meaning curved, and *andros*, meaning stamens, in reference to the spirally curved fertile staminal filaments (the filaments recoil back into the corolla tube after dehiscence as a mechanism against self-pollination). Its range is from the Nicobar Islands in the West, southern Thailand, throughout Malesia to the Philippines, Taiwan, southern Ryukyu Islands, south east to Queensland and the Loyalty Islands and east to the Hawaiian islands. Its main centres of species diversity are:

i) Sundaland (Peninsular Malaysia, Sumatra, Java and Borneo);
ii) the Philippines
iii) New Guinea
iv) Hawaiian Archipelago

Each has a high percentage of endemics, and the species or species groups that link them are relatively few (Burtt, 1998a).

Cyrtandra can be herbs, lianas, epiphytes, shrubs or even small trees. The leaves are simple, opposite or sometimes pseudoalternate. Flowers are usually one to numerous in cymes, usually in the upper leaf axils but occasionally cauliflorous or on underground stems. The corolla is tubular, sometimes bilabiate but more frequently divided into five small lobes near the mouth. It is often white but can be yellow, green, red, pink or violet. There are two fertile stamens and often three staminodes. The ovary is superior and a nectary disc is often persistent around the ovary in fruit. The fruit is an indehiscent fleshy or firm berry, often tipped by the persistent stylar beak. Placentation is parietal. Cytological investigations of 50 species from across the distribution of the genus, have determined the chromosome number to be n=17, 2n=34 (rarely 2n=32) (Ratter & Prentice, 1964; Kiehn & Weber, 1998). Full generic descriptions are in chapters two, four and six.

Cyrtandra species usually grow as an understorey element in dense rain forest, often in ravines and gorges characterised by high humidity, very low light intensities and an almost constant moisture supply (Gillett, 1967). Populations are scattered and usually consist of a small assemblage of individuals. These may be subject to evolutionary change through genetic drift. The operation of mutation and selection, with isolation, provides a possible explanation for the large number of *Cyrtandra* species (Gillett, 1973).

The breeding system in *Cyrtandra* was discussed by Gillett (1967) and a study of the reproductive biology of *Cyrtandra grandiflora* Gaudich. on Oahu was undertaken by

Roelofs (1979). It appears that *Cyrtandra* is self-compatible, as thought to be the case in all Gesneriaceae, and that both self-pollination and cross-pollination requires unknown insect pollinators. The flowers are protandrous, and through the earlier maturity of the anthers and the positioning of both the anthers and stigma, there seems to be a provision for outcrossing. Further studies on the Hawaiian islands (Smith *et al.*, 1996) have found that interspecific hybridisation events have occurred.

1.3.3 *Cyrtandra* taxonomy

It has often been noted that *Cyrtandra* taxonomy is difficult (Wagner *et al.*, 1990, Burtt, 1998a). Indeed, Gillett (1967) stated that the great diversity and the large number of species in this genus impose formidable demands on the taxonomist who aspires to interpret its infrageneric taxonomy. The last overall treatment of the genus was by C.B.Clarke in 1883 in A.C. De Candolle's *Monographie Phanerogamarum.* However, Clarke had few specimens to study and these were often inadequate and frequently sterile, a factor that caused his treatment to be weak and artificial. In fact, all the sections proposed by Clarke contain a mixture of species that would not now be classified together (Burtt, 1990).

The massive size of *Cyrtandra* makes completing a monograph difficult. Areas within its range remain under-collected or have never been visited, and the high proportion of local endemic species means that the whole range would have to be covered to ensure a treatment was comprehensive. Even working with the specimens already existing in herbaria the task would be considerable, for example, the Canberra Herbarium has 457 sheets of unidentified Papua New Guinea *Cyrtandra* collections alone. The basic process of specimen management would be huge. It is because of these reasons that any attempts at taxonomic work on *Cyrtandra* since Clarke (1883) have been on a regional scale.

In 1923, Schlecter published a treatment of the *Cyrtandra* of New Guinea (96 species). Gillett (1967, 1973) completed accounts of *Cyrtandra* in Fiji (35 species) and the South Pacific (54 species). At the Royal Botanic Garden Edinburgh

(RBGE), a Gesneriaceae research programme, started by B.L. Burtt in the 1950s, has included a substantial amount of work on *Cyrtandra*. As well as working on other Gesneriaceae genera, Burtt has focused on revising the *Cyrtandra* of Sundaland, especially the Bornean species (e.g. Burtt, 1978; 1990), on which he currently continues to work with O.M. Hilliard. In addition, Atkins and Cronk (2001) revised the *Cyrtandra* species of Palawan (12 species), and Atkins (e.g. 2003) is currently revising Sulawesi members of the genus. In other institutes, the main region of study has been the Hawaiian islands. The Hawaiian species have been the subject of five revisions (Clarke, 1883: 34 species; Hillebrand, 1888: 29 species; Rock, 1917, 1918, 1919a, 1919b: 52 species; St John, 1966: 131 species on Oahu; Wagner *et al.*, 1990, 1999: 53 species). In addition, there have been studies in Hawaii on reproductive biology and hybridisation (Roelofs, 1979; Smith *et al.*, 1996).

1.3.4 Taxonomic Approaches to *Cyrtandra*

In order to evaluate some of the approaches to large genera outlined in part one, this thesis will take three different approaches to *Cyrtandra*. Two are geographical, and one phylogenetic:

1) Local: the *Cyrtandra* of Mount Kerinci, Sumatra
2) Regional: the *Cyrtandra* of Peninsular Malaysia and Singapore
3) Monographic: *Cyrtandra* section *Dissimiles* C.B.Clarke.

Each approach involves both taxonomic revision and molecular phylogenetic analyses. In taking these three approaches, I intend to highlight the benefits and drawbacks of each, with a view to finding the most suitable way in which to produce a monograph of *Cyrtandra*. By using both taxonomic revision and molecular phylogenetics I will investigate how tropical plant diversity is assembled on a local scale, and, the geographical affinities of the Peninsular Malaysian *Cyrtandra* species.

2 CHAPTER TWO: THE *CYRTANDRA* SPECIES OF MOUNT KERINCI, SUMATRA

This chapter is the first of two addressing the local approach to *Cyrtandra* adopted in this thesis. It is based on a taxonomic revision of the *Cyrtandra* species of Mount Kerinci, Sumatra (Bramley & Cronk, 2003). It includes keys and descriptions of the thirteen species found on the mountain followed by a discussion of the advantages and disadvantages of this taxonomic approach.

2.1 INTRODUCTION

2.1.1 Mount Kerinci

Mount Kerinci, situated in the west of the Jambi province of Sumatra, forms part of the Barisan mountains (Figure 2.1). This range runs the length of Sumatra and was uplifted as a result of thrust associated with the collision of the Indian plate with Asia about 70 million years ago (Whitten *et al.*, 1997). The mountain is still volcanically active and, at 3805 m, is the highest Indonesian mountain outside Irian Jaya. It forms part of the Kerinci-Seblat National Park, which extends for nearly 350 km throughout the Barisan mountains.

Ecological surveys (e.g. Jacobs, 1958; Oshawa *et al.*, 1985) have concluded that there are four distinguishable vegetation zones on Mt Kerinci: a) submontane forest, at 1750 - 2400 m, dominated by *Ficus*, *Lithocarpus* and other large trees, with *Gleichenia* scrub in places; b) a montane forest, at 2400 - 2900 m, dominated by *Symplocos* and *Rapanea* with ericoid elements increasing with altitude; c) a *Rhododendron-Vaccinium* scrub, at 2900 - 3200 m; d) low open vegetation with no more than 30% cover, diminishing to scattered plants of *Histiopteris incisa* (Thunb.) J.Sm. in gulleys only, ending around 3400 m. There is scarce, if any, vegetation above this altitude due to the active state of the volcano. It is in the submontane and montane forest that species of *Cyrtandra* are common, with their upper altitudinal limit being about 2500 m.

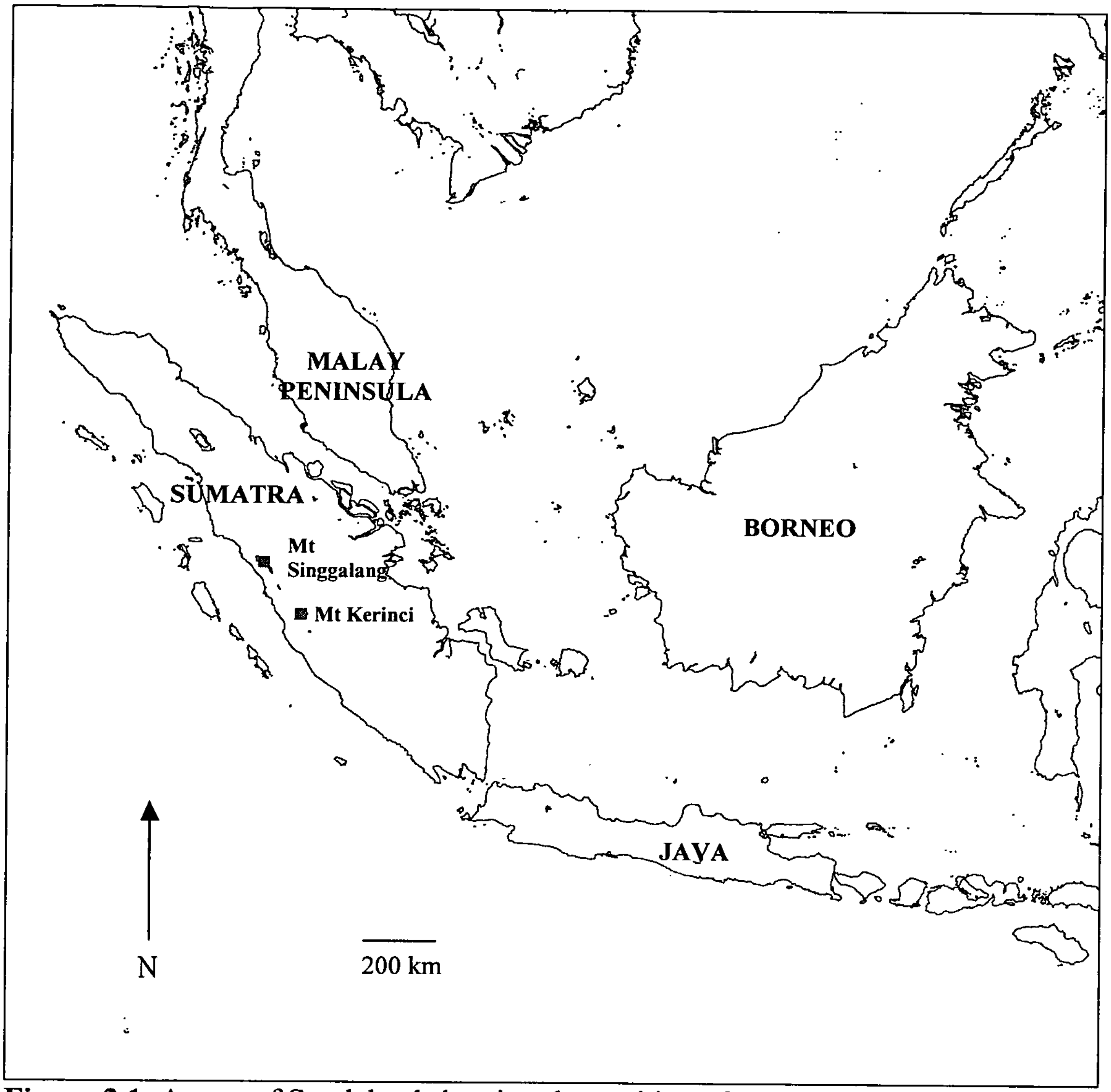


Figure 2.1: A map of Sundaland showing the position of Sumatra, Mount Kerinci and Mount Singgalang.

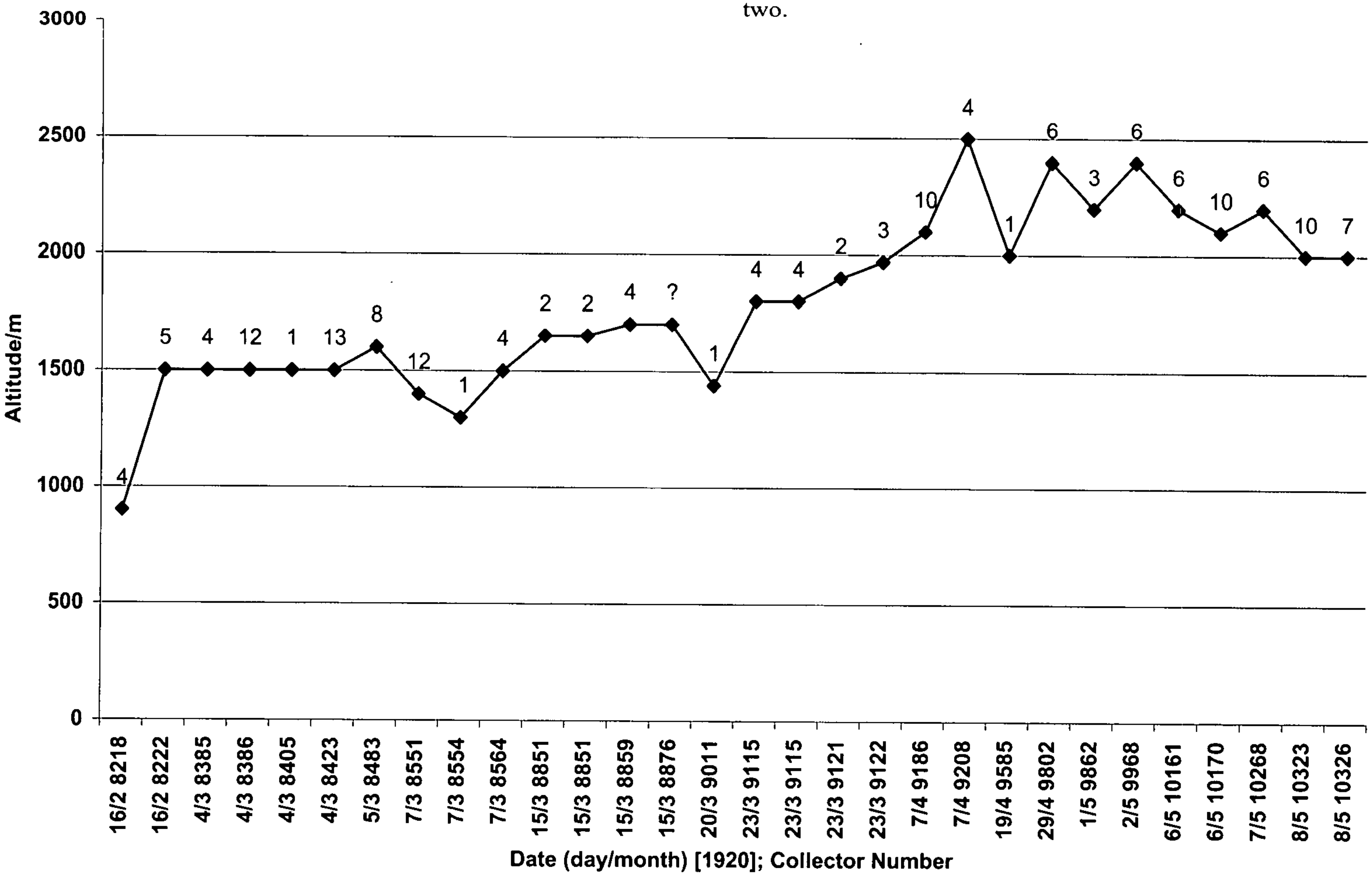
2.1.2 *Cyrtandra* in Sumatra

Although *Cyrtandra* taxonomy is poorly developed for Sumatran species, there are 62 published names, 46 of which are accepted (Boggan, unpubl.). In 1917 H.N. Ridley commented that 'it is somewhat remarkable that the flora of so large and accessible an island as Sumatra should have up to the present date received so little attention'. The situation has not changed much since that time, as Laumonier (1990, 1997) has remarked.

One of the earliest collectors was William Jack, sent to Bengkulu in 1820 as surgeon naturalist on the staff of Sir Stamford Raffles. He described about 125 new species, including 11 new *Cyrtandra* species (Merrill, 1952). However he died there in 1822 and his herbarium and manuscripts were destroyed in the burning of the ship 'Fame'. Species described by Jack have not often been recollected and as his published descriptions were not widely available and his types were destroyed, his names were therefore rarely taken up (Merrill, 1952). The Dutch botanists Miquel, Teysmann, Korthals and de Vriese, amongst others, collected in various parts of the island, chiefly in the lowland districts, the most extensive account being given in Miquel's (1856) *Flora Indiae Batavae* (Ridley, 1917). The Italian, Odoardo Beccari, was another important collector, chiefly in west Sumatra, especially on Mount Singgalang.

In 1877-78 Mount Kerinci was visited by the Dutch Mid-Sumatra expedition and some plants were collected; indeed the collections included *Cyrtandra rhyncanthera* C.B.Clarke. At this time Kerinci was still independent, making some areas difficult to access, but it came under Dutch control in 1903. The first specifically biological explorers of the mountain, in 1914, were H.C. Robinson and C. Boden Kloss, from the Federated Malay States Museum in Kuala Lumpur. They collected a number of *Cyrtandra* specimens from the peak subsequently published in an account by H.N. Ridley (1917). In terms of numbers of herbarium collections, the most important botanist was H.A.B. Bünnemeyer, in the employment of the Herbarium Bogoriense, who visited the peak in 1920. Figure 2.2 is a graph illustrating his *Cyrtandra* collections. The other notable collectors were A.H.G. Alston in 1954 and W. Meijer in 1956. Jacobs (1958) provided an account of Meijer's expedition to the Kerinci area. In addition, in July 2000, Radhiah Zakaria and Q.C.B. Cronk, on a BIOTROP-RBGE expedition, collected many *Cyrtandra* specimens from the Peak and other locations in west Sumatra.

Figure 2.2: A graph showing the dates and numbers of Bünnemeyer's *Cyrtandra* collections from Mt Kerinci against the altitudes at which they were collected. The numbers above each specimen refer to the species numbers in chapter two.



2.2 KEYS AND DESCRIPTIONS

What follows are keys and descriptions of the thirteen *Cyrtandra* species known from Mount Kerinci.

In the keys and descriptions:

i) Measurements are given for leaves presumed to be mature, and their shape is described following Hickey (1979).

ii) All measurements of floral characters were taken from herbarium material that had been rehydrated and softened in spirit.

iii) All details of plant heights and colours in the descriptions are taken from the collectors' notes, in most cases the collectors being Radhiah and Cronk.

iv) All locations follow the American National Imagery and Mapping Agency's (NIMA) GEOnet Names Server (http://164.214.2.59/gns/html/index.html).

v) Descriptions of stigmas: in rehydrated material stigma characters are very difficult to see, nevertheless, there are some differences between species. The following terms have been used to reflect the basic stigma structure:

a) bilobed: when two lobes are present;

b) horizontally bilobed: when the two lobes appear to be spread flat, at right angles to the style;

c) two short blunt lobes: the lobes are shorter and more rounded than in the other species;

d) two triangular lobes: the lobes are distinctly triangular in shape;

e) biflabellate: the two lobes are each distinctly fan shaped.

vi) All measurements refer to length unless stated otherwise.

The first key is designed for use in the herbarium. To this end, the characters chosen are principally vegetative, since many *Cyrtandra* specimens encountered are sterile and of poor quality. However, a second key based on floral characters is also included. Species are arranged in informal groups, I, II & III, according to the molecular phylogenetic analysis in chapter three. Figure 2.3 illustrates leaf outlines and margin detail for each of the thirteen species described. Figure 2.4 shows floral dissections of two of the new species described, *Cyrtandra aureotincta* and *Cyrtandra patentiserrata*.

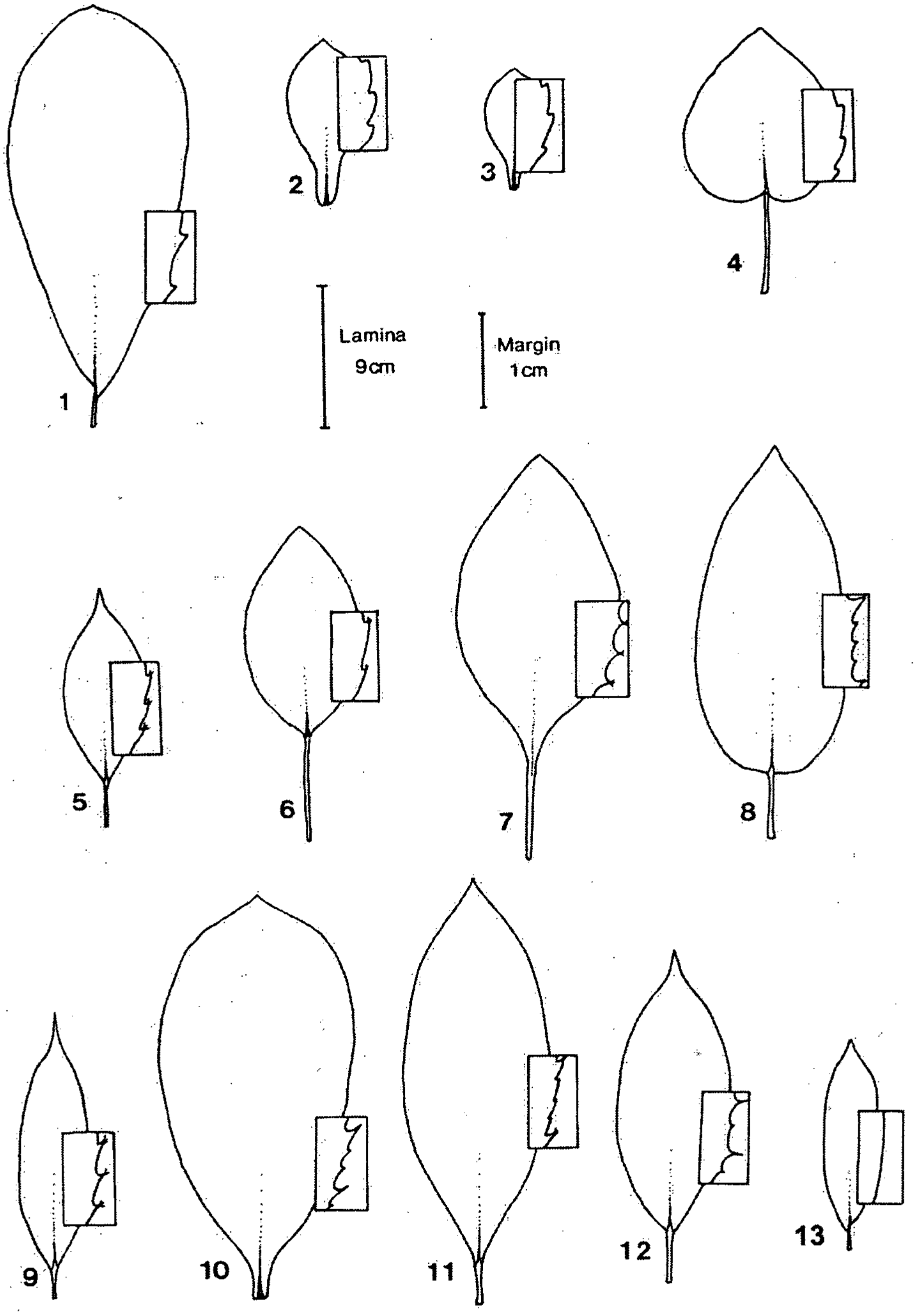


Figure 2.3. 1-13. Leaf spectrum of all thirteen *Cyrtandra* species from Mount Kerinci. Numbering of species follows the account. Trichomes on the leaf margin in species 5,6,7 and 9 are enlarged.

The following generic description applies to the Sumatran material encountered in this study only.

Cyrtandra J.R. & G.Forst., *Char. gen. pl.* 5 (1776).

Herbs, epiphytes or shrubs. *Leaves* simple, opposite or sometimes pseudoalternate; the leaves in a pair being equal (isophyllous), subequal, or one member being very reduced (anisophyllous), hairy to glabrous above, the venation below often raised and hairy. *Inflorescence* usually in the upper leaf axils but occasionally cauliflorous, sessile, subsessile or pedunculate; flowers one to numerous in cymes. *Bracts* often enclosing or subtending inflorescence. *Calyx* 5-lobed, often hairy, persistent or caducous in fruit. *Corolla* tubular, five lobed, lobes subequal to bilabiate, usually white but can be green, red, pink or violet; the lobes sometimes differing in colour from the corolla tube. *Stamens* 2. *Staminodes* 3, if visible. *Ovary* superior, hairy or glabrous; placentation parietal. *Disk* cupular or unilateral, often persistent around the ovary in fruit. *Fruit* a fleshy or firm berry, often tipped by the persistent stylar beak. ETYMOLOGY. The generic name is derived from 'kyrtos', greek. = curved, and 'andros', greek. = male, apparently referring to the spiral filaments that recoil back into the corolla after anther dehiscence.

2.2.1 Keys to the species of *Cyrtandra* on Mount Kerinci, Sumatra

2.2.1.1 Key One (based on vegetative characters)

1a. Leaf arrangement opposite and markedly anisophyllous or pseudoalternate........2
1b. Leaf arrangement opposite and equal or slightly unequal in size..........................4

2a. Leaf margins entire, lamina narrowly oblong............................**13. C. flabelligera**
2b. Leaf margins serrate, lamina ovate or elliptic to obovate or oblanceolate...3

3a. Lamina narrowly elliptic to obovate to oblanceolate, petioles c. 2 cm...**1. C. anisophylla**
3b. Lamina ovate to broadly ovate, petioles 8 - 15 cm.................**4. C. longepetiolata**

4a. Terrestrial herb..5
4b. Shrub (may be unbranched or branched)..7

5a. Lamina ovate or broadly ovate with rounded or cordate base, petiole distinct, 8 - 15 cm..**4. C. longepetiolata**
5b. Lamina oblanceolate, spathulate or narrowly elliptic to narrowly obovate, decurrent to base of stem, petiole indistinct...6

6a. Leaves oblanceolate, bullate...**2. C. fenestrata**
6b. Leaves spathulate to narrowly elliptic to narrowly obovate, non-bullate..**3. C. rhyncanthera**

7a. Inflorescence sessile or on a peduncle less than 1 cm long...................................8
7b. Inflorescence on a peduncle greater than 1 cm long...13

8a. Leaf decurrent or petiole narrowly winged or ridged...9
8b. Leaf not decurrent, petiole unwinged..10

9a. Leaf margin serrate, lamina usually less than 20 cm, decurrent with petiole narrowly winged or ridged to the stem...**7. C. stenoptera**
9b. Leaf margin biserrate, lamina usually greater than 20 cm, decurrent, c.1 cm either side of petiole at base...**10. C. rosea**

10a. Margins serrate, leaves elliptic to narrowly elliptic..............**5. C. membranacea**
10b. Margins biserrate, leaves narrowly ovate, elliptic or narrowly elliptic.............11

11a. Leaves with all venation below raised and densely hairy, tertiary veins hairy..**11. C. aureotincta**
11b. Leaves with only midrib and lateral nerve pairs below either raised and hairy or subglabrous, tertiary veins subglabrous...12

12a. Lamina elliptic, base acute...**12. C. patentiserrata**

12b. Lamina narrowly ovate, base obtuse or cordate..................................**8. C. ampla**

13a. Lamina narrowly elliptic with a distinct acuminate tip, surface rugose from impressed venation, corolla less than 2 cm long.............................**9. C. impressivenia**

13b. Lamina narrowly elliptic to elliptic, tip acute to acuminate, surface smooth, corolla greater than 3 cm long...**6. C. trichodon**

2.2.1.2 Key Two (based on floral characters)

1a. Corolla greater than 3 cm long...2

1b. Corolla less than 2.5 cm long..3

2a. Flowers solitary...4

2b. Number of flowers greater than one...5

3a. Corolla 1-3 cm long..6

3b. Corolla less than 1 cm long...13

4a. Leaves bullate...**2. C. fenestrata**

4b. Leaves non-bullate...**3. C. rhyncanthera**

5a. Calyx divided into five equal lobes, inflorescence subsessile..**4. C. longepetiolata**

5b. Calyx with the three upper lobes more deeply divided than the two lower, inflorescence pedunculate.......................................**6. C. trichodon**

6a. Calyx divided into five even lobes..7

6b. Calyx divided into three upper lobes distinct from two lower lobes...................10

7a. Calyx less than 0.5 cm long...**13. C. flabelligera**

7b. Calyx greater than 0.5 cm long..8

8a. Inflorescence enclosed in bracts greater than or equal to 2 cm long......................9
8b. Inflorescence enclosed in bracts less than 1.5 cm long.......................................12

9a. Bracts delicate, c. 2.5 cm long...**5. C. membranacea**
9b. Bracts verrucose, c. 2 cm long...**7. C. stenoptera**

10a. Corolla white or greenish-white...11
10b. Corolla red, pink or violet...**10. C. rosea**

11a. Disk hairy..**11. C. aureotincta**
11b. Disk glabrous...**7. C. stenoptera**

12a. Calyx c. 8 mm long, lobes triangular, c. 2 mm long..........................**8. C. ampla**
12b. Calyx c. 12 mm long, lobes narrow, c. 6 mm long
with very fine tips c. 4 mm long..**12. C. patentiserrata**

13a. Calyx asymmetric, three lobes fused to form one,
the other two divided to the base..**1. C. anisophylla**
13b. Calyx divided into five even lobes...**9. C. impressivenia**

2.2.1.3 Group I (=group two in chapter three)

1. Cyrtandra anisophylla C.B.Clarke in A. & C.DC., Monogr. phan. 5: 249 (1883).
Type: SUMATRA. West Sumatra: Mount Singgalang, 1700 m, vi - vii 1878, *Beccari* s.n. (holotype: FI [*n.v.*]; isotype K).

Erect shrub to 2 m. *Leaves* markedly anisophyllous: the major leaf with a c. 2 cm petiole, lamina 15 - 29 x 6.5 - 12 cm, elliptic to narrowly obovate to oblanceolate, apex obtuse to shortly acuminate, base asymmetric, one side up to 2 cm shorter and more acute than the longer, margins serrate for the upper three quarters of the lamina, the serrations quite widely spaced, upper and lower surfaces glabrous, lateral nerve pairs 9 - 13, connected by a faint marginal vein c. 4 mm from the margin; the minor leaf sessile 1.5 - 3 x 1 - 1.5 cm, ovate, the basal part sheathing the stem, the upper part deflexed, apex acuminate, margins entire, upper and lower surfaces glabrous. *Inflorescence* axillary, more or less sessile, with many flowers clustered together. *Bracts* c. 1 cm long, green tinged brownish, overlapping and covering inflorescence, broadly ovate, margins entire, outer surface somewhat verrucose at base, inner surface hairy. *Bracteoles* smaller, more numerous. *Pedicels* 2 - 3 mm. *Calyx* asymmetric, the upper three lobes fused to form one, c. 9 x 6 mm, obovate, the apex divided into three rounded tips c. 1 mm; the lower two lobes slightly shorter c. 8 x 3 mm, completely divided to the base, apices rounded; outer surface of calyx glabrous, verrucose at base, inner surface with glandular and eglandular hairs. *Corolla* off white, c. 8 mm, completely enclosed by calyx (intact lobes not seen); outer surface of corolla with glandular hairs on the backs of the lobes, inner surface with short glandular hairs under the two upper lobes and in the throat. *Filaments* c. 4 mm, with sessile glands. *Anthers* c. 1 mm. *Gynoecium* c. 6 mm, ovary glabrous except for a few short glandular hairs near the tip where it passes into the style, style with short glandular hairs, stigma bilobed. *Disk* c. 1.5 mm high, cupular, margin undulate. *Fruit* 5 - 10 x 5 - 12 mm, more or less globose, somewhat fleshy, verrucose, sometimes apiculate from the persistent style.

ETYMOLOGY. 'anisophylla' = unequal, referring to the anisophyllous leaf pairs.

ECOLOGY. 450 - 2000 m, lowland to upper montane forest.

DISTRIBUTION. Sumatra: Aceh, Jambi (Kerinci), North Sumatra, West Sumatra.

MOUNT KERINCI SPECIMENS EXAMINED.

SUMATRA. Jambi: Mount Kerinci. 1 iii 1954, *Alston* 13972 (BM); c. 1500 m, 4 iii 1920, *Bünnemeyer* 8405 (L); c. 1300 m, 7 iii 1920, *Bünnemeyer* 8554 (L); c. 1440 m, 20 iii 1920, *Bünnemeyer* 9011 (L); c. 2000 m, 19 iv 1920, *Bünnemeyer* 9585 (BO); c. 1950 m, vii 1979, *Ohsawa et al.* A-176 (BO); 1800 - 2000 m, 27 vii 2000, *Radhiah & Cronk* 109 (E).

SELECTED ADDITIONAL SPECIMENS EXAMINED.

SUMATRA. North Sumatra, south of Sidikalang, nr Parbuluan, 28 iii 1954, *Alston* 14856 (BM); North Sumatra, Asahan, Aek Salabat, c. 450 m, 15 - 26 vii 1936, *Boeea* 9591 (A); Aceh, Gunung Leuser Nature Reserve, c. 1250 m, 26 vi 1979, *de Wilde & de Wilde-Duyfjes* 18992 (L).

NOTES. This is a very common and widespread species in Sumatra. It is easily recognisable in the herbarium by the pale underside of the leaves that have very dark venation when dried. However, it is similar to *C. beccarii* C.B.Clarke, also from Sumatra, that has the same leaf type but bears a pedunculate rather than sessile inflorescence.

It is the only species to fall into any of the sections that Clarke recognised. This section, *Dissimiles*, is also upheld by B.L. Burtt (Burtt, 1990). It is defined by well-marked characters including anisophyllous leaves and a zygomorphic calyx and contains *C. trisepala* C.B.Clarke and *C. multibracteata* C.B.Clarke of Borneo and *C. stonei* B.L.Burtt of the Malay Peninsula as well as *C.anisophylla* C.B.Clarke and *C. beccarii* C.B.Clarke (see chapter six).

2.2.1.4 Group II (=group one in chapter three)

2. Cyrtandra fenestrata C.B.Clarke in A. & C.DC., Monogr. phan. 5: 233 (1883). Type: SUMATRA. West Sumatra: Mount Singgalang, 1878, *Beccari* 65 (syntypes: K, L), 253 (syntypes: BM, K, L).

Terrestrial herb; stem, when mature, somewhat woody and glabrescent, but fleshy and with scabrous hairs when young. *Leaves* opposite and slightly anisophyllous, the larger of the pair 9.5 - 13.5 x 3 - 4 cm, the smaller 1 - 2 cm shorter, lamina oblanceolate, acute, bullate, margin crenate-serrate, decurrent onto stem, up to 1 cm wide at the very base, midrib broadening towards base, scabrous hairy above, all venation below prominent and hairy; lateral nerve pairs 8 - 9. *Inflorescence* in axils of leaves, single flowered. *Bracts* in a pair at the base of the pedicel; c. 1 cm long, linear, entire, hairy. *Pedicels* c. 5 mm. *Calyx* c. 13 mm, externally with short hairs, internally somewhat verrucose; tube c. 8 mm; lobes subulate c. 5 mm. *Corolla* white, c. 5 cm, narrow within calyx (c. 5 mm) but then widening to form a broad mouth, c. 2.5 cm wide; outer surface with long silky hairs, except the parts of lobes covered by the aestivation of the corolla, inner surface papillose. *Filaments* c. 1 cm, with small area of papillae just below anthers. *Anthers* c. 2 mm, the connective extending to form hooked tips, c. 1 mm long, above anthers. *Gynoecium* c. 2.5 cm, style with eglandular hairs becoming shorter towards ovary, top of ovary with short scattered glands; stigma biflabellate, outer surface hairy, inner face papillose. *Disk* c. 2.5 mm, cupular. *Fruit* not seen.

ETYMOLOGY. The epithet 'fenestrata' refers to the bullate leaves of this species.

ECOLOGY. Lower to upper montane forest, 1300 - 2000 m.

DISTRIBUTION. SUMATRA. Jambi (Kerinci), West Sumatra.

MOUNT KERINCI SPECIMENS SEEN.

SUMATRA. Jambi: Mount Kerinci. c. 1650 m, 15 iii 1920, *Bünnemeyer* 8851 (K, L); c. 1900 m, 23 iii 1920, *Bünnemeyer* 9121 (L).

SELECTED ADDITIONAL SPECIMENS EXAMINED.

SUMATRA. West Sumatra, Mount Singgalang, 1800 m, 25 v 1957 *Meijer* 5824 (L); Jambi, Mount Tujuh, c. 1800 - 2000 m, vii 1956, *Meijer* 7281 (L); Jambi, Lake Tujuh, 31 vii 2000, *Radhiah & Cronk* 147; West Sumatra, Mount Singgalang, 1300 - 1400 m, 26 vii 1894, *Schiffner* 2563 (A).

NOTES. This species is distinct due to its bullate leaves and large solitary white flower, usually axillary towards the top of the stem. Furthermore, the connective is extended into small hooks above the anthers. It shares this character with *C. rhyncanthera* C.B.Clarke which appears to be closely related. A lectotype is not suggested because of mixed collections of *Beccari* 65 and 253.

3. Cyrtandra rhyncanthera C.B.Clarke in A. & C.DC., Monogr. phan. 5: 233 (1883). Lectotype (chosen here): SUMATRA. West Sumatra: Mount Singgalang, *Curtis* 77 (K).

Terrestrial herb, creeping, putting forth erect stems to c. 40 cm; stems at first scabrous, becoming glabrescent. *Leaves* opposite and somewhat anisophyllous, the larger of the pair 7 - 13 x 4 - 6 cm, the smaller 6 - 9 x 3 - 4 cm, both decurrent onto stem, up to 1 cm wide at base; lamina spathulate, or less often narrowly elliptic to narrowly obovate, acute apex formed by terminal serration, margin serrate to crenate serrate, serrations varying in depth and spread, often with tufts of hair at tips; new growth with scabrous hairs above, hairs soon becoming scattered, all venation raised and hairy below; lateral nerve pairs 6 - 10. *Inflorescence* in axils of leaves, single flowered. *Bracts* in a pair at the base of the pedicel; green, linear, hairy, c. 10 x 1 mm. *Pedicels* 5 - 10 mm, hairy. *Calyx* green, 11 - 15 mm, externally with short angular hairs especially concentrated on ridges, internally glabrous; tube 7 - 9 mm; lobes 4 - 6 mm, slightly ridged in the centre, the ridges narrowing to form fine tips c. 2 mm. *Corolla* white, 4 - 4.5 cm, narrow within calyx then quickly expanding to 2 - 2.5 cm wide, lobes with a frilled edge, outer surface with silky hairs except on parts of lobes covered by the aestivation of the corolla, inner surface with papillae that follow the edges of corolla lobes down corolla tube. *Filaments* c. 8 mm with a small area of papillae just below anthers, the connective extending to form small hooks, c. 1 mm, beyond the anthers. *Anthers* c. 2.5 mm. *Gynoecium* c. 1.8 cm; ovary with scattered short glandular hairs, hairs becoming longer and eglandular on style; stigma 2 mm, biflabellate, inner face papillose. *Disk* cupular, c. 2 mm, margin irregularly dentate. *Fruit* ovoid, 15 - 19 x 6 - 7 mm, calyx sometimes persisting.

ETYMOLOGY. The distinctive connectives that extend to form hooks beyond the anthers are recognised in the epithet 'rhyncanthera' = beaked anthers.

ECOLOGY. Lower to upper montane forest, 1600 - 2500 m.

DISTRIBUTION. SUMATRA: Jambi (Kerinci), West Sumatra.

MOUNT KERINCI SPECIMENS EXAMINED.

SUMATRA. Jambi: Mount Kerinci. c. 1970 m, 23 iii 1920, *Bünnemeyer* 9122 (L); c. 2200 m, 1 v 1920, *Bünnemeyer* 9862 (BO); 1877-78, *Dutch Mid-Sumat. Exped.* s.n. (L); c. 2300 m, 30 vii 1921, *Frey-Wyssling* 121 (BO); 1800 - 1900 m, 31 vii 1956, *Meijer* 6419 (L); c. 2000 m, 1 viii 1956, *Meijer* 6462 (L); c. 2000 m, 27 vii 2000, *Radhiah & Cronk* 111 (E); 2000 - 2500 m, 28 vii 2000, *Radhiah & Cronk* 112 (E); 2000 - 2500 m, 28 vii 2000, *Radhiah & Cronk* 118 (E); c. 2225 m [7300ft], v 1914, *Robinson & Kloss* s.n. (BM).

SELECTED ADDITIONAL SPECIMENS EXAMINED.

SUMATRA. West Sumatra, Mount Merapi, c. 1600 m, 14 ix 1918, *Bünnemeyer* 4578 (L); West Sumatra, Mount Talang, c. 1900 m, 8 xi 1918, *Bünnemeyer* 5547 (L); West Sumatra, Mount Singgalang nr Bukittinggi, c. 1800 m, 25 v 1957, *Meijer* 5823 (L); Jambi, Kerinci, Lake Tujuh, 31 vii 2000, *Radhiah & Cronk* 146 (E).

NOTES. *Radhiah & Cronk* 111 has reddish pigmentation, the leaves are more elliptic and margins minutely crenate-serrate, but this probably represents intraspecific variation. *Cyrtandra rhyncanthera* is closely allied to *C. fenestrata* although the leaves are spathulate or narrowly elliptic to narrowly obovate and smooth rather than oblanceolate and bullate. The large solitary white flower is, however, very similar to that of *C. fenestrata* and the extended connectives are also present.

4. **Cyrtandra longepetiolata** de Vriese, Pl. Ind. bat. orient.: 12 (1856). Type: JAVA. Mount Patuha, *Reinwardt* s.n. (L [photo]).

Terrestrial herb with branching stem. *Leaves* opposite, sometimes subequal or sometimes one member of the pair reduced to a leafy scale, petioles 8 - 15 cm long, lamina ovate to broadly ovate, 10 - 14 cm x 8 - 10 cm, shortly acuminate at the apex, rounded to cordate at the base, margins serrate, lamina surface glabrous or subglabrous above, venation with short dense hairs below; lateral nerve pairs 5 - 6. *Inflorescence* in axils of leaves, sessile or subsessile, usually with 4 - 8 clustered flowers. *Bracts* purplish-green, enclosing inflorescence. *Pedicels* very short, c. 3 mm. *Calyx* reddish brown, c. 1.5 cm, externally with short fine hairs, internally verrucose; tube c. 9 mm; lobes, c. 6 mm, triangular, prominently ridged in the centre, the ridges narrowing to form fine tips c. 3 mm. *Corolla* white, sometimes with a reddish flush and a purple pink speckle in the throat, 3.5 - 4 cm, broadening towards mouth, outer surface with silky hairs, inner surface papillose. *Filaments* c. 8 mm, glabrous. *Anthers* c. 2 mm. *Gynoecium* c. 1.7 cm, style with short hairs, ovary glabrous; stigma with two short blunt lobes, inner face papillose. *Disk* cupular, c. 2 mm high, margin undulate. *Fruit* ellipsoid, c. 15 x 5 mm including c. 5 mm beak, calyx not persistent.

ETYMOLOGY. 'longepetiolata' refers to the distinctively long petioles of this species.

ECOLOGY. Lower to upper montane forest, 900 - 2500 m.

DISTRIBUTION. JAVA. SUMATRA. Jambi (Kerinci), West Sumatra.

MOUNT KERINCI SPECIMENS EXAMINED.

SUMATRA. Jambi: Mount Kerinci. c. 900 m, 16 ii 1920, *Bünnemeyer* 8218 (BO); c. 1500 m, 4 iii 1920, *Bünnemeyer* 8385 (L); c. 1500 m, 7 iii 1920, *Bünnemeyer* 8564 (BO); c. 1700 m, 15 iii 1920, *Bünnemeyer* 8859 (BO); c. 1800 m, 23 iii 1920, *Bünnemeyer* 9115 (BM, L); c. 2500 m, 7 iv 1920, *Bünnemeyer* 9208 (BO); c. 1600 m, 30 vii 1956, *Meijer* 6358 (L); c. 1900 m, 27 vii 2000, *Radhiah & Cronk* 108 (E).

SELECTED ADDITIONAL SPECIMENS EXAMINED.

SUMATRA. West Sumatra: Mount Singgalang, c. 2400 m, 24 v 1918, *Bünnemeyer* 2634 (L); West Sumatra, Mount Merapi, c. 1500 m, 14 x 1918, *Bünnemeyer* 4579 (L); Jambi, Kerinci, Mount Tujuh, c. 1300 m, 4 viii 1956, *Meijer* 6590 (L); West Sumatra, road from Padang to Solok, c. 900 m, 25 vii 2000, *Radhiah and Cronk* 102 (E); Jambi, Kerinci, Lake Tujuh, 31 vii 2000, *Radhiah & Cronk* 140 (E).

NOTES. The long petiolate, subglabrous ovate leaves, often cordate at the base, make this species easily recognisable. It could be confused with *C. pendula* Blume (described from Java), a species that is vegetatively very similar but has an inflorescence that extends to the ground, and in fruit often becomes buried on a long peduncle.

Notes on the Flora of Java (Bakhuizen van den Brink, 1950) list *C. longepetiolata* de Vriese as a synonym of *C. picta* Blume (described from Java). There is some confusion in the Leiden type database, since the same type specimen is listed for *C. longepetiolata* and *C. picta*. However, the specimen, collected by Reinwardt and originally identified by him as *Rhynchocarpus glabra* Reinw. (this is noted in the protologue by de Vriese) is the type of *C. longepetiolata*, not *C. picta*. Since I have not been able to see or locate the type of *C. picta*, I recognise *C. longepetiolata* as dstinct here. Further work is needed to clarify the relationship between *C. picta* and *C. longepetiolata*.

It is not clear from the specimens available whether the Kerinci material is truly referable to *C. longepetiolata* of Java. The type specimen of *C. longepetiolata* resembles the specimens described here, in that the characteristics of the lamina, the long petioles and subsessile or sessile inflorescences are similar. However, De Vriese described the flowers as '*rubris*'; the Sumatran specimens in this revision have white flowers.

5. Cyrtandra membranacea Ridl. in J. Fed. Malay States Mus. 8 (4): 71 (1917). Type: SUMATRA. Jambi: Kerinci, Siulakderas, c. 1340 m [4400 ft], 16 iii 1914, *Robinson & Kloss* s.n. (holotype: BM; isotype: K).

Erect, unbranched shrub. *Leaves* opposite, pairs slightly subequal on petioles 3 - 3.5 cm long, lamina elliptic to narrowly elliptic, 10 - 13 x 4 - 5 cm, apex acuminate, base shortly decurrent, margin with serrations with distinct tufts of hair at tips, surface hairy or sparsely hairy above, venation below raised and hairy; lateral nerve pairs 7 - 8. *Inflorescence* in axils of leaves, almost sessile, few flowered. *Bracts* enclosing inflorescence, c. 2.5 cm, white, delicate and hairy with venation prominent on the external surface, margins serrate. *Calyx* c. 13 mm, externally with long silky hairs, verrucose at base, internally with scattered hairs; tube c. 8 mm; lobes c. 5 mm with fine tips, these twisting together to form a point above the corolla when in bud. *Corolla* white, c. 2.3 cm, c. 3 mm wide within calyx, broadening to c. 1 cm at mouth, outer surface with silky hairs, inner surface glabrous. *Filaments* c. 1 cm, glabrous. *Anthers* c. 2 mm. *Gynoecium* c. 1.3 cm, style with glandular hairs, stigma bilobed. *Disk* c. 1.5 mm, cupular, margin undulate. *Fruit* not seen.

ETYMOLOGY. The epithet 'membranacea' refers to the delicate white bracts of this species.

ECOLOGY. Lower to upper montane forest, 1300 - 1500 m.

DISTRIBUTION. SUMATRA. Jambi (Kerinci).

MOUNT KERINCI SPECIMENS EXAMINED.

SUMATRA. Jambi: Mount Kerinci. c. 1500 m, 16 ii 1920, *Bünnemeyer* 8222 (BO).

SELECTED ADDITIONAL SPECIMENS EXAMINED.

SUMATRA. Jambi, Kerinci, Sungai Kering, 3 iii 1954, *Alston* 14123 (A, BM, L); Jambi, Kerinci, Mount Tujuh, 1300 m, 4 viii 1956, *Meijer* 6588 (L); Jambi, Kerinci, Sungai Kumbang, 1 v 1914, *Robinson & Kloss* s.n. (BM).

NOTES. In the herbarium, specimens are often notable for their lack of discolouration in leaves and bracts and extensive herbivore damage.

6. Cyrtandra trichodon Ridl. in J. Fed. Malay States Mus. 8 (4): 70 (1917). Type: SUMATRA. Jambi: Kerinci, Mount Kerinci, c. 2225 m [7300ft], 6 v 1914, *Robinson & Kloss* s.n. (holotype: BM; isotype: K).

Erect shrub, stem branched. *Leaves* opposite and isophyllous on petioles 3.5 - 7 cm, lamina narrowly elliptic to elliptic, 10 - 15 x 3.5 - 7.5 cm, acute to acuminate at the apex, base acute, margins usually with shallow serrations, with distinct tufts of hair at tips, surface with scattered hairs above and short coarse hairs on venation below; lateral nerve pairs 6 - 8. *Inflorescence* in axils of leaves, usually 4 - 6 flowers. *Bracts* c. 2 cm, enclosing inflorescence; hairy on both outer and inner surfaces, somewhat verrucose at base. *Peduncles* 1 - 2.5 cm. *Pedicels* c. 5 mm. *Calyx* c. 12 mm, externally with long silky hairs, internally glabrous; tube c. 6 mm; lobes, the lower two shorter (c. 4 mm) and upper three longer (c. 6 mm) both types narrowing to form fine tips c. 0.5 mm wide for c. 3 mm. *Corolla* white, c. 4 cm, narrow within calyx but widening to form a tube c. 1.2 cm wide that usually does not further broaden at the mouth, outer surface with silky hairs, inner surface papillose especially in the upper half, including the lobes, lobes sometimes with an undulate edge. *Filaments* c. 9 mm, glabrous. *Anthers* c. 2 mm. *Gynoecium* c. 2.3 cm, ovary glabrous, style with glandular or sometimes eglandular hairs, stigma c. 2.5 x 1.5 mm, horizontally bilobed, inner face papillose. *Disk* cupular, c. 2 mm, margin undulate. *Fruit* ovoid, verrucose, c. 13 x 6 mm, including 2 mm beak.

ETYMOLOGY. 'trichodon' = hairy teeth, and refers to the toothed leaf margins which have tufts of hair at their tips.

ECOLOGY. Upper montane forest, 2000 - 2500 m.

DISTRIBUTION. SUMATRA. Jambi: (Kerinci peak endemic).

MOUNT KERINCI SPECIMENS EXAMINED.

SUMATRA. Jambi: Mount Kerinci. c. 2400 m, 29 iv 1920, *Bünnemeyer* 9802 (BO); c. 2400 m, 2 v 1920, *Bünnemeyer* 9968 (BO); c. 2200 m, 6 v 1920, *Bünnemeyer* 10161 (BO); c. 2200 m, 7 v 1920, *Bünnemeyer* 10268 (BO); c. 2300 m, *Laumonier* TFB 528 (L); 1800 - 1900 m, 31 vii 1956, *Meijer* 6420 (L); 2000 - 2500 m, 28 vii 2000, *Radhiah & Cronk* 124 (E); 2000 - 2500 m, 28 Vii 2000, *Radhiah & Cronk* 126 (E).

NOTES. Whilst the specimens *Radhiah & Cronk* (*R&C*) 124 and 126 have been included in *C. trichodon*, there are some morphological differences. *R&C* 124 was devoid of complete inflorescence material, but *R&C* 126 has bracts that extend into c. 1.5 cm tips, c. 4 mm broad. The leaves are slightly larger, 12 - 16 x 5 - 7.5 cm and the bases slightly more decurrent. The corolla broadens at the mouth; hairs are not present on the parts of the corolla lobes covered by the aestivation of the corolla; there are less papillae on the actual corolla lobes, and the style has eglandular hairs that become shorter just above the ovary and are more like large papillae. *Laumonier* TFB 528 is also an outlying specimen; its leaves are narrowly elliptic, 11 - 12 x 4 - 4.5 cm, and the margin has deeper serrations. These differences demonstrate the variation within the species.

7. Cyrtandra stenoptera Bramley & Cronk *sp. nov.*

Type: SUMATRA. Jambi: Mount Kerinci, 1800 - 2000 m, 27 vii 2000, *Radhiah & Cronk* 110 (holotype: E; isotypes: BIOT, BO).

Folia marginibus serratis et petiolis anguste alatis vel ad caules porcatis, inflorescentiae in bracteis albis inclusae. A C. trichodonti inflorescentiis sessilibus vel subsessilibus et foliis decurrentibus differt.

Shrub to c. 1.2 m on unbranched stem. *Leaves* opposite and isophyllous, sometimes subequal, main section of lamina 17 - 20 x 8.5 - 11 cm, elliptic, decurrent to stem, lamina narrowing to only a few mm wide either side of petiole, or forming a narrower ridge for 5 - 10 cm, apex acute, margin with serrations with distinct tufts of hair at tips, new growth hairy above, hairs becoming more scattered with age but often original covering remaining on midrib, hairy below, especially on venation, hairs finer than those above; lateral nerve pairs 7 - 8. *Inflorescence* in axils of leaves and lower on the stem in axils of leaves that have fallen, flowers usually in clusters of 3 - 12. *Bracts* overlapping and enclosing inflorescence; white, c. 2 x 2 cm, ovate, hairy, verrucose, margins serrate, the inner bracts becoming more lanceolate, c. 5 mm wide. *Peduncles* very short, c. 5 - 8 mm. *Pedicels* c. 5 mm. *Calyx* seen only in bud, at this stage c. 13 mm, externally with stiff angular hairs, internally glabrous; lobes twisting together to form a c. 3 mm column above the corolla bud. *Corolla* (from bud) white, outer surface with long silky hairs, inner surface papillose. *Gynoecium* (immature) c. 1 cm, style with eglandular hairs, these shorter near ovary. *Disk* cupular, c. 3 mm, undulate. *Fruit* ovoid, 10 - 13 x 6 - 8 mm, style not persistent.

ETYMOLOGY. The epithet 'stenoptera' refers to the narrow wing formed by the lamina down the petiole.

ECOLOGY. Upper montane forest, 1800 - 2500 m

DISTRIBUTION. SUMATRA: Jambi (Kerinci).

MOUNT KERINCI SPECIMENS EXAMINED.

SUMATRA. Jambi: Mount Kerinci. 4 iii 1954, *Alston* 14182 (BM); c. 2000 m, 8 v 1920, *Bünnemeyer* 10326 (BO); 2000 - 2500 m, 28 vii 2000, *Radhiah & Cronk* 114 (E).

ADDITIONAL SPECIMEN EXAMINED.

SUMATRA. Jambi: Kerinci, Lake Tujuh, 31 vii 2000, *Radhiah & Cronk 145* (E).

NOTES. *Bünnemeyer 10326* is labelled as having lurid violet bracts. *Cyrtandra stenoptera* is closely related to *C. trichodon* but its leaves have a narrow wing or ridge down the petiole, and its inflorescence is sessile or subsessile rather than pedunculate.

2.2.1.5 Group III (=group three in chapter three)

8. Cyrtandra ampla C.B.Clarke in A. & C.DC., Monogr. phan. 5: 259 (1883).

Type: SUMATRA. West Sumatra: Mount Singgalang, vi-vii 1878 *Beccari* 173 (holotype: FI [*n.v.*]; isotypes: BM, K, L).

Shrub, stem somewhat quadrangular, hairy becoming glabrescent. *Leaves* opposite and isophyllous on petioles c. 4 cm long, lamina c. 19 - 25 x 8.5 - 15 cm, narrowly ovate, shortly acuminate at apex, base obtuse or cordate, margins biserrate, surface hairy above when young, becoming glabrescent with age although some hairs remain on the slightly impressed midrib near the base, glabrous below but venation raised and hairy; lateral nerve pairs 12 - 14. *Inflorescence* cauliflorous, sessile, with many clustered flowers. *Bracts* small, c. 11 x 5 mm, hairy, verrucose, margins serrate. *Pedicels* 1 - 1.5 cm long. *Calyx* c. 8 mm, externally hairy, internally verrucose; tube c. 6 mm; lobes triangular, c. 2 mm. *Corolla* c. 15 mm, broadening from c. 4 mm at base to c. 9 mm at mouth, with a small pouch present behind where the anthers lie against the lower side of corolla tube; outer surface with silky hairs, inner surface glabrous. *Filaments* c. 4 mm, glandular in region below anthers and on connective. *Anthers* c. 2 mm. *Gynoecium* c. 1.2 cm, style and ovary hairy, stigma horizontally bilobed c. 2.5 mm wide. *Disk* c. 2 mm high, unilateral, undulate. *Fruit* (young) 15 x 5 mm, including the 5 mm style, ovoid, verrucose, hairy; style initially persistent and covered by the decaying corolla; calyx persistent.

ETYMOLOGY. 'ampla' refers to the large leaves of this species.

ECOLOGY. Lower to upper montane forest, 1300 - 1600 m.

DISTRIBUTION. JAVA. SUMATRA. Jambi (Kerinci), West Sumatra.

MOUNT KERINCI SPECIMENS EXAMINED.

SUMATRA. Jambi: Mount Kerinci. c. 1600 m, 5 iii 1920, *Bünnemeyer* 8483 (BO).

SELECTED ADDITIONAL SPECIMENS EXAMINED.

SUMATRA. Jambi: Kerinci. Kayu Aru, Sungai Tanduk, 6 iii 1954, *Alston* 14273 (BM); nr Jl. Djapan, 1300 - 1400 m, 1 viii 1956, *Jacobs* 4431 (A).

NOTES. *Bünnemeyer* 8483 bears a close resemblance to the type of *C. ampla* although the leaves are smaller than the measurements given by C.B.Clarke in his description (25 x 15 cm). It is likely that this specimen is a young plant or shoot.

It is noted under Clarke's description of *C. ampla* that it occurs in Java. If it indeed does also occur in Java, it represents a very interesting disjunct distribution since I have seen no collections of this species collected outside Jambi and West Sumatra.

9. Cyrtandra impressivenia C.B.Clarke in A. & C.DC., Monogr. phan. 5: 212 (1883). Type: SUMATRA. West Sumatra: Mount Singgalang, c. 1700 m, *Beccari* 177 (holotype: FI [*n.v.*]; isotype: K).

Shrub to 1 m, stems quadrangular, hairy, becoming glabrescent. *Leaves* opposite and isophyllous, petioles hairy, 1.5 - 3 cm long; lamina 14 - 18 x 3.5 - 5 cm, narrowly elliptic, acuminate tip c. 1.5 cm long, acute at base, margins with shallow serrations with distinct tufts of hair at tips, surface rugose above due to impressed venation, hairy within these impressions, coarsely hairy below, hairs dense on the raised venation; lateral nerve pairs 8 - 10. *Inflorescence* in axils of leaves, flowers up to 13, in umbels. *Bracts* in a pair, subtending inflorescence; lanceolate, hairy, c. 10 x 1.5 mm. *Peduncles* 1.5 - 3 cm, hairy. *Pedicels* 5 - 10 mm long. *Calyx* green, c. 9 mm, externally with fine bristly hairs held at all angles, internally verrucose; tube c. 3 mm; lobes c. 6 mm, subulate. *Corolla* white with a tawny orange guide mark at the base of the throat, the upper side c. 8 mm with two brown lobes c. 2 x 2 mm, the lower side c. 1 cm, the three lobes white, the centre lobe c. 3 x 3 mm, the other two c. 3 x 2 mm; outer surface with silky hairs except for a glabrous area covered by the calyx tube, inner surface glabrous. *Filaments* c. 3 mm, hairy especially in upper half. *Anthers* c. 1 mm. *Gynoecium* c. 6 mm, the style and ovary densely hairy, stigma horizontally bilobed, inner face papillose. *Disk* c. 2 mm, unilateral with a curved top. *Fruit* hairy, oblong, c. 17 x 6 mm, style semi-persistent, calyx persistent.

ETYMOLOGY. The epithet 'impressivenia' refers to the distinctive impressed leaf venation of this species.

ECOLOGY. Upper montane forest, 1700 - 2500 m.

DISTRIBUTION. SUMATRA. Jambi (Kerinci), West Sumatra.

MOUNT KERINCI SPECIMENS EXAMINED.

SUMATRA. Jambi: Mount Kerinci. 2000 - 2500 m, 28 vii 2000, *Radhiah & Cronk* 116 (E); 2225 m [7300ft], 6 v 1914, *Robinson & Kloss* s.n. (BM).

NOTES. This species is easily recognisable by the rugose leaves due to impressed venation and the long peduncles bearing umbels of small, mainly white flowers.

10. Cyrtandra rosea Ridl. in J. Fed. Malay States Mus. 8(4): 70 (1917). Type: SUMATRA. Jambi: Kerinci, Siulakderas, c. 910 m [c. 3000ft], 17 iii 1914, *Robinson & Kloss* s.n. (holotype: BM; isotype: K).

Shrub, often branched at base, stem stout, woody. *Leaves* opposite and isophyllous, decurrent onto stem, lamina 20 - 30 x 7 - 13 cm, narrowly obovate to oblanceolate, tip obtuse but with a point due to terminal serration, margin biserrate, surface silky hairy above when young, soon becoming subglabrous, venation below raised, somewhat horizontal and covered with hair; lateral nerve pairs 17 - 22, at c. 90° to midrib. *Inflorescence* in axils of leaves and cauliflorous, sessile, flowers 4 to many. *Bracts* small, somewhat verrucose, hairy, serrate. *Pedicels* c. 15 mm long. *Calyx* c. 9 mm, externally hairy, internally verrucose, sometimes hairy; tube c. 5 mm; lobes c. 4 mm, the lower two almost fused, the upper three free with narrow tips of c. 1.5 mm. *Corolla* c. 2 cm, brownish red or purple or dark pink, tubular, not broadening at mouth, lobes c. 2 - 3 x 2 mm, outer surface with silky hairs, inner surface glabrous. *Filaments* c. 8 mm, hairy especially in upper half. *Anthers* c. 2 mm. *Gynoecium* c. 1.2 cm, style and ovary hairy, stigma horizontally bilobed, c. 3 mm when lobes fully open, inner face papillose. *Disk* unilateral, with a central section c. 2 mm, lowering to c. 1.5 mm either side. *Fruit* obovoid, hairy, c. 15 - 18 x 6 - 10 mm, including beak c. 1 - 7 mm, calyx persistent.

ETYMOLOGY. The colour of the corolla, which ranges from brownish red to purple or dark pink, gives this species the epithet 'rosea'.

ECOLOGY. Most commonly found in upper montane forest, but the type collection is from lower montane forest, (900 -)2000 - 2500 m.

DISTRIBUTION. SUMATRA. Jambi (Kerinci).

MOUNT KERINCI SPECIMENS EXAMINED.

SUMATRA. Jambi: Mount Kerinci. 4 iii 1954, *Alston* 14181 (A, BM); c. 2100 m, 7 iv 1920, *Bünnemeyer* 9186 (BO); c. 2100 m, 6 v 1920, *Bünnemeyer* 10170 (BO); c. 2000 m, 8 v 1920, *Bünnemeyer* 10323 (L); 2000 - 2500 m, 28 vii 2000, *Radhiah & Cronk* 115 (E); 2225 m [7300ft], 30 iv 1914, *Robinson & Kloss* s.n. (BM).

ADDITIONAL SPECIMEN EXAMINED.

SUMATRA. Jambi: Lake Tujuh, 31 vii 2000, *Radhiah & Cronk* 151 (E).

NOTES. Ridley described *C. rosea* from the Robinson & Kloss collections that were the result of the first expedition to Kerinci in 1914. The type specimen is not particularly informative, with little reproductive material in good condition, and a further Robinson & Kloss specimen from Kerinci Peak is sterile. The listed specimens have been determined to be *C. rosea* but there is variation within this species. It is allied to *C. sandei* de Vriese, described from Java, and it is possible that future work may recognise more than one species.

11. Cyrtandra aureotincta Bramley & Cronk *sp. nov.*

TYPE: SUMATRA. Jambi: Mount Kerinci, c. 2000 - 2500 m, 28 vii 2000, *Radhiah & Cronk* 129 (holotype: E; isotypes: BIOT, BO).

Tota planta hirta (disco et ovario inclusis), pilis aureis, corolla angusta cum lobis parvis distincta. A C. rosea foliis minoribus ellipticis, disco cupulato hirto et corolla viridi-alba differt.

Shrub, unbranched or branched at base only, up to 2.2 m tall. *Leaves* opposite and isophyllous on hairy petioles 3 - 5 cm long, lamina 19 - 23 x 7.7 - 9 cm, elliptic to narrowly elliptic, apex acuminate, base shortly decurrent, margin biserrate, irregularly spaced and hairy, surface golden felted above when young, older leaves with rough hairs, these often breaking off leaving bases giving a rough upper surface, venation raised below with dense, fine, almost matted hairs; lateral nerve pairs 12 - 15. *Inflorescence* in axils of leaves and of leaves that have fallen, sessile, with up to 20 flowers. *Bracts* enclosing inflorescence; green, c. 1.5 cm, ovate, hairy on both surfaces, somewhat verrucose, margins irregularly serrate. *Pedicels* c. 1.5 cm, hairy. *Calyx* c. 1 cm, externally with straight silky hairs, internally verrucose; tube c. 6 mm; lobes subulate, the lower two divided for 3 mm, the upper three divided for 4 mm. *Corolla* greenish-white, c. 1.5 cm, tubular, not broadening at the mouth, with small even lobes, 2 x 1.5 mm, outer surface with a thick covering of silky hairs, inner surface with papillae concentrated on area behind anthers. *Filaments* c. 5 mm, glabrous apart from a small area of hairs at tip, just below anthers. *Anthers* c. 1.5 mm. *Gynoecium* c. 1.5 cm, style and ovary densely hairy, stigma with two triangular lobes, papillose on the inner face. *Disk* cupular, 1.5 mm, margin undulate and hairy. *Fruit* ovoid, hairy, c. 15 x 5 mm including c. 3 mm stylar beak, calyx persistent. (Figure 2.4).

ETYMOLOGY. The specific epithet 'aureotincta' = golden tinted, was chosen because of the distinctive golden hair that covers the leaves of this species.

ECOLOGY. Upper montane forest, 2000 - 2500 m.

DISTRIBUTION. SUMATRA. Jambi: (Kerinci peak endemic).

MOUNT KERINCI SPECIMENS EXAMINED.

SUMATRA. Jambi: Mount Kerinci, c. 2400 m, 28 vii 2000, *Radhiah & Cronk* 122 (E).

NOTES. *Cyrtandra aureotincta*, a species apparently endemic to Mount Kerinci, is particularly distinctive due to the golden hair that covers the whole plant, even the ovary and the disk. It is known only from its type specimen and one further collection from the same locality.

12. Cyrtandra patentiserrata Bramley & Cronk *sp. nov.*

Type: SUMATRA. Jambi: Mount Kerinci, c. 1400 m, 7 iii 1920, *Bünnemeyer* 8551 (holotype: L).

Inflorescentiis sessilibus, bracteis parvis, petiolis brevibus, foliis ellipticis biserratis, serraturis acuminatis patentibus vel subpatentibus distinguitur. A C. rosea foliis ellipticis, calyce lobis quinque aequis perangustis et corolla albida differt.

Erect shrub. *Leaves* opposite, pairs isophyllous or subisophyllous, on petioles 2 - 4 cm long, lamina 14 - 17 x 5.8 - 6.9 cm, elliptic, apex acuminate, the narrow tip 1 cm long, base acute, margin biserrate, serrations with distinctly pointed tips, surface subglabrous to glabrous above, with fine hairs on venation below; lateral nerve pairs 9 - 10. *Inflorescence* in axils of leaves, sessile, with 2 - 4 flowers. *Bracts* c. 12 x 4 - 6 mm, enclosing inflorescence; elliptic to narrowly elliptic, free, overlapping, hairy on both surfaces and externally verrucose, margins irregularly serrate. *Pedicels* c. 5 mm long. *Calyx* c. 12 mm long, externally with short angular hairs, internally verrucose; tube c. 6 mm long; lobes c. 6 mm long, narrowing to form very fine tips for c. 4 mm, these twist together over the top of corolla bud. *Corolla* off-white, c. 1.5 cm, c. 1 cm broad at mouth, outer surface with a dense covering of silky hair, inner surface with a small area of papillae on the corolla tube where the anthers rest. *Filaments* with small area of papillae under the anthers, otherwise glabrous. *Anthers* c. 1 mm. *Gynoecium* c. 1.2 cm, style with eglandular hairs, these becoming shorter on ovary, stigma with two triangular lobes c. 1 mm long, inner face papillose. *Disk* c. 1.5 mm, unilateral, undulate. *Fruit* (immature) c. 1.2 cm including c. 5 mm style, narrowly ellipsoid, calyx and style persistent. (Figure 2.4).

ETYMOLOGY. 'patentiserrata' refers to the distinctive patent serrations of the leaf margins of this species.

ECOLOGY. Lower to upper montane forest, 900 - 1700 m.

DISTRIBUTION. SUMATRA: Jambi (Kerinci), West Sumatra.

MOUNT KERINCI SPECIMENS EXAMINED.

SUMATRA. Jambi: Mount Kerinci. c. 1500 m, 4 iii 1920, *Bünnemeyer* 8386 (BO).

SELECTED ADDITIONAL SPECIMENS EXAMINED.

SUMATRA. Jambi: Kerinci, Sungai Kering, 3 iii 1954, *Alston* 14126 (BM). West Sumatra: Mount Merapi, c. 1700 m, 14 ix 1918, *Bünnemeyer* 4562 (L); Mount Sago, ravine of Batang Lakin, c. 1000 m, 30 ix 1956, *Meijer* 5329 (L); road from Padang to Solok, c. 900 m, 25 vii 2000, *Radhiah & Cronk* 103 (E).

NOTES. *C. patentiserrata* is distinctive because of its patent or subpatent serrations of the leaf margins. Amongst Sumatran *Cyrtandra* it seems most similar to *C. rosea*, in that it shares with this species a unilateral disk and has similar bracts and corolla shape. However, it differs from *C. rosea* by its white rather than reddish corolla, elliptic rather than obovate leaves, and its calyx, which has long narrow lobes, unlike the shorter triangular lobes of the *C. rosea* calyx.

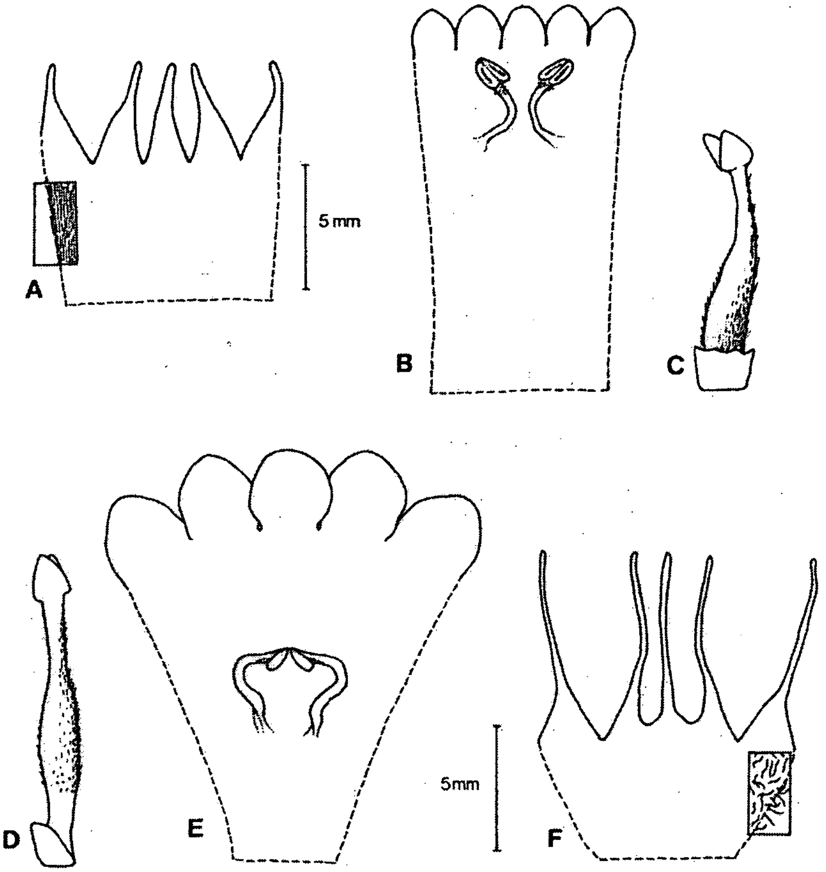


Figure 2.4: A-C. *Cyrtandra aureotincta* Bramley & Cronk: A, calyx, dissected ventrally with indumentum detail; B, corolla, dissected dorsally, showing stamens; C, gynoecium and disk. Drawn from the holotype. D-F. *Cyrtandra patentiserrata* Bramley & Cronk: D, gynoecium and disk; E, corolla, dissected dorsally, showing stamens; F, calyx, dissected ventrally with indumentum detail. Drawn from the holotype. It must be noted that the difference in stamen position between species is due to the developmental stage of the flower. The joined anthers in *C. patentiserrata* are an earlier stage to the separate anthers in *C. aureotincta.*

13. Cyrtandra flabelligera Ridl. in J. Fed. Malay States Mus. 8 (4): 69 (1917). Type: SUMATRA. Jambi: Kerinci, Sungai Kumbang, 1914, *Robinson & Kloss* s.n. (holotype: BM; isotype: K).

Epiphyte. *Leaves* opposite and anisophyllous or sometimes pseudoalternate, the larger of the pair on c. 1 cm petiole, lamina 14 - 16 x 3.5 cm, narrowly oblong, asymmetric (c. 2 cm wide on one side of midrib, c. 1 cm wide on the other), apex acute, base asymmetric, the narrower side ending before the wider side, margins entire, surface glabrous above, sparsely hairy on venation below; the smaller of the pair sometimes absent, on c. 5 mm petiole, lamina 3.5 x 1.5 cm, asymmetric, ovate, apex acute, base asymmetric, margins entire, surface glabrous above and below. *Inflorescence* in axils of leaves, 2 - 3 flowers. *Bracts* in a pair, c. 2 x 1 cm, subtending inflorescence, narrowly obovate, acuminate, glabrous, margins entire. *Peduncles* 1.3 - 1.5 cm. *Pedicels* c. 3 mm, hairy. *Calyx* c. 3 mm, externally hairy, lobes triangular, c.1 mm. *Corolla* white, c. 2 cm, c. 2 mm wide for c. 0.8 cm, then widening to c. 1.2 cm at mouth, outer surface glabrous, inner surface not seen. *Gynoecium* c. 1.5 cm, style hairy, ovary glabrous, stigma bilobed. *Disk* unilateral with a curved top. *Fruit* oblong, c. 2 x 0.3 cm, the length depending on the varying length of the remaining style, glabrous, calyx persistent. (Figure 2.4).

ETYMOLOGY. Ridley gave this species the epithet 'flabelligera' because of its fan-shaped bracts.

ECOLOGY. Lower to upper montane forest, c. 1340 - 1500 m.

DISTRIBUTION. SUMATRA. Jambi: (Kerinci).

MOUNT KERINCI SPECIMENS EXAMINED.

SUMATRA. Mount Kerinci, c. 1500 m, 4 iii 1920, *Bünnemeyer* 8423 (K).

SELECTED ADDITIONAL SPECIMENS EXAMINED.

SUMATRA. Jambi, Kerinci, Kayu Aru estate, Sungai Tanduk, 28 ii 1954, *Alston* 13933 (BM); Jambi, Kerinci, Kayu Aru estate, Sungai Tanduk, 6 iii 1954, *Alston* 14260 (BM); Jambi, Kerinci, c. 1340 m [4400 ft], Siulakderas, 16 iii 1914, *Robinson & Kloss* s.n. (BM).

NOTES. *C. flabelligera* belongs to section *Whitia* (Blume) C.B.Clarke, a section of about ten West Malesian species (Burtt, 1999) that includes *C. oblongifolia* (Blume)

C.B.Clarke and *C. suffruticosa* Ridl. (see chapter four). The most diagnostic characters of the section are usually ovate paired bracts, a reduced calyx, the triangular segments of which scarcely reach 4 mm long, and a long narrow fruit.

2.3 ADVANTAGES AND DISADVANTAGES OF THIS LOCAL REVISIONARY APPROACH

This revision of *Cyrtandra* on Mount Kerinci highlighted a number of advantages and disadvantages of a local revisionary approach.

Firstly, Mount Kerinci is an easily defined area, making fieldwork straightforward and increasing the chance of collecting all species. However, in order to be able to report species distributions and species endemism, and also to know whether species are new to science, it is necessary to examine species from a much larger area than the local study area. In this case, specimens from the whole of Sumatra were examined. This makes this approach time consuming.

Once the number of species present in a particular area such as a mountain is determined, the number of species in a similar disjunct area can be more reliably estimated, or, the value can be scaled to apply it to a larger area. In a local revision, the fact that specimens would be examined from a larger area than the local area under revision may be advantageous, since species that had distributions extending to other areas could be noted, allowing us to estimate the number of endemic species that might be present. For example, preliminary observations from Sumatran *Cyrtandra* collections show that Mount Singgalang shares six species with Mount Kerinci, has a further four species that occur in other areas, and apparently one endemic species. It could then be estimated to have perhaps one or two further endemic species, if Mount Kerinci is used as an example, because Mount Kerinci has two endemic species, but is a younger mountain.

In larger local areas such as national parks, local revisions could be used to produce field guides. Continued revisions of small areas, especially if disturbance was a problem, could allow the monitoring of such areas, using species of a particular genus as indicators of the status of the habitat. *Cyrtandra* would be particularly appropriate for this as it is a genus that only survives in primary rain forest.

Local studies such as this can provide a starting point for larger scale studies, especially in a large and complex genus such as *Cyrtandra*, when it seems difficult to know how to initiate monographic studies. A local approach may be suitable for introducing new taxonomists to the genus, allowing a knowledge of the species of a wider area to be gained.

In addition, work on such a small scale allows detailed ecological observations to be made, giving insight at the community level. Chapter three shows how a local revisionary approach can lead to molecular phylogenetic work that can address questions concerning the evolution of rain forest diversity on a local scale.

3 CHAPTER THREE: ASSEMBLY OF TROPICAL PLANT DIVERSITY ON A LOCAL SCALE: *CYRTANDRA* (GESNERIACEAE) ON MOUNT KERINCI, SUMATRA

This chapter forms the second part of the local approach. It is a molecular phylogenetic analysis of *Cyrtandra* ITS sequences, particularly those *Cyrtandra* of Mount Kerinci and Sumatra (based on Bramley *et al.*, 2004a). It shows how information on a local scale can be used to pose hypotheses about the evolution of rain forest diversity.

3.1 INTRODUCTION

Tropical forest biodiversity has traditionally been considered from a regional perspective (e.g. Moritz *et al.*, 2000; Richardson *et al.*, 2001) or local ecological viewpoint (e.g. Newbery *et al.*, 1998). At an evolutionary scale, Stebbins (1974) has suggested that the generation of modern forest diversity (gamma diversity), defined here in terms of numbers of species, is the result of a gradual accumulation of species through time with low extinction rates (the museum hypothesis). This hypothesis has been challenged by data showing that rapid recent speciation in large species-rich genera may be responsible for high species numbers, as observed by Richardson *et al.* (2001) in the neotropical tree genus *Inga* (Leguminosae).

Few studies have considered the evolutionary origin of local diversity (alpha diversity), that is, the phyletic origin of communities of related species, for instance members of the same genus. The recent speciation demonstrated by Richardson *et al.* (2001) suggests that community diversity of a genus may be generated recently. In contrast, the 'museum hypothesis' (e.g. Stebbins, 1974) would suggest that community diversity in a particular genus has accumulated gradually over time - speciation is more likely to have been ancient. In addition to this dimension of time, there is a second issue of the number of distant lineages that have contributed to a local community. In the first situation, where the community has resulted from recent speciation, it is perhaps more likely to have a single origin - *in situ* radiation of a single lineage has occurred, and all species are more or less closely related. On the other hand, in the second situation, where the community diversity has accumulated gradually over time, with perhaps more ancient speciation, I suggest the community is perhaps more likely to be assembled by the migration of species from different distinct, and ancient phyletic lineages.

In order to test these ideas in the Indo-Malayan rain forest, I focused on the species-rich genus *Cyrtandra*. The Indo-Malayan region is the second largest global expanse of rain forest (Whitmore, 1998), its largest forest areas being in the Malay Peninsula, Sumatra and Borneo (Sundaland). Sundaland is the second 'hottest' global hotspot for plants, with estimates of 15,000 endemic plant species, and 5% of the total global plant species (Myers *et al.*, 2000). In addition it is one of the three most significant areas for all biodiversity, appearing in the top ten hotspots for all five factors tested by Myers *et al.* (numbers of endemic plants; numbers of endemic vertebrates; endemic plants/area ratio; endemic vertebrates/area ratio; remaining primary vegetation as a percentage of the original extent).

Sumatra is a large island forming part of Sundaland (figure 2.1). It has an area of 476,000 km^2 and probably 10,000 species of higher plants (Whitten *et al.*, 1997). Politically it forms part of Indonesia, a country second only to Brazil in the amount of rain forest it possesses (Whitmore, 1998). The west coast is dominated by the Barisan Mountains, uplifted as a result of thrust associated with the collision of the Indian plate with Asia about 70 million years ago (Whitten *et al.*, 1997). A significant part of this range falls within the boundaries of Kerinci-Seblat National Park. This is the largest national park in Sumatra, covering approximately 1.4 million hectares, and perhaps the most undiminished of Sumatra's representative ecosystems. At its heart is Mount Kerinci, an active volcano that at c. 3805 m is the second highest peak in Indonesia. Kerinci is a young volcano; it forms the youngest peak in a volcanic formation breaking through the Barisan range in an E-W direction (Jacobs, 1958). The last major period of mountain building in the range occurred about three million years ago (Whitten *et al.*, 1997) suggesting that the still active

Kerinci has a late Pliocene origin. Emissions of volcanic gases and ash mean that the vegetation ceases at an altitude of about 3400 m. Mount Kerinci forms an easily definable geographical area with primary rain forest remaining, making it an appropriate location for study.

Cyrtandra (Gesneriaceae), with over 600 species, is a highly suitable genus for the study of tropical forest plant community diversity. As seen in chapter one, it occurs as an important understorey element in primary rain forest, with habit ranging from epiphytes, herbs and shrubs, and occasionally small trees. It is distributed from the Nicobar Islands in the west, and southern Thailand in the north, throughout Malesia to the Philippines, Taiwan, southern Ryukyu Islands, south-east to Queensland and the Loyalty Islands and east to the high islands of the Pacific to the Hawaiian Islands. One of its most remarkable features is its capacity for producing local endemics, making it particularly suitable to study local species richness. Furthermore, one of its centres of species diversity is Sundaland (Burtt, 1998a). Fieldwork carried out by Radhiah and Cronk in 2000 on Mount Kerinci and other locations in West Sumatra led to the taxonomic revision of the *Cyrtandra* species of Mount Kerinci (chapter two of this thesis; Bramley & Cronk, 2003). This study recognised 13 species of *Cyrtandra* on Mount Kerinci, two of which are apparently endemic to Mount Kerinci, four to Kerinci and the immediate surrounding area and four that occur more widely in West Sumatra. An additional two species occur also in West Sumatra and are also reported in Java. Only one species, *C. anisophylla* C.B.Clarke, appears to be widespread in Sumatra. Herbarium collection data suggest that altitudinal zonation of these species of *Cyrtandra* on Mount Kerinci is weak and that they form part of one broad community (figure 3.1).

A number of studies have shown the presence or absence and type of foliar sclereids to vary significantly in *Cyrtandra*, and that they have the potential to be important taxonomic characters (Atkins & Cronk, 2001; Bokhari & Burtt, 1970). Leaves from Sumatran *Cyrtandra* species were therefore examined for sclereids, in order to assess the phylogenetic relevance of this character.

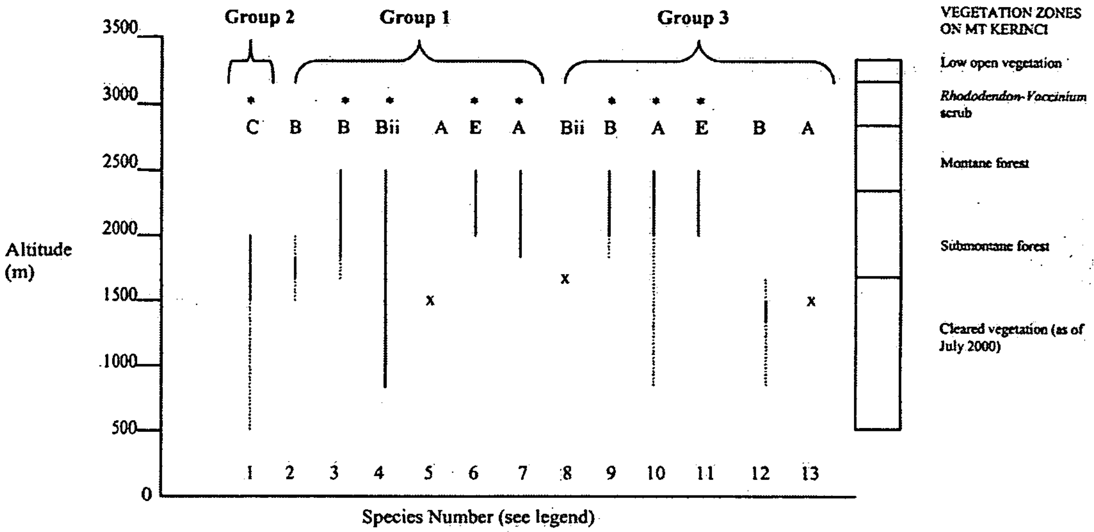


Figure 3.1: Altitudinal ranges of species.* = included in molecular analysis; x = only one altitude recorded (one specimen only). Distributions: E = endemic to Mount Kerinci; A = Mount Kerinci and immediate surrounding area; B = Mount Kerinci, extending to West Sumatra; Bii = Mount Kerinci, extending to West Sumatra (with records in Java); C = All Sumatra. Unbroken lines designate the altitudinal range of each species on Mount Kerinci; dotted lines are distribution wide altitudinal ranges for each species. 1=*C. anisophylla*; 2=*C. fenestrata*; 3=*C. rhyncanthera*; 4=*C. longepetiolata*; 5=*C. membranacea*; 6=*C. trichodon*; 7=*C. stenoptera*; 8=*C. ampla*; 9=*C. impressivenia*; 10=*C. rosea*; 11=*C. aureotincta*; 12=*C. patentiserrata*; 13=*C. flabelligera.*

Cyrtandra and other genera in the Gesneriaceae have been the subjects of systematic and biogeographic studies using the internal transcribed spacer (ITS) region of 18-26S nuclear ribosomal DNA (Atkins *et al.*, 2001 [*Cyrtandra*]; Möller & Cronk, 1997 [*Saintpaulia, Streptocarpus*]; Denduangboripant *et al.*, 2001 [*Aeschynanthus*]). These studies have shown that ITS is particularly suitable for species-level phylogenetics in this family. Using an ITS phylogeny of *Cyrtandra* species from Mount Kerinci and west Sumatra, and species representing other areas within the distribution, I test the following two hypotheses:

i) the *Cyrtandra* community of Mount Kerinci will have a single origin with rapid recent radiation, appear in one clade in the phylogenetic tree, and be the result of recent speciation.

ii) the Kerinci *Cyrtandra* community will have multiple origins, appear in various clades in the phylogenetic tree, and be due to more ancient speciation in many phylogenetic lineages over time.

3.2 MATERIALS AND METHODS

3.2.1 Outgroup and Ingroup Taxa

Aeschynanthus pulcher (Blume) G.Don was selected as the outgroup following Atkins *et al.* 2001: from sequencing at RBGE (Möller & Cronk, unpublished) *Aeschynanthus* appears to be one of the most closely related genera to *Cyrtandra*. The ingroup contained ITS sequences for 38 *Cyrtandra* accessions (for accession details see appendix 2). Ten sequences representing seven of the thirteen *Cyrtandra* species known to occur on Mount Kerinci (chapter two of this thesis; Bramley & Cronk, 2003) were included in the analysis. Sequences for the 21 non-Sumatran *Cyrtandra* accessions (collections other than those made by Radhiah and Cronk) were obtained from work previously carried out at RBGE (Atkins *et al.*, 2001; J. Preston, unpublished data). Non-Sumatran *Cyrtandra* were included to elucidate the relationships between Sumatra and other geographic areas within the overall distribution of the genus.

3.2.2 DNA Extraction, PCR and Sequencing Protocol

DNA was extracted from silica dried leaf material collected by Radhiah and Cronk. The protocol was a modified CTAB procedure following Doyle & Doyle (1990): see appendix 3.

The complete ITS region was amplified using the Polymerase Chain Reaction (PCR) with the primers 'ITS 5P' (forward) (modified from White *et al.*, 1990) GGA AGG AGA AGT CGT AAC AAG and 'ITS 8P' (reverse) (Möller & Cronk, 1997) CAC GCT TCT CCA GAC TAC A. The PCR reaction mixture is described in full in appendix 4, along with the PCR program which follows Möller & Cronk (1997).

Following successful amplification, the PCR product was purified using the QIAquick PCR purification kit (Qiagen Ltd., Crawley, W.Sussex, UK).

Sequencing primers were identical to those used for PCR (ITS 5P, ITS 8P) but in addition, to ensure that both ITS1 and ITS2 regions were sequenced in both forward and reverse directions, the internal primers 'ITS 3P' (modified from White *et al.*, 1990) GCA TCG ATG AAG AAC GTA GC and 'ITS 2G' (modified from Möller and Cronk, 1997) GTG ACA CCC AGG CAG ACG T were used. All primers were obtained from MWG, Copenhagen. The annealing sites of the primers 3P and 2G are located at the beginning and end, respectively, of the conserved 5.8S region.

Purified PCR products were sequenced using a Thermosequenase II dye terminator kit (Amersham pharmacia biotech) according to the manufacturer's recommendations (for protocol see appendix 6).

Sequencing products were analysed on an ABI 377 Prism Automatic DNA Sequencer (Perkin Elmer, Applied Biosystems Division, Foster City, CA, USA).

3.2.3 Analysis of Sequence Data

Sequences were imported into Sequence Navigator (Version 1.0.1, Perkin Elmer, Applied Biosystems Division, Foster City, CA, USA) and aligned manually. Alignment of the 39 ITS sequences analysed resulted in a 559-bp long data matrix. Sequence characteristics were calculated using PAUP Version 4.08b (Swofford, 2001) except for the transition/transversion ratio, which was determined using MacClade Version 3.07 (Maddison & Maddison, 1997). (Table 3.1).

Phylogenetic trees were generated using PAUP Version 4.08b (Swofford, 2001) and Mr Bayes (version 2.01; Huelsenbeck & Ronquist, 2001). Maximum parsimony (MP) analyses involved a heuristic search strategy with 10,000 random stepwise addition sequence replicates and TBR branch swapping with the option 'collapse branches if minimum length is zero' selected. Further searches (with options MULTREES and steepest descent on) using the trees stored in the memory from the initial search as the starting trees were carried out for tree optimisation, but no additional trees were found. Only combined ITS1 and ITS2 data were subjected to analyses. Individual gap characters were treated as missing data and gaps were coded as additional characters according to the simple method of Simmons and Ochoterena (2000). To investigate the effects of the additional gap characters, a sensitivity analysis (Wheeler, 1995) was carried out without them. Ambiguous regions that allowed alternative alignment interpretations were excluded (bp 260-6, 267-90, 483-9). A sensitivity analysis (Wheeler, 1995) including these regions was carried out in order to test their effects. A successive reweighting analysis was carried out using the rescaled consistency index for each character in order to select a phylogram from the unweighted analysis identical in topology to the reweighted tree for display.

Bootstrap values (Felsenstein, 1985) were calculated from a 1000 replicate analysis using a heuristic search strategy with simple addition of the taxa, MULTREES option on and TBR branch swapping. Decay indices (Bremer, 1988) were determined by running the programme AutoDecay (Eriksson, 1998) in conjunction with PAUP version 4.08b (Swofford, 2001).

Parameters and assumptions used in the maximum likelihood (ML) searches were selected using the programme Modeltest (Posada & Crandall, 1998) and based on the hierarchical likelihood ratio tests (hLRTs) and the Akaike Information Criterion (AIC). The model selected was TrN (Tamura & Nei, 1993) with a gamma distribution. ML heuristic search parameters were simple addition sequence of taxa with TBR branch swapping, MULTREES and COLLAPSE. An ML analysis was performed using Bayesian methods and a general time reversible (GTR) model with a gamma distribution in MrBayes. For this analysis four simultaneous Monte Carlo Markov Chains (MCMC) were run for 1,000,000 generations, saving a tree every 100 generations.

3.2.4 Measures of Confidence in ITS Data

In order to provide a degree of confidence in the phylogenies presented here, based only on a single locus from the nuclear genome, it was decided to use further chloroplast *trn*L-F region sequences and morphological evidence (foliar sclereids): this is outlined below.

3.2.4.1 Sequencing of the trnL-F region

The *trn*L-F region was sequenced for 23 *Cyrtandra* species, and phylogenetic analyses carried out. This work is presented in chapter five, as the sample included species not included in the ITS phylogeny presented there.

3.2.4.2 Examination of leaves for the presence of foliar sclereids

Sections of dried leaf were soaked in 5% KOH for 1-5 hours, rinsed, then transferred to FAA for a minimum of 30 minutes. Transverse sections 15μm thick were taken using a freezing microtome. The sections were bleached, stained with 2% safranin in absolute alcohol and destained with absolute alcohol. They were then mounted with euparal and examined under a light microscope. Notes on each species examined are displayed in appendix 13.

3.3 RESULTS

3.3.1 Sequence Characteristics

The average lengths of ITS1 and ITS2 were 225 and 243 bp respectively (table 3.1). Alignment of all taxa required the insertion of 74 gaps of 1-11 bp length, 30 in ITS1 and 44 in ITS2, of which 15 in ITS1 and 12 in ITS2 were potentially phylogenetically informative. The lengths of aligned ITS1 and ITS2 regions were 266 and 293 bp, respectively. Due to alignment ambiguities (where alternative alignments were possible) 38 sites were excluded (7 sites in ITS1 and 31 sites in ITS2). Of the remaining 521 unambiguously aligned sites, 48.9% were constant, 27.8% were phylogenetically informative, and 23.2% were autapomorphic (table 3.1).

Within the ingroup, sequence divergence (table 3.2) of unambiguously alignable positions of ITS1 ranged from 0-16.8%, and from 11.5-17.7% between the ingroup

Table 3.1: Sequence characteristics

Parameter	**ITS1**	**ITS2**	**ITS1 and ITS2**
Length range (total) (bp)	219-242	229-264	449-506
Length mean (total) (bp)	225	243	473
Length range (ingroup) (bp)	219-242	229-264	449-506
Length mean (ingroup) (bp)	225	243	473
Length range (outgroup) (bp)	228	249	477
Aligned length (bp)	266	293	559
G+C content range (%)	53.3-62.1	52.6-60.6	52.9-60.6
G+C content mean (%)	58.1	58	58
Number of excluded sites (%)	2.6	10.6	6.8
Sequence divergence (ingroup) (%)*	0-16.8	0-22.6	0-18.9
Sequence divergence (in/outgroup) (%)*	11.5-17.7	15.1-25.1	13.7-20.1
Number of indels (ingroup)*	27	42	69
Number of indels (total)*	30	44	74
Size of indels (ingroup)*	1-7	1-11	1-11
Size of indels (total)*	1-7	1-11	1-11
Number of sites after exclusion*	259	262	521
Number of variable sites*	130	136	266
Number of constant sites (%)*	49.8	48.1	48.9
Number of informative sites (%)*	27.8	27.9	27.8
Number of autapomorphic sites (%)*	22.4	24.1	23.2
Transitions (min-max)*	210-216	179-186	389-402
Transversions (min-max)*	81-87	114-121	248-261
Mean No.Transitions/Mean no. transversions*	2.54	1.55	1.55

*Based on alignment excluding ambiguous sequence sites

Table 3.2: Sequence divergence between groups

GROUP	Sequence Divergence (%)		
	ITS1 and ITS2	ITS1	ITS2
Ingroup/Outgroup	13.7-20.1	11.5-17.7	15.1-25.1
Ingroup	0-18.9	0-16.8	0-22.6
Sumatran species	0-11.3	0-13.5	0-11.4
Kerinci species	0.2-11.3	0-13.5	0.45-11.0
Between clades containing Sumatran material (groups 1, 2 & 3)	8.7-11.3	7.6-13.5	6.4-11.0
Between Bornean and Sumatran material	3.0-14	3.6-13.5	1.4-15.9
Bornean species	1.8-13.0	1.8-12.5	1.8-14.8

and the outgroup. ITS2 was more variable with 0-22.6% divergence within the ingroup, and 15.1-25.1% between the ingroup and the outgroup. Pairwise comparisons of individual taxa across both spacer regions revealed 0-18.9% sequence divergence within the ingroup, and 13.7-20.1% divergence between the ingroup and outgroup analysed. Atkins *et al.* (2001) found a maximum sequence divergence of 15.7% within an ingroup of different *Cyrtandra* species.

Among the Sumatran *Cyrtandra*, combined ITS1 and ITS2 sequences showed 0-11.3% divergence (table 3.2); *Cyrtandra* from Mount Kerinci showed a similar divergence of 0.23-11.3%. The greatest divergence between Sumatran collections occurred between two Kerinci species (*C. impressivenia* C.B.Clarke and *C. stenoptera* Bramley & Cronk). Maximum sequence divergence was between *C. ferruginea* Merrill (from the Philippines) and *C. chrysea* C.B.Clarke (from Borneo). The lowest sequence divergence between different species was 0.23%, between *C. stenoptera* and *C. trichodon* Ridl. (from Sumatra).

3.3.2 Phylogenetic Patterns

Parsimony analysis of unambiguously aligned ITS sequences yielded five most parsimonious trees of 650 steps when the gap characters were added to the data matrix (consistency index [CI] = 0.61; retention index [RI] = 0.68). Reweighting yielded a single most parsimonious tree. Figure 3.2 is a phylogram, showing branch lengths, of one of the five most parsimonious trees, chosen to be identical in topology to the single most parsimonious reweighted tree: nodes that collapsed on the strict consensus tree are indicated. Analysis including the ambiguously alignable regions (bp 260-6, 267-90, 483-9) resulted in more trees of a longer length (15 of 711 steps) with an identical consensus topology. Analysis without the gap matrix produced 10 most parsimonious trees of 596 steps; the strict consensus topology was identical.

Sumatran *Cyrtandra* are present in three different groups on the strict consensus tree (figure 3.3). Group one, which includes a Philippine species (*C.* sp. Lantuyang) and is nested within a larger clade of Bornean species, is poorly supported (Bootstrap value [BS] <50, Decay Index [DI] +1) but the whole clade, within which it is nested, is well supported (BS 85, DI +4). Group two is the Sumatran *C. anisophylla* C.B.Clarke which forms a pair with the Bornean species *C. fulvisericea* Bramley ined. (BS 84, DI +4). Group three is purely Sumatran and particularly well supported (BS 96, DI +7).

The *Cyrtandra* from areas outside of Sundaland (the Philippines, Australia, New Guinea, the Pacific and Taiwan) form a separate clade to *Cyrtandra* from Sundaland, with the exception of *C.* sp. Lantuyang, from Mindoro, the Philippines.

The ML tree (figure 3.4) is very similar to the MP tree except for the position of *C. smithiana* B.L.Burtt and *C. aurantiaca* B.L.Burtt. The Bayesian analysis also gave a similar tree; the Bayesian majority rule consensus percentages are plotted on the ML tree in figure five. The majority of nodes supported in the MP analysis are also supported in the Bayesian analysis.

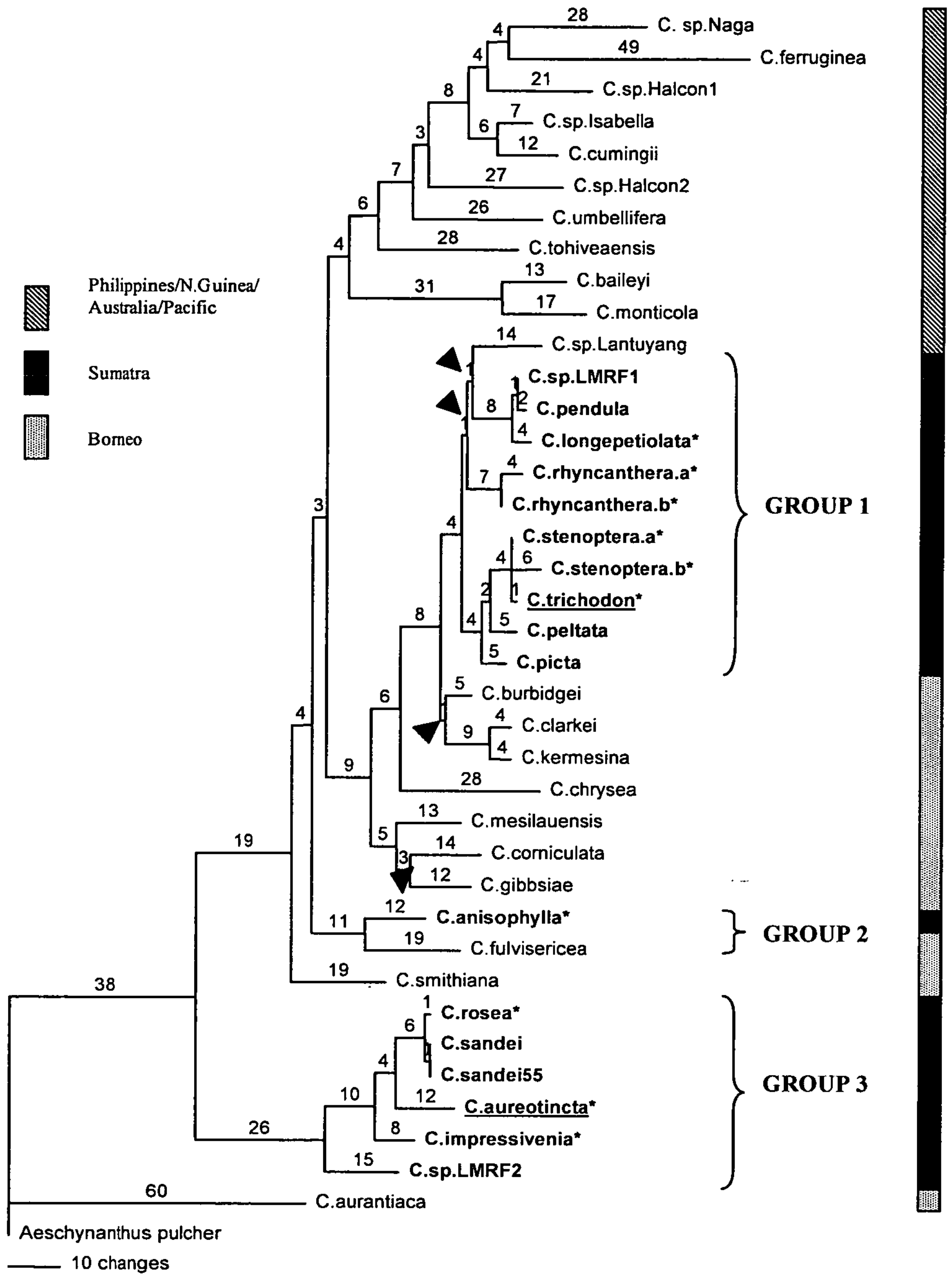


Figure 3.2: Phylogram, one of five most parsimonious trees identical in topology to the single most parsimonious reweighted tree, based on parsimony analysis of ITS sequence data plus alignment gap matrix. Numbers indicate branch lengths. Triangles indicate nodes that collapse in the strict consensus tree. Species from Sumatra are in bold; asterisks mark species from Mount Kerinci; species thought to be endemic to Mount Kerinci are underlined. Bars show the geographical distribution of the species.

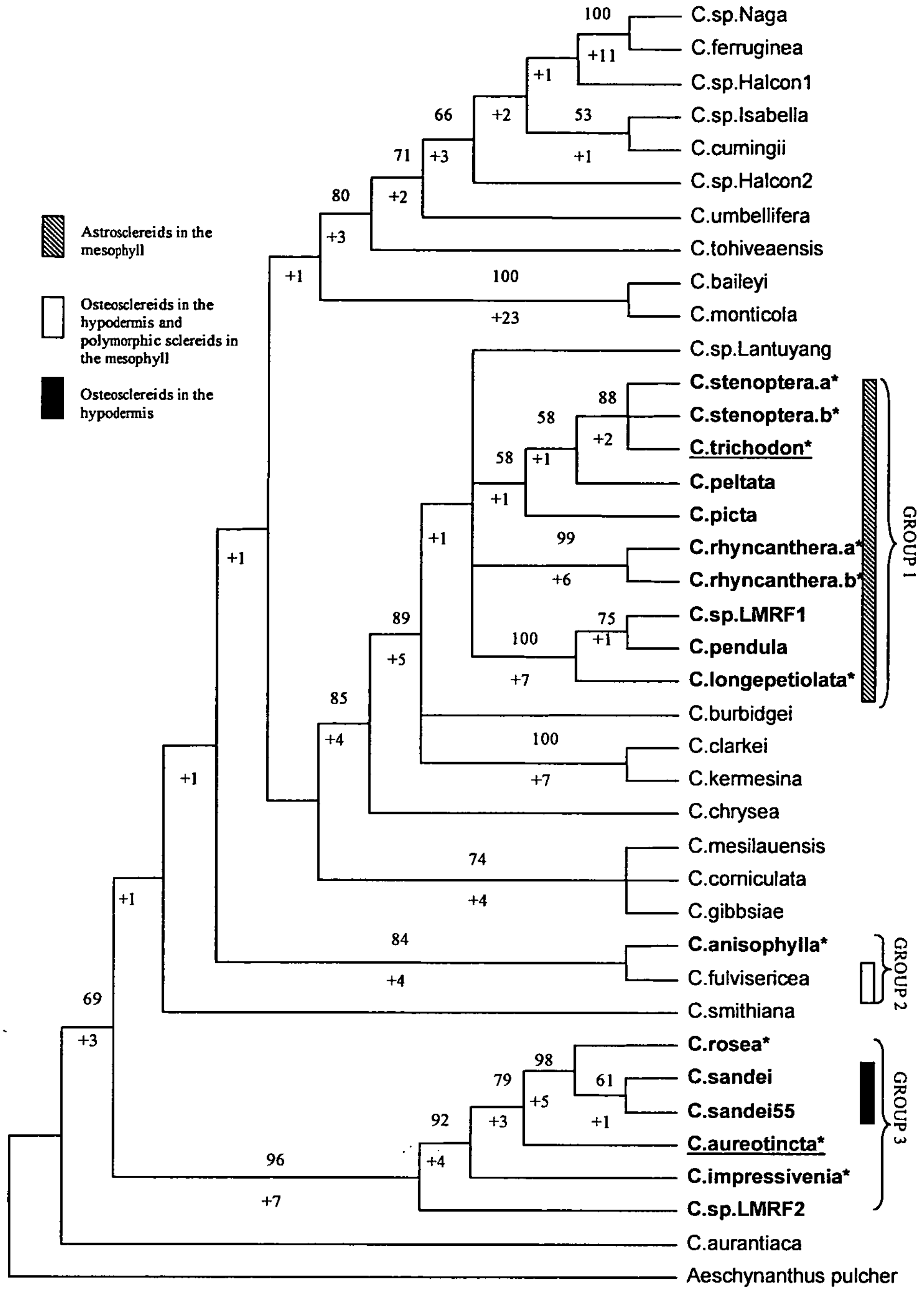


Figure 3.3: Strict consensus tree of five most parsimonious trees of 650 steps based on parsimony analysis of ITS sequence data plus alignment gap matrix. Numbers above the branches are Bootstrap values, numbers below are Decay Indices. Species from Sumatra are in bold; asterisks mark species from Mount Kerinci, those thought to be endemic to Mount Kerinci are underlined. Bars denote pattern of foliar sclereids.

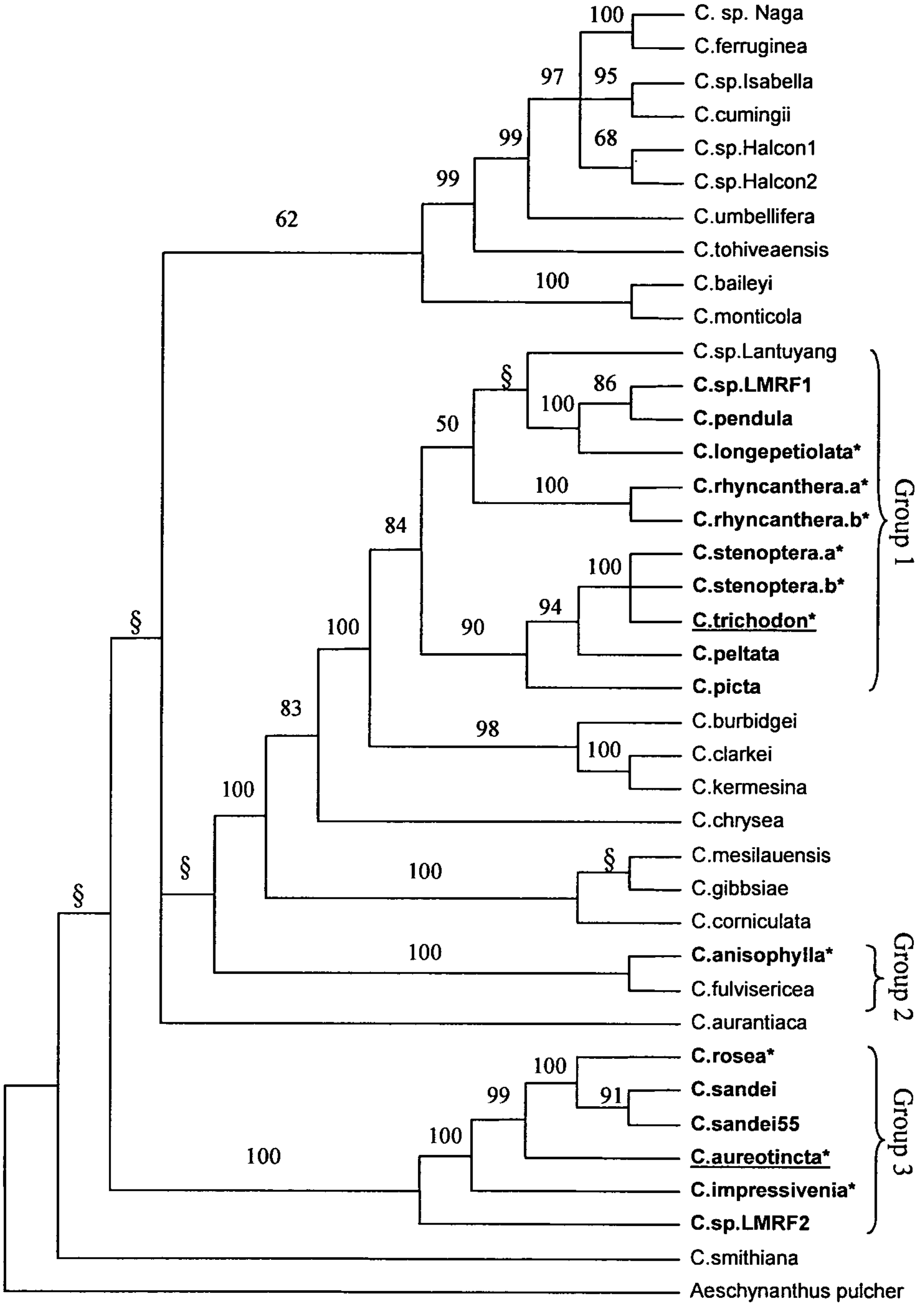


Figure 3.4: ML tree. Values on nodes are the Bayesian majority rule consensus percentages. § denotes nodes that conflict with or are unsupported by the Bayesian analysis. Species from Sumatra are in bold; asterisks mark species from Mount Kerinci, those thought to be endemic to Mount Kerinci are underlined.

3.3.3 Estimated Ages of Lineages

To assess whether substitution rates in ITS are clock-like, a likelihood-ratio test (Felsenstein, 1981) that is twice the difference in log likelihood of branch lengths between a tree that is constrained by a molecular clock and a tree that is unconstrained, was carried out. The log likelihoods (3832.2 versus 3766.7) were significantly different, therefore the null hypothesis, that the data were constrained by clock-like change, was rejected with $p<0.005$. In a case such as this, where the molecular clock is rejected, algorithms that accommodate ancestor-descendant rate variation such as non-parametric rate smoothing (NPRS) (Sanderson, 1997) and penalized likelihood (Sanderson, 2002) are the preferred means of estimating ages for cladogram nodes. However, both require the calibration of at least one node on the tree using independent evidence such as fossils or geological events. Such evidence is not available for *Cyrtandra*, so these methods were not used.

Given the rejection of the molecular clock, the following approximate approach was taken. The generation time of taxa is the major determinant of the rate of accumulation of neutral mutations (e.g. Gaut *et al.*, 1992). I therefore suggest that a typical substitution rate for ITS in taxa with similar life histories to *Cyrtandra*, would be an approximate substitution rate for *Cyrtandra*. Such a typical rate for other herbaceous taxa is 5×10^{-9} substitutions per site per year, according to the available rate estimates summarised in Richardson *et al.* (2001), which range from 1.72×10^{-9} to 7.83×10^{-9} substitutions per site per year. Using this rate, the minimum ages for the three crown groups of Sumatran *Cyrtandra* were calculated by summing the minimum number of substitutions separating any two terminal taxa, as measured by parsimony branch lengths, via the most basal node of the clade. The maximum ages were calculated using exactly the same method, but using the maximum number of substitutions between any two terminal taxa via the most basal node of the clade. At the chosen substitution rate, the implied ages of the three crown groups of Sumatran *Cyrtandra* are as follows: group one 1.9-3.4 million years old; group two 6.6 million years old; group three 7.0-8.7 million years old. These dates can only be considered as extremely rough estimates, and are not integral to the hypotheses posed in this chapter, but nevertheless do provide support for a pre-Pleistocene start of diversification for the three lineages present on Mount Kerinci.

3.3.4 Morphological Characters and Phylogeny

Each group tends to have a typical morphology (figure 3.5). Group one is supported by the presence of astrosclereids in the mesophyll of the leaves of all of its members. Apart from *C. rhyncanthera* C.B.Clarke which has very thin leaves, group one species have thick mesophyll layers compared to the epidermis and hypodermis. The species also tend to be herbaceous in habit, with the exception of *C. stenoptera* and *C. trichodon*. Radiation within the group seems to have allowed the development of many morphological forms. For example, *C. pendula* Blume has flowers that are held on long trailing peduncles, *C. peltata* Jack has peltate leaves and *C. rhyncanthera* C.B.Clarke has creeping stems. All species bear fairly large (usually >3cm), predominantly white flowers.

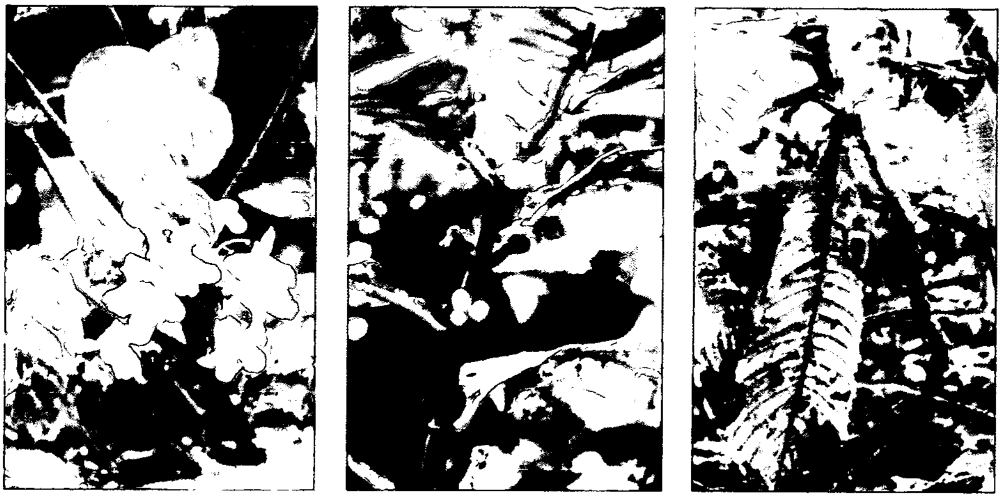


Figure 3.5: Representative species from each group of Sumatran *Cyrtandra*. Left = Group one: *C. longepetiolata* de Vriese; centre = group two: *C. anisophylla* C.B.Clarke; right = group three: *C. rosea* Ridl.

Group two is supported by a number of morphological characters: marked anisophylly in the leaves, a zygomorphic calyx with the upper three lobes united into chapter, but nevertheless do provide support for a pre-Pleistocene start of diversification for the three lineages present on Mount Kerinci.

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Group two is supported by a number of morphological characters: marked anisophylly in the leaves, a zygomorphic calyx with the upper three lobes united into a tridentate tip, the lower two being divided to the base, small rather fleshy white corollas and the species have very characteristic cells of the upper leaf epidermis which have a conical outer wall (Burtt & Bokhari, 1973). The sclereid pattern seems to vary: *C. anisophylla* has no sclereids, but *C. fulvisericea* has osteosclereids in the hypodermis and polymorphic sclereids in the mesophyll (Bokhari, unpublished note on specimen label (E)).

Group three is a group of woody Sumatran shrubs. No foliar sclereids appear to be present in the specimens examined except in *C. sandei* de Vriese, of which two accessions from West Sumatra are analysed here: this species has osteosclereids in the hypodermis. All the species have large hairy leaves with prominent venation with no distinct anisophylly. Flowers are small (usually 1.5 cm or less), hairy, and vary in colour from white to red or purple. They are usually enclosed in bracts.

3.4 DISCUSSION

3.4.1 Patterns of Evolution in Sumatran *Cyrtandra*

The phylogeny gives clear evidence to support the existence of three groups of Sumatran *Cyrtandra*, all of which occur on Mount Kerinci. It seems likely that these groups are the result of three independent developments since there are, at least within this sample, distinct morphological characters associated with each group, therefore giving confidence in the single locus molecular results. Each group and its characteristic features are discussed individually.

3.4.1.1 Group one: Sumatran species nested within a larger Bornean clade

Group one (eight Sumatran species) is suggested by the phylogeny (Figures 3.2, 3.3, 3.4) to form part of a large clade of Bornean species. Also present in this clade is one Philippine species (*C.* sp. *Lantuyang*). This species also fell in a Bornean clade in Atkins *et al's.* (2001) study.

All species appear to have astrosclereids present in the mesophyll of their leaves. Sclereids are thought to provide leaf rigidity and perhaps act as defence against herbivores. The fact that the sclereid pattern found in this group is the same in all species might suggest that this is a species group with a particular ecological uniformity (Bokhari & Burtt, 1970). This is supported by the herbaceous habit shared by the majority of the species; the exceptions, *C. stenoptera* and *C. trichodon*, are pole plants with stiff erect unbranched stems, enabling them to grow taller, presumably to increase gain of light.

It seems likely that group one, and the clade of Bornean species in which it is nested, would form part of a larger Bornean clade should the sampling of species be increased. This suggests that Sumatran and Bornean species of *Cyrtandra* are closely related. This may be the result of lowering of sea levels in intermittent periods from the Oligocene to the Pleistocene that allowed extensive land bridges to connect the now isolated areas of Sundaland (Hall, 1998; Morley & Flenley, 1987; Voris, 2000). Geographical separation due to sea level rises may have since furthered the radiation of *Cyrtandra* on each individual land area.

3.4.1.2 Group two: the anisophylla-fulvisericea *pair*

This pair belongs to a monophyletic group of *Cyrtandra* that can be defined by a number of morphological synapomorphies. It is a rare example (Burtt, 1990) of a group consistent with the last overall treatment of the genus (Clarke, 1883), corresponding to Clarke's section *Dissimiles* (11 species, chapter six). Its members have the characteristic calyx, corolla, and anisophyllous leaves described in the results.

It is interesting that group two (section *Dissimiles*) is unusually widespread in Sundaland. Furthermore, a number of the species in this group seem to have wide distributions and exist at low altitudes, e.g. *C. anisophylla* has been recorded between altitudes of 450 and 2000 m and is widespread in Sumatra. Most *Cyrtandra* species tend to occupy habitats above 1000 m, perhaps where the forest becomes slightly less dense and they are able to survive more successfully in the understorey layer. Two possible explanations could be advanced for the widespread distribution of species of section *Dissimiles*, i) occurrence at lower altitudes may allow a wider range; ii) dispersal of the fruit, which is unusually fleshy for western Malesian species, may be more effective.

3.4.1.3 Group three: the woody shrubs

This monophyletic group of Sumatran *Cyrtandra* appears to be a radiation of woody shrubs (sometimes pole plants). They seem to have evolved from a different lineage to the other groups of *Cyrtandra* found and from their morphology appear to be exploiting a different range of niches. Altitudinal range varies within the group, but tends to be 2000 - 2500 m.

It is expected, due to morphological similarities, that other accessions of species of Kerinci *Cyrtandra* that could not be sequenced (*C. patentiserrata* Bramley & Cronk, *C. ampla* C.B.Clarke, *C. flabelligera* Ridl.) would also fall in this clade.

3.4.2 Assembly of *Cyrtandra* Biodiversity on Mount Kerinci

All the three groups of Sumatran *Cyrtandra* identified here are found on Mount Kerinci. The *Cyrtandra* community on Kerinci is composed of species from three different phylogenetic lineages: there has been phyletic assembly rather than local diversification. Hypothesis two proposed that the Kerinci *Cyrtandra* community would have multiple origins, appearing in various clades in the phylogenetic tree. It also stated that there would have been an accumulation of diversity in many phylogenetic lineages over time as a result of these lineages co-occurring and ancient speciation. Whilst the results support the first statement, there is less evidence in support of the second statement. It seems that there have been differing degrees of speciation in each lineage, and diversity has not accumulated due to equal amounts of speciation within all the lineages. In group one, there has been some recent speciation as there are morphologically similar and closely related species e.g. *C. trichodon* and *C. stenoptera*. However, group two has shown no growth in terms of species numbers, with only one representative species on Mount Kerinci, and group three, for the most part, shows evidence of older speciation events, with species on much longer branches, with a greater amount of nucleotide substitutions between them, such as *C. impressivenia* and *C. aureotincta* Bramley & Cronk. The composition of the community therefore seems to be the result of a balance of not only ancient, but also recent speciation, but the recent speciation appears to have occurred in one lineage. Hypothesis one, which suggested that the *Cyrtandra* community on Mount Kerinci would be composed of one lineage that had undergone rapid and recent speciation, is not supported. However, if speciation continues to occur in group one only, the community may eventually become predominantly composed of one lineage.

3.4.2.1 Endemic species

The analysis included two species known only from Kerinci, *C. trichodon* and *C. aureotincta*. The results tend to suggest that one of these endemics is relatively recent and the other a member of an older lineage. In group one, the endemic *C. trichodon* is very closely related to *C. stenoptera*, which has a slightly wider range and has been collected on the neighbouring Mount Tudjuh. These species have only 1-6 mutations between them, and whilst it is possible to distinguish them morphologically, it is also obvious from their morphology that they are closely related. However, in group three, *C. aureotincta*, sister to *C. rosea*, is characterised by more nucleotide changes and a number of unique indel events. It also has a number of unique morphological characters such as a hairy disk, and may be a relict species. This single species lineage may be older than Mount Kerinci and is expected to occur (or to have occurred) elsewhere.

3.4.3 Origins of the *Cyrtandra* Community on Mount Kerinci

The rough estimates of the ages of these lineages indicated that the primary diversification of *Cyrtandra* was pre-Pleistocene. It therefore seems likely that the lineages are older than the volcano, which probably has a late Pliocene/Pleistocene origin. Many of the species present on Mount Kerinci are also present on other volcanoes such as Mt Singgalang (Bramley & Cronk, 2003) perhaps indicating that such areas were colonised by a similar *Cyrtandra* community.

Investigations involving palynological, geological, fossil and termite data (e.g. Flenley, 1979; Newsome & Flenley, 1988; Morley, 2000; Gathorne-Hardy *et al.*, 2002) have suggested that during Quaternary glaciations, the Barisan Mountain range remained an area of forest, acting as a rain forest refugium. The stable environment within this refugium is likely to have allowed the low extinction rates and gradual accumulation of species suggested by the museum hypothesis, resulting in the present-day assembly of the Kerinci *Cyrtandra* community, which is composed of different ancient lineages. Further evidence provided by these studies has suggested that montane forest migrated downhill during colder times in the Pleistocene, then gradually receded to higher levels, leaving higher altitude species confined to peaks. All of this evidence could explain the similarity of *Cyrtandra* species on the Barisan mountains, and perhaps also why the more widespread species, such as *C. anisophylla*, are those that are successful at lower altitudes.

3.4.3.1 Conservation

The identification of the three lineages of *Cyrtandra* on Mount Kerinci shows that the species in this community are diverse genetically, most probably due to the Barisan mountains acting as a rain forest refugium during Quaternary climate changes. Information such as this demonstrates the importance of refugia sites in providing long-term stability, and highlights the need to conserve them as modern rain forest refugia (Gathorne-Hardy *et al.*, 2002).

3.5 ADVANTAGES AND DISADVANTAGES OF THIS MOLECULAR PHYLOGENETIC APPROACH

The main benefit of this approach is that it enables us to investigate the assembly of a *Cyrtandra* community from a phylogenetic angle, and therefore to address bigger biological questions such as the evolution of local rain forest diversity. A further advantage is that historical explanations for present-day species compositions can be considered. It would not have been possible without the prior taxonomic account of the *Cyrtandra* species of Mount Kerinci (chapter two).

4 CHAPTER FOUR: THE GENUS *CYRTANDRA* (GESNERIACEAE) IN PENINSULAR MALAYSIA AND SINGAPORE

This chapter is the first of two taking a regional approach to the genus *Cyrtandra*. It is based on a taxonomic revision of the genus in Peninsular Malaysia and Singapore (Bramley *et al.* 2004b), with additional comments on the advantages and disadvantages of this approach. Unlike the other taxonomic revisions in this thesis (chapters two and six), this regional revision includes notes on the conservation status of each species treated due to the availability of more accurate information on species distributions.

4.1 INTRODUCTION

In Peninsular Malaysia *Cyrtandra* is surprisingly poorly represented. It has not diversified as in Borneo, where 120 species have been described, and the Peninsular Malaysian species are apparently the northwestern outliers of the genus. In his 'Flora of the Malay Peninsula', Ridley (1923) recognised 12 species. Burtt (1978) reduced two species and a variety, *C. grandiflora* Ridley, *C. pilosa* auct. non Blume and *C. decurrens* De Vriese var. *wallichii* C.B.Clarke, to synonymy under the name *C. wallichii*. *Cyrtandra grandiflora* is a homonym of *C. grandiflora* Gaudich and specimens described by Ridley as *C. pilosa* do not match Blume's (1826) Javan *C. pilosa*. Stone (1980) described *C. dispar* DC. var. *glabriflora* which Burtt (1990) raised to species rank as *C. stonei*, the epithet *glabriflora* having already been used for a Hawaiian species (St. John, 1987). These changes maintained the number of species recognised at 12. However, in Ridley's work, there is some confusion in the citing of specimens for particular species, for instance the same specimens are cited for *C. falcata* Ridl. and *C. suffruticosa* Ridl., and material cannot be found for others, for example *C. barbata* Ridl.. This, together with the examination of other specimens and experience in the field, has led here to the reduction of a further three Ridley species to synonymy.

4.2 KEYS AND DESCRIPTIONS

The following keys and descriptions present the nine *Cyrtandra* species here recognised as occurring in Peninsular Malaysia.

In the keys and descriptions:

i) Measurements are given for leaves presumed to be mature, and their shape is described following Hickey (1979).

ii) All measurements of floral characters were taken from herbarium material that had been rehydrated and softened in spirit, except for those species illustrated (collected by *Bramley et al.* in July 2002)

iii) All details of plant heights and colours in the descriptions are taken from the collection notes of *Bramley et al.*, or from observations or photographs of *Weber et al.*, unless stated otherwise.

iv) All locations follow the American National Imagery and Mapping Agency's (NIMA) GEOnet Names Server (http://164.214.2.59/gns/html/index.html). Thai specimens are cited for the rarer species only.

v) Descriptions of stigmas: in dry and rehydrated material stigma characters are difficult to see, nevertheless, there seem to be some interesting differences between the species. The following terms have been used to reflect the basic stigma structure (the lobes are always in median position, i.e. each carpel forms a lobe):

a) bilobed: when it is only possible to see that there are two lobes present;

b) semi-oval lobes; the whole structure is oval, but divided into two lobes;

c) two triangular lobes with pointed tips;

d) two triangular lobes with blunted tips;

e) two narrowly triangular lobes with pointed tips.

vi) All measurements refer to length unless stated otherwise.

vii) Certain species have characteristic fleshy protruberances on the bracts and calyx. I follow Ridley (1909) in his use of the term 'utricles' for these.

viii) *Cyrtandra* flowers are protandrous, therefore flowers examined are either immature, or in the male phase (the stamens not yet dehisced and gynoecium not at mature length), or the female phase (the stamens having recoiled back into the corolla tube after dehiscence, and the gynoecium at full length) of development.

Effort has been made to describe male and female organs when both mature, but when this was not possible it is noted.

ix) All specimens cited have been seen by the author, unless stated otherwise.

x) Where a date cannot be given for a particular specimen, '?' is used.

xi) Notes are included about the conservation status of each species.

xii) Distribution maps show all the specimens examined for each species, not just those that are cited after each description.

The first key includes both reproductive and vegetative characters, and can be used in the field for the identification of fertile plants. In the second key, the characters chosen are principally vegetative, and it can therefore be used to identify sterile plants and poor herbarium specimens.

GENERIC DESCRIPTION (for Peninsular Malaysian species only)

Cyrtandra J.R. & G.Forst., *Char. gen. pl.* 5 (1776).

Terrestrial (rarely epiphytic) perennial herbs, shrubs or small trees. *Leaves* simple, petiolate, opposite; the leaves in a pair being either equal (isophyllous), subequal, anisophyllous (one member of a pair very reduced in size), or one member reduced to a leafy scale so that the leaves appear alternate (pseudoalternate), or pseudodistichous, with the leaf blades of a stem or branch forming a single plane; the lamina hairy to glabrous above, the venation below often raised and hairy. *Inflorescence* usually in the upper leaf axils but occasionally cauliflorous (emerging from the axils of fallen leaves); sessile, subsessile or pedunculate; flowers one to many in pair-flowered cymes. *Bracts*[1] often enclosing inflorescence. *Calyx* five lobed, sometimes the lobes fused so that the tube appears bi- or tri-lobed, often hairy, persistent or caducous in fruit. *Corolla* tubular to funnel-shaped, limb zygomorphic, five-lobed, lobes often subequal, but the two upper lobes usually distinguishable from the three lower; white but more rarely pale yellow or with a greenish or pinkish tint, the throat often marked with yellow, red, brown or purple. *Fertile stamens* 2. *Staminodes* 3. *Ovary* superior, hairy or glabrous; placentation parietal; style glabrous

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[1] The term 'bracts' is used here for the first pair of bracteoles (prophylls) of the axillary cyme. In *Cyrtandra* these are usually more prominent than the subsequent bracteoles.

or with glandular or eglandular hairs, stigma with two median lobes. *Disk* cupular or unilateral. *Fruit* a hard (sclerocarpous) or fleshy berry, often tipped by the persistent stylar beak.

ETYMOLOGY. The generic name is derived from 'kyrtos', greek. = curved, and 'andros', greek. = male, apparently referring to the spiral filaments that recoil back into the corolla after anther dehiscence.

4.2.1 Key One (based on vegetative and floral characters)

1a. Leaves pseudoalternate or pseudodistichous, one member of a pair reduced to a rudiment..2

1b. Leaves anisophyllous, one member of a pair developing to less than half the size of the fully developed member..3

1c. Leaves isophyllous or subisophyllous, both members of a pair approximately the same size, sometimes one member slightly reduced..4

2a. Leaves narrow to wide ovate or elliptic, petioles 8 - 20 cm long, inflorescence borne on a downcurving peduncle 2 - 20 cm long..................................**5. C. pendula**

2b. Leaves elliptic to narrow elliptic to obovate, petioles 1.5 - 3 cm long, inflorescence subsessile, peduncle upright..**8. C. dispar**

3a. Terrestrial sub-shrub, the developed leaf in a pair, narrow elliptic to oblanceolate, glabrous; bracts narrow ovate to lanceolate, glabrous; calyx zygomorphic, the upper three lobes fused to form a 3-toothed upper lip, the lower two divided to the base...**7. C. stonei**

3b. Sub-shrub, sometimes epiphytic, the developed leaf in a pair, oblong to narrow or very narrow elliptic, (sub)falcate, with scattered hairs, bracts wide ovate, hairy; calyx very reduced (c. 2 mm), the lobes reduced to five small teeth..**6. C. suffruticosa**

4a. Inflorescence on a peduncle 2 - 20 cm long.......................................**5. C. pendula**

4b. Inflorescence on a peduncle less than 2 cm, subsessile or sessile........................5

5a. Bracts connate for at least 0.5 cm..6
5b. Bracts free...7

6a. Bracts usually 3 - 6 cm, forming a wide, white cup, sparsely to densely hairy, corolla glabrous, white with pink to brown mark in the throat...............**1. C. cupulata**
6b. Bracts usually 2 - 4 cm, connate for 0.5 cm, purple or green, glabrous or with small 1-2 mm utricles, corolla silky hairy, white with purple spotting in the throat...**2. C. wallichii**
7a. Inflorescence at the base of the stem..**4. C. lanceolata**
7b. Inflorescence on leafy shoots...8

8a. Leaf margin entire, corolla mostly glabrous...............................**6. C. suffruticosa**
8b. Leaf margin serrate or biserrate, corolla hairy..9

9a. Leaves oblanceolate, decurrent to the stem, margin serrate, corolla white with two purple bars in the throat...**3. C. gimlettei**
9b. Leaves obovate or narrow elliptic, on petioles 2-3 cm long, margin biserrate, corolla off-white with a brown marking in the throat................................**9. C. patula**

4.2.2 Key Two (based on leaf characters, especially for use in the herbarium)

1a. Leaf margins entire...**6. C. suffruticosa**
1b. Leaf margins to some degree serrate, biserrate or crenate-serrate.........................2

2a. Leaf margins biserrate (especially in leaves of young plants)...............................3
2b. Leaf margins serrate or crenate-serrate...4

3a. Leaves pseudodistichous, one member reduced to a rudiment; bark flaky..**8. C. dispar**
3b. Leaves in a pair, equal or subequal; bark more or less smooth............**9. C. patula**

4a. Leaves in a pair, anisophyllous or pseudoalternate..5
4b. Leaves in a pair, equal or subequal..6

5a. Petiole 8 - 20 cm, the fully developed leaf of a pair narrow to wide ovate or elliptic...**5. C. pendula**
5b. Petiole 3- 4 cm, the fully developed leaf of a pair narrow elliptic to oblanceolate...**7. C. stonei**

6a. Leaf base decurrent, up to 1.5 cm wide either side of the petiole at the stem, sometimes partly covering the leaf axil, overlapping with the opposite leaf base.......7
6b. Leaf base sometimes forming a narrow wing down the petiole, or acute.............9

7a. Leaf margin with shallow serrations, leaves less than 25 cm long..**3. C. gimlettei**
7b. Leaf margin distinctly serrate, leaves up to 40 cm long.......................................8

8a. Leaf apex acuminate; bracts connate, white, forming a wide cup, up to 6 cm long, sparsely to densely hairy...**1. C. cupulata**
8b. Leaf apex acute or shortly acuminate; bracts connate for 0.5 cm, purple or green, up to 4 cm long, sometimes with 1 - 2 mm utricles................................**2. C. wallichii**

9a. Petioles 8 - 20 cm; leaves narrow to wide ovate or elliptic...............**5. C. pendula**
9b. Petioles less than 6 cm; leaves narrow elliptic, elliptic, obovate or oblanceolate...10

10a. Inflorescence axillary; leaf margins serrate....................................**1. C. cupulata**
10b. Inflorescence at the base of the stem; leaf margins crenate-serrate..**4. C. lanceolata**

1. **Cyrtandra cupulata** Ridl. J. Linn. Soc. 32: 527 (1896). Type: Peninsular Malaysia, Pahang, Tahan Woods, Aug. 1891, *Ridley* 2150 (lectotype: K [chosen here]; isolectotypes: BM, SING). *Cyrtandra barbata* Ridl. J. Straits Branch Roy. Asiat. Soc. 57: 75 (1910). Type: Peninsular Malaysia, Perak, Temengoh, *Ridley* s.n. (not seen, loc. unknown). Syn.: *Cyrtandra cupulata* var. *minor* Ridl., Fl. Malay Penins. 2: 547 (1923). Type: Peninsular Malaysia, Kelantan, by the river at Chaning and Kwala Lebir, 6 ii 1917, *Ridley* s.n. (K).

Shrub, c. 1 - 1.2 m, stems usually unbranched, with dense, coarse, brown hair when young, becoming woody and usually less hairy with age, although sometimes the hair remaining dense, especially around the leaf axils. *Leaves* opposite and isophyllous, on hairy petioles 1 - 4 cm long, or lamina decurrent to the stem, or the lamina forming a narrow wing down the petiole to the stem; lamina dark glossy green with a pale green underside, elliptic, narrow elliptic, obovate or narrow obovate, 18 - 35 x 4 - 13 cm, sometimes asymmetric about the midrib, apex acuminate, base acute where not decurrent, margin serrate, the serrations sometimes with hooked hairy tips; upper surface with coarse, red-brown hair when young, this hair becoming sparse with age; the lower surface sometimes with tiny pustules, red-brown hairy, all veins raised, densely hairy; lateral nerve pairs 8-12. *Inflorescence* axillary, shortly pedunculate, with up to 10 flowers. *Bracts* pale green when young, maturing to bright cream or white, up to 6 cm long, connate for most of their length to form a cup containing the flowers, the tips acuminate, the surface sparsely to densely hairy, margin serrate. *Bracteoles* c. 4 cm, white, serrate, hairy. *Peduncle* 0.5 - 1.5 cm long, hairy. *Pedicels* less than 0.5 cm long, hairy. *Calyx* white, c. 2 cm long, externally with occasional hairs near lobe tips, internally with scattered papillae; tube c. 1.5 cm, bilobed, lobes triangular with rounded tips. *Corolla* white with a pink to brown marking in the throat, c. 3 - 3.5 cm, funnel shaped, broadening towards the mouth, the two upper lobes 8 x 8 mm, the three lower 7 x 7 mm; outer and inner surfaces glabrous. *Filaments* white, c. 1 cm, the connective fringed with glandular hairs. *Anthers* c. 2 mm. *Gynoecium* c. 2.5 cm long, the ovary with a collar of glandular hairs at its tip (at the base of the style), the style with glandular hairs, stigma bilobed, the two lobes bluntly triangular. *Disk* c. 2 mm, cupular, margin undulate or dentate. *Fruit* green, 1.2 - 2 x 0.3-0.5 cm, narrow and curved, or shorter and straighter, tapered towards the apex, warty, sometimes with a tuft of hair at the tip (the remains of the collar of hair at the top of the young ovary); bracts, calyx and style caducous. (Figure 4.1).

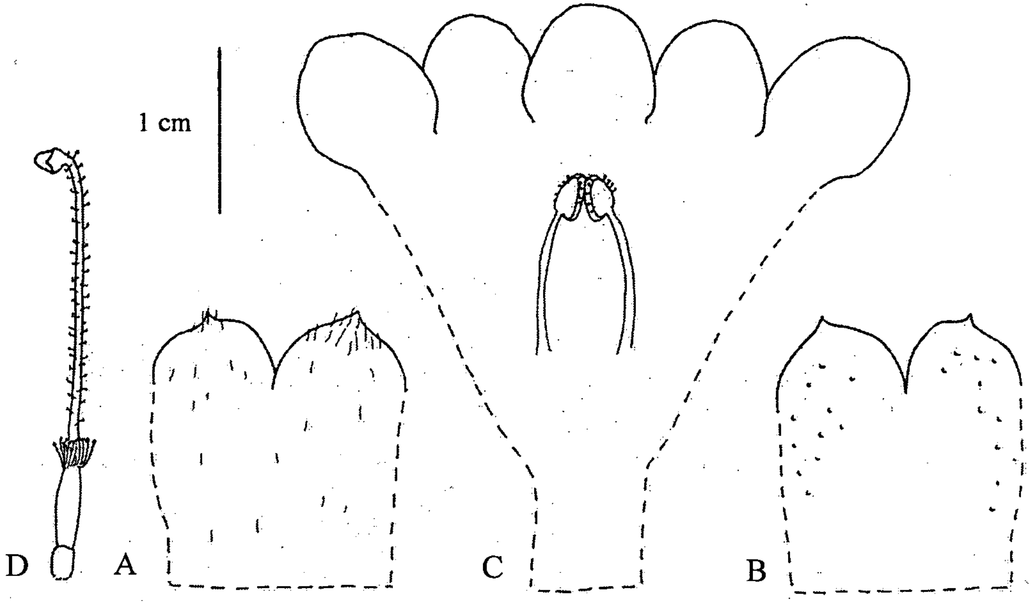

Figure 4.1. A-D. *Cyrtandra cupulata* Ridl.: A, calyx, dissected ventrally, outer surface; B, calyx, dissected ventrally, inner surface; C, corolla, dissected dorsally, showing stamens; D, gynoecium and disk. Drawn from Bramley *et al.* GB28.

ETYMOLOGY. 'cupulatus' = cup-shaped, referring to the axillary inflorescences with two large fused bracts embracing the flower cluster.

ECOLOGY. Lowland and hill forest; 0 – 1000m.

DISTRIBUTION. Peninsular Malaysia, southern Thailand. (Figure 4.2).

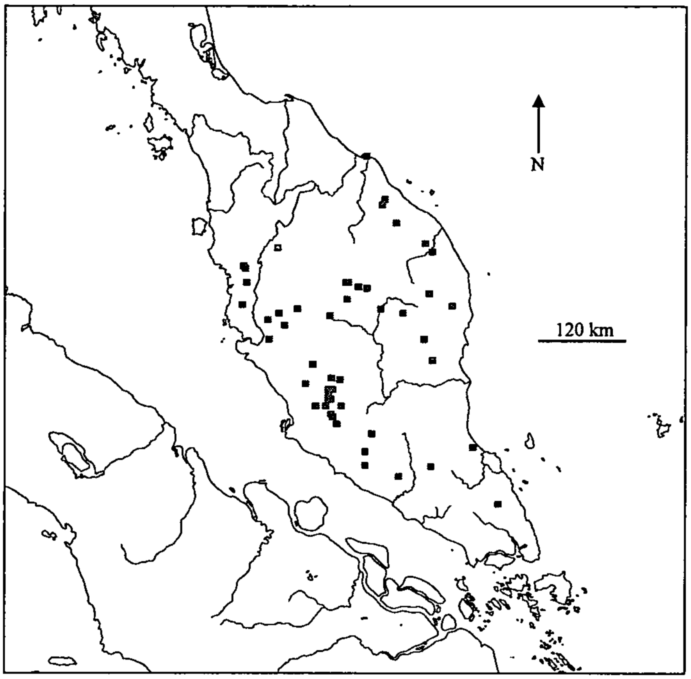

Figure 4.2. *Cyrtandra cupulata* Ridl. distribution map

SELECTION OF SPECIMENS EXAMINED:

Vegetatively, *C. cupulata* is very variable, especially in lamina shape and petiole development. The degree of hairiness of leaves, stems and bracts also differs markedly between specimens, as does the fruit shape. To represent this considerable morphological variation, the specimens are cited under five informal groups (table 4.1).

Table 4.1: Summary of the morphological characteristics of the five informal groups of *C. cupulata*.

Group 1	Stems, leaf axils and bracts are densely clad with brown hairs, the hairs often quite long (3 - 4mm) and upcurved. The bracts are usually less than 3cm.
Group 2	The stems have brown hair concentrated at their tips and sometimes in leaf axils, but the hair is never long and dense. The leaf shape is variable, the upper surface of the lamina subglabrous, and the lower surface of the lamina with red-brown hair on the venation. The bracts are large, usually between 3 - 6cm, and have some hair on the outside,

	but this is not dense.
Group 3	The fruits are smaller and narrower, c. 1.5 - 2 × 0.2cm, and are more clustered, and on longer pedicels, c. 0.5 cm long. The leaves are often winged to the stem. Like group one, the stems and bracts are very densely hairy.
Group 4	Stems and bracts are hairy to densely hairy. The bracts are no longer than c. 3cm, and the fruit shorter, straighter and broader than the other groups, measuring 1 - 1.5 × 0.5cm.
Group 5	The plants are smaller, and more slender, with subglabrous leaves and little hair on the stems. The bracts are also smaller, up to c. 3cm long, and the leaves c. 12 - 26 × 3.5 - 8cm, on c. 1cm petioles. Ridley (1923) noted that the flower is pure white, with no brown marking in the throat like that found in *C. cupulata*, but this has not been observed in this study.

Group 1 (includes type): north of Pahang, and in Perak, Kedah and Kelantan. PENINSULAR MALAYSIA: Pahang, Teku river, Gunung Tahan, 21 vi 1922, *Haniff & Nur* SFN8056 (SING); Kelantan, Kuala Krai, 23 i 1923, *Haniff & Nur* SFN10133 (SING); Kelantan, Kuala Relai, 31 i 1923, *Haniff & Nur* SFN10226 (SING); Pahang, Tembeling, 13 vii 1929, *Henderson* SFN21847 (BM, SING); Kelantan, Gua Musang-Kuala Betis track, 14 vii 1935, *Henderson* SFN29653 (SING); Kedah, Gunung Lang, 25 iii 1938, *Kiah* SFN 35050 (BM, K, L, SING); Pahang, Sungai Tahan, 19 vii 1936, *Kiah* SFN31729 (SING); Perak, Larut, [500 ft] 150 m, vii 1881, *King's Collector* 2057 (SING); Kedah-Perak, Gunung Bintang, *Nat. Coll. FMS Mus.* 13028 (SING); Pahang, Kuala Tahan, [350 ft] 100 m, ii 1921, *Seimund* 946 (SING); Pahang, Ulu Sungai Tembeling, 6 iii 1968, *Shah* MS1585 (E, K, L, SING); Pahang, Ulu Sungai Tembeling, 6 iii 1968, *Shah* MS1585 (E, K, L, SING); Pahang, Kuala Teku, [500 - 1000 ft] 150 - 300 m, 5 viii 1905, *Wray & Robinson* 5540 (BM, K, SING).

Group 2: the most common form of *C. cupulata*. This extends much further south than Group 1, to the states of Selangor and Negeri Sembilan.

PENINSULAR MALAYSIA: Selangor, Kanching Forest Reserve, 140 m, 17 vii 2002, *Bramley et al.* GB28 (E, K, KEP, L); Selangor, Ulu Gombak, 520 m, 19 vii 2002, *Bramley et al.* GB29 (E, K, KEP, L); Terengganu, Gunung Lawit, [1000 - 2000 ft] 300 - 600 m, 1 iv 1970, *Davidson* 1303 (L); Pahang, Bukit Chintamani, Bentong, 4 x 1931, *Henderson* SFN25042 (K, SING); Negeri Sembilan, Senaling Inas Forest Reserve, 28 xi 1922, *Holttum* 9776 (SING); Negeri Sembilan, Gunung Tampin, 22 xi 1922, *Holttum* 9538 (SING); Pahang, Bentong, Sungai Telom, [c. 500 ft] 150 m, 30 viii 1930, *Kiah & Strugnell* SFN24009 (SING); Selangor, 16th Mile Ulu Gombak, [1000 ft] 300 m, 24 x 1937, *Nur* SFN34209 (SING); Negeri Sembilan, Bukit Tangga, 19 xii 1920, *Ridley* s.n. (K); Perak, Maxwell's Hill, [c. 2600 ft] 800 m, 16 ix 1949, *Sinclair & Kiah* SFN38781 (SING).

Group 3: represented by fewer specimens than Groups 1 or 2. Its distribution is northern.
PENINSULAR MALAYSIA. Kelantan, Bukit Batu Papan, Sungai Lebir, [500 ft] 150 m, 6 vii 1935, *Henderson* 29582 (SING); Pahang, Sungai Merapoh, 2 ii 1924, *Nur & Foxworthy* 11928 (SING); Perak, Tapah, xi 1908, *Ridley* s.n. (SING).

Group 4: distributed in the southernmost states of Johore and Malacca.
PENINSULAR MALAYSIA. Malacca/Johore, Bukit Besar Ophir, xii 1898, *Ridley* 10086 (SING); Johore, Ulu Sungei Segamat, [1000 ft] 300 m, 17 ii 1972, *Samsuri & Shukor* SA680 (SING).

Group 5: represents specimens referrable to *C. cupulata* var. *minor* Ridl.. So far recorded from Kelantan only.
PENINSULAR MALAYSIA. Kelantan, Gua Ninik, 26 x 1927, *Henderson* 19685 (SING); Kelantan, Chaning, 6 ii -, *Ridley* s.n. (K, type of var. *minor*); Kelantan, Kelantan river, 1 ii 1917, *Ridley* s.n. (K).

CONSERVATION STATUS. *C. cupulata* has a wide distribution and is common, so it can be assumed to be at low risk. However, if subspecies or varieties are recognised in this complex, some could have restricted distributions and might be vulnerable.

NOTES. *Cyrtandra cupulata* is easily recognised by its striking white bracts, fused to form a cup containing the flowers. The cup often fills with water causing the flowering material to rot into a mucilage; the role of this mucilage, and whether it confers any benefit, is not known. Within the bracts one is able to find many larvae and mites, and *Drosophila* are commonly seen around the inflorescence. The bracts dry out and fall before fruiting.

A shortage of specimens in good reproductive condition makes recognising formal infraspecific taxa subjective, and in addition, the variation is highlighted here is continuous. Future collection may allow new varieties or subspecies to be described.

C. cupulata var. *minor* Ridl. is here reduced to synonymy, and included as one of the five informal groups within *C. cupulata.*

In addition, *Cyrtandra barbata* Ridl. is reduced to synonymy for a number of reasons. The features highlighted by Ridley (1910) (abundant and dense red-brown hair on the bract, calyx and veins) fall with certainty within the variation found in *C. cupulata*, and indeed match with Group 1, which contains the type specimen. Ridley described *C. barbata* as having white cupular bracts, similar to those of *C. cupulata*, and the entity he described as *C. barbata* may since then have been identified as *C. cupulata*, although no specimens with leaves as small as described by Ridley (5 by 3 inches) have been found.

2. Cyrtandra wallichii (C.B.Clarke) B.L.Burtt, Notes Roy. Bot. Gard. Edinburgh 36(1): 179 (1978). Type: Peninsular Malaysia, Penang, 1830, *Wallich* Numer. list 807 (holotype: K; isotype WU!). Syn.: *C. decurrens* de Vriese var. *wallichii* C.B.Clarke in A. & C.DC., Monogr. phan. 5: 232 (1883). Type as above.

C. grandiflora Ridl., J. Fed. Malay States Mus. 4: 52 (1909) - non Gaudich. *C. pilosa* auct. non Blume; C.B.Clarke in A & C.DC., Monogr. phan. 5: 232 (1883), pro parte; Ridl., Fl. Malay Penins. 2: 546 (1923). Type: Pahang, Telom, *Ridley* s.n. (K, SING).

Shrub, up to c. 1.5 m, unbranched; stems woody, glabrous, often distinctively scarred where leaves have fallen. *Leaves* opposite and isophyllous or subisophyllous, lamina fleshy, often with purple colouring underneath, decurrent to the stem, forming a wing up to 1.5 cm wide either side of the petiole, 16 - 40 x 3.5 - 12 (including the 4 - 7 x 1 - 1.5 cm narrower wing along petiole), narrow elliptic to oblanceolate, apex acute or shortly acuminate, base decurrent, the lamina often wide enough to overlap with the base of the opposite leaf, almost sheathing the axil; margin serrate, the serrations sometimes with tufts of hair at their tips; the upper surface subglabrous to hairy; the lower surface glabrous or with varying amounts of hair on the veins and the lamina, the lateral nerve pairs and midrib raised, the midrib thickened at the base causing it to curve outwards from the stem; lateral nerve pairs 8 to 12. *Inflorescence* axillary, shortly pedunculate, flowers 4 or more. *Bracts* green to purple, 2 - 4 x 1.5 - 3 cm, in a pair and connate for c. 0.5 cm, ovate, apex acuminate, margin irregularly serrate, outer surface subglabrous to hairy, sometimes with scattered c. 1 - 2 mm utricles, inner surface with long adpressed hairs. *Bracteoles* c. 1 x 0.4 cm, narrow ovate, hairy. *Peduncles* c. 0.5 cm. *Pedicels* 3 - 5 mm. *Calyx* c. 2 - 2.3 cm, externally with scattered hair and sometimes c. 1 - 2 mm utricles concentrated on the upper part of the lobes and the lobe tips; internally with dense long hair; tube c. 1 cm, bilobed, the lobes rounded with c. 5 mm acuminate tips, or the corolla breaking through one side leaving the lobes and lobe tips still joined on the other side. *Corolla* white with purple dots in the throat, 3 - 4 cm, funnel shaped, the upper two lobes 1.2 - 1.5 x 0.8 - 1.1 cm, erect and divided for 0.5 - 0.8 cm, the lower three lobes spreading 1 - 1.2 x 0.6 - 1 cm; outer surface with dense silky hair, inner surface with stalked glands on the upper two lobes and some of the upper part of the throat, otherwise glabrous. *Filaments* white, c. 12 mm, thickened to form a darkened knee at c. 4 mm from the base, glabrous. *Gynoecium* 2 - 3 cm, ovary glabrous except for a collar of hairs at its tip (at the base of the style), style with glandular hairs, stigma bilobed, the lobes blunt rounded triangles. *Disc* c. 2 mm, cupular. *Fruit* brown, 1.5 - 2.5 x 0.6 - 1.2, ovoid, warty, calyx and style caducous. (Figure 4.3).

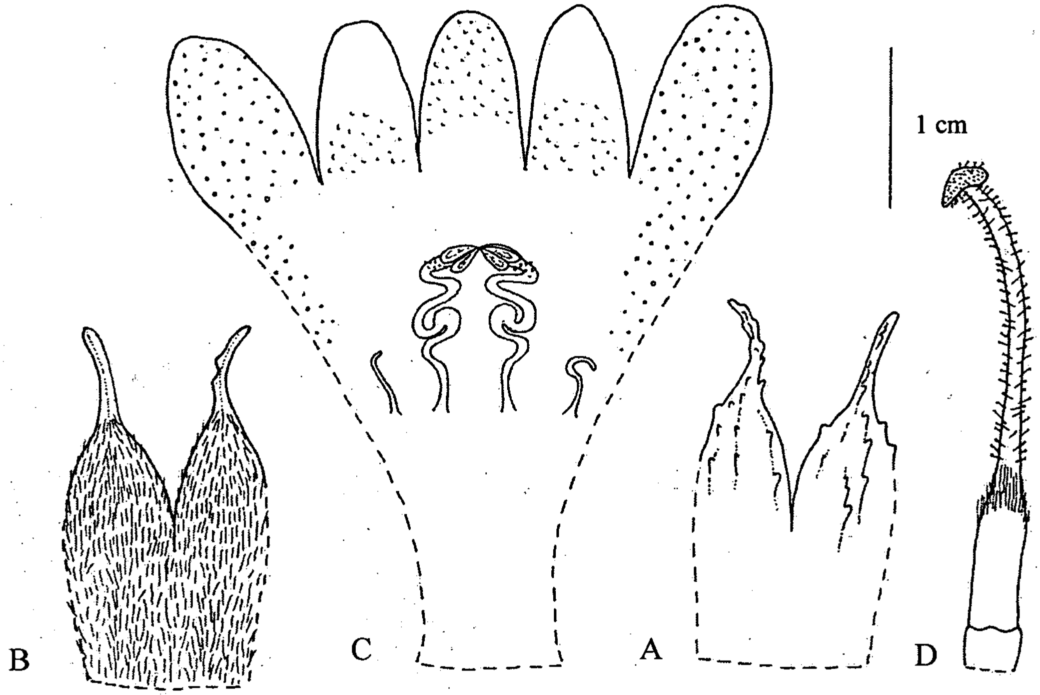

Figure 4.3. A-D. *Cyrtandra wallichii* (C.B.Clarke) B.L. Burtt: A, calyx, dissected ventrally, outer surface; B, calyx, dissected ventrally, inner surface; C, corolla, dissected dorsally, showing stamens with thickened knee; D, gynoecium and disk. Drawn from Bramley *et al.* GB26.

ETYMOLOGY. The specific epithet commemorates Nathaniel Wallich (1786-1854), a distinguished Danish botanist, working in India, Nepal and the Malay Peninsula; he was the collector of the type specimen.

ECOLOGY. In primary (often slightly disturbed) lowland and hill forest; 0 – 1000 (-1500) m.

DISTRIBUTION. Peninsular Malaysia, southern Thailand. (Figure 4.4).

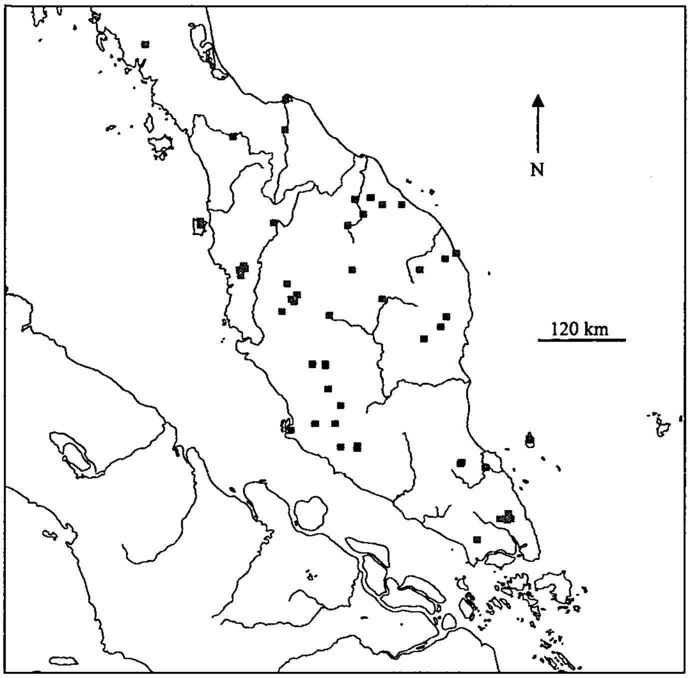

Figure 4.4. *Cyrtandra wallichii* (C.B.Clarke) B.L.Burtt distribution map

SELECTION OF SPECIMENS EXAMINED.

Specimens are cited under informal groups to highlight the variation within *C. wallichii* between its more common form (group one) and its 'pilosa' form (group two).

Group one: this includes the majority of the specimens examined and also the plants seen in the field. Characteristic to this group are quite large, utricular bracts and a calyx which also bears some utricles. Further explanation is given in the notes. PENINSULAR MALAYSIA: Selangor, Ulu Semangkok, c. 600 m, 16 vii 2002, *Bramley et al.* GB25, GB26 (E, K, KEP, L); Selangor, Awana Eco park, 770 m, 29 vii 2002, *Bramley et al.* GB35 (E, KEP); Pahang, Cameron Highlands, Jungle Trail 9, 1280 m, 27 vii 2002, *Bramley & Neale* GB33 (E, K, KEP, L); Terengganu, Jeranggau forest reserve, 30 iii 1957, *Chew* CWL75 (K); Penang, Penara Bukit, x 1886, *Curtis* 1018 (K, SING); Pahang, Pulau Tioman, Sungei Ayer Besar, [1000 ft] 300 m, 9 iv 1962, *Kadim & Noor* KN518 (L); Johore, Sungai Kayu, 26 x 1936, *Kiah* SFN32181 (BM, K); Negeri Sembilan, Bukit Tangga, 1903, *Napier* s.n. (SING); Negeri Sembilan, Gunung Angsi, [2000 ft] 600 m, 20 xi 1923, *Nur* 11551 (SING);

Johore, Gunung Pulai, xii 1904, *Ridley* s.n. (SING); Pahang, Telom, xi 1908, *Ridley* 13673 (BM, SING); Perak, Gunung Bujang Melaka, [c. 2000 ft] 600 m, 12 ii 1975, *Shah & Shukor* MS3403 (SING); Kelantan, Bukit Baka Forest Reserve, 500 m, 2 vi 1982, *Stone, Chin et al.* 15271 (L).

Group two ('PILOSA'): specimens is this group represent the 'pilosa' form of *C. wallichii* s.l.. The plants are much more slender and smaller in stature than those of group one. Bracts are smaller and not utricular, and the calyx also bears no utricles. Specimens with good flowering material are scarce, but one recently collected specimen (*Sam* FRI44491) with flowering material preserved in spirit suggests more evidence that this group may be distinct to *C. wallichii* s.s.

PENINSULAR MALAYSIA. Pahang, Cameron Highlands, rd down Gunung Brinchang, 1755 m, 26 vii 2002, *Bramley & Neale* GB32 (E); Pahang, Bentong, 7 xi 1924, *Burkill & Haniff* 16670 (SING); Terengganu, Gunung Padang, Ulu Tersat, [3800 ft] 1150 m, vi 1937, *Moysey & Kiah* SFN33945 (SING); Penang, Penang Hill, [1800 ft] 550 m, 24 ix 1941, *Nauen* s.n. (SING); Perak, Gunung Kerbau, [1000 ft] 300 m, 25 iii 1913, *Robinson* s.n., (BM); Kelantan, Nengirri Forest Reserve, Gua Musang, 350 m, 1 x 2002, *Sam* FRI44491 (KEP).

CONSERVATION STATUS. Widespread, therefore not likely to be at risk.

NOTES. Material of *Cyrtandra wallichii* was originally determined as *C. pilosa* Blume by Ridley, and is still generally referred to as *C. pilosa* in the Malaysian literature. However, Burtt (1970, 1978) noted that true *C. pilosa*, from Java, is a different species: 'the stem of the Javanese plant being more slender, the internodes longer, and the bracts of the inflorescence smaller than in most material in the Malay Peninsula'. Clarke (1883) had earlier recognised Peninsular Malaysian material as *C. decurrens* var. *wallichii.* Though *C. decurrens* is related, it is different from the Peninsular Malaysian species. *Cyrtandra decurrens* is smaller and differs in having a very densely long pilose style (Burtt, 1978). Ridley (1909) also described a *C. grandiflora*, but this is a homonym of *C. grandiflora* Gaudich.; Burtt (1978) therefore raised Clarke's var. *wallichii* to species rank, and reduced *C. pilosa* (auct. non Blume), *C. decurrens* var. *wallichii*, and *C. grandiflora* Ridl. to synonymy.

The description given here is based on the majority of specimens (Group 1), relating to Ridley's *C. grandiflora* in their utricular bracts and broad corolla. However, there is considerable variation in the leaf shape, degree of lamina decurrence and hairiness. There are specimens more similar to Ridley's description of *C. pilosa*; these are usually smaller and more slender than *C. grandiflora* Ridl. and do not have utricular bracts. These specimens are cited here under 'pilosa' (Group 2), but are mostly sterile and do not provide sufficient evidence to split *C. wallichii*. Therefore, *C. wallichii* remains a large and variable species until more thorough fieldwork can be carried out.

In his notes on *C. wallichii*, Burtt (1978) described the style as glabrous apart from a few scattered hairs towards the top. In all material I examined, the style is covered with glandular hairs, and the ovary topped with a collar of eglandular hairs. *Cyrtandra wallichii* is affiliated to a Bornean group of species including *C. erectipila* B.L.Burtt and *C. cuprea* B.L.Burtt (see chapter five; Burtt, 1978).

3. Cyrtandra gimlettei Ridl., J. Straits Branch Roy. Asiat. Soc. 49: 21 (1908).
Type: Peninsular Malaysia. Kelantan, Kwala Lebir, s.dat., *Gimlette* s.n. (SING).

Herb, stem shortly hairy in younger parts, becoming woody at the base. *Leaves* opposite and subequal, with one member of a pair sometimes slightly shorter than the other, usually decurrent to the stem, sometimes with a short petiole c. 1.5 cm long; lamina oblanceolate, 8.5 - 25 x 4 - 8 cm, apex rounded with a short acuminate tip, base decurrent, sometimes up to c. 0.5 cm either side of the midrib, somewhat sheathing the leaf axil; the upper surface hairy, the hairs erect with thickened bases; the lower surface covered with short erect hairs, especially dense on the venation, margin shallowly serrate. *Bracts* c. 1 cm long, ovate, whitish, hairy. *Inflorescence* axillary, almost sessile. *Peduncles* if present less than 3 mm long. *Pedicels* 2 - 4 mm, hairy. *Calyx* c. 1 cm long, bilobed, divided to approximately one third of its length, externally hairy, internal surface not seen. *Corolla* c. 2 cm, creamy-white with deep purple blotching ending in two purple bars on the lower lip (Ridley, 1908), outer surface with silky hairs, inner surface papillose and with scattered hair on the lobe surface. *Filaments* not seen, purple (Ridley, 1908). *Anthers* not seen. *Gynoecium* c. 1.5 cm, style with glandular hairs. *Disk* not seen. *Fruit* c. 0.8 - 1.5 x 0.3 - 0.4 cm, narrow ovate, warty, style semi-persistent leaving a short beak, c. 2 - 3 mm.

ETYMOLOGY. Named after J.D. Gimlette (1867-1934), member of the Duff Company, plant collector and author of papers and books on Malayan medicinal plants.

ECOLOGY. Probably mainly lowland forest, to 550m.

DISTRIBUTION. Peninsular Malaysia (Perak, Kedah, Kelantan), southern Thailand. (Figure 4.5).

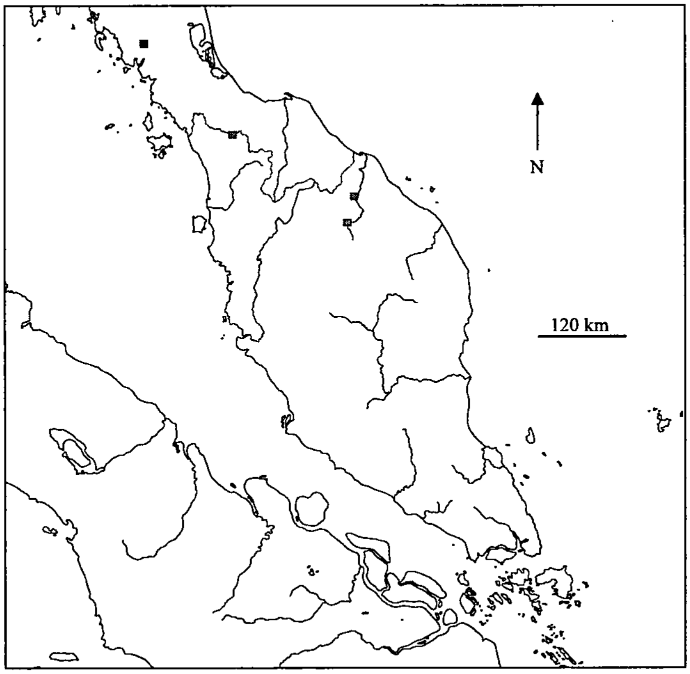

Figure 4.5. *Cyrtandra gimlettei* Ridl. distribution map

SPECIMENS EXAMINED.

PENINSULAR MALAYSIA: Kelantan, Pergau, 550 m, 7 x 1992, *Karim & Shah* NK48 (SING); Kedah, Koh Mai forest reserve, 2 iv 1938, *Kiah* SFN35130 (BM, SING); Kelantan, Kuala Sameh, 23 ii 1924, *Nur & Foxworthy* s.n. (SING); Kelantan, 15 vi 1908, *Ridley* s.n. (K); Perak, Kuala Lebir, ii 1917, *Ridley* s.n., (K); Kelantan, Kampong Gobek, Kerilla est., 28 ii 1959, *Shah & Kadim* MS472 (L, SING). THAILAND: Trang, Khao Soi Dao, 27 iv 1930, *Kerr* 19155 (BM); Phangnya, Takua Pa, 17 ii 1929, *Kerr* 17122 (BM); Phangnya, Khao Katakwam?, 400 m, 7 iii 1930, *Kerr* 18410 (BM); Naratiwat, Sungei Kolok, Nikom Waeng, 1 iii 1974, *Larsen & Larsen* KL32786 (E).

CONSERVATION STATUS. Not widely collected, but the present collection details suggest a narrow distribution, restricted to the north of Perak, and Kedah and Kelantan and therefore *C. gimlettei* could be vulnerable.

NOTES. *C. gimlettei* is found only in the northern states of Peninsular Malaysia and its range extends over the border into southern Thailand. Its closest relative is *C. wallichii* s.l.. *Cyrtandra gimlettei* can be recognised by its smaller stature, less distinctively serrate leaf margins, and the indumentum of the lamina, which is much shorter, erect and dense than that of *C. wallichii*. In addition it has smaller white flowers with purple bars and blotching in the throat; *C. wallichii* has small purple dots towards the mouth of the corolla. It could perhaps be confused with the smaller 'pilosa' forms of the *C. wallichii* group but it is more hairy, and the flower markings are distinct.

4. Cyrtandra lanceolata Ridl., J. Linn. Soc. 32: 527 (1896). Type: Peninsular Malaysia, Johore, Gunung Panti, 8 xii 1892, *Ridley* s.n. (SING).

Herb, on creeping stem, the stem with short hairs when young, becoming woody towards the base, quadrangular. *Leaves* opposite and isophyllous, on petioles 2.5 - 5 cm long; lamina elliptic to narrow elliptic to oblanceolate, 14 - 25 x 5 - 8.5 cm, apex acute, base acute, margin shallowly crenate-serrate; upper surface hairy when young, becoming subglabrous; lower surface hairy when young, this hair remaining on the venation but becoming scarce on the lamina; lateral nerve pairs 9 - 12. *Inflorescence* at the base of the stem, in subsessile cymes of 4 or more flowers. *Peduncles* up to 5 mm. *Pedicels* 0.5 - 1 cm, hairy. *Bracts* small, lanceolate, hairy (Ridley, 1896). *Calyx* c. 15 mm, externally with short stiff hairs, internally with small papillae; tube c. 8 mm, trilobed, the lobes with narrow lanceolate tips. *Corolla* c. 4 cm long (lobes not seen intact), white with a yellow throat (Ridley, 1896) or cream with pink tinges on the lobes, lower lobes protruding more than upper, outer surface with short hair, inner surface papillose. *Filaments* c. 1 cm. *Anthers* c. 2 mm. *Gynoecium* c. 2.2 cm, ovary papillose/verrucose with a collar of hair at its tip, style with short hair, stigma bilobed. *Disk* c. 3 mm, cupular, irregular margin. *Fruit* c. 1 x 0.4 cm, narrow elliptic, verrucose, slightly hairy at the tip (the remains of the collar of hair at the tip of the young ovary).

ETYMOLOGY. 'lanceolatus' = lanceolate, like a lance; referring to the leaf shape.

ECOLOGY. Lowland (and hill?) forest; "among quartzitic rocks by stream" (*Corner* SFN30651).

DISTRIBUTION. Endemic to Peninsular Malaysia, Johore, Gunung Panti and Sungai Linggui. (Figure 4.6).

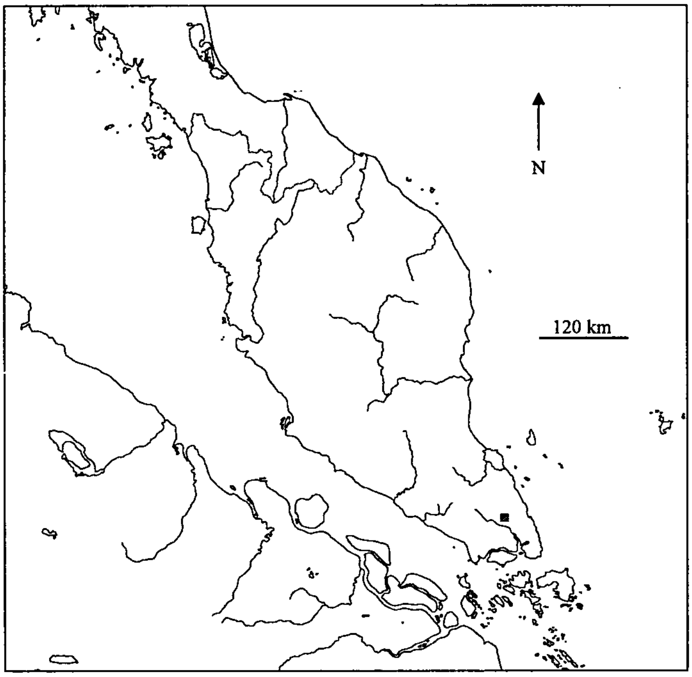

Figure 4.6. *Cyrtandra lanceolata* Ridl. distribution map

SPECIMENS EXAMINED.

PENINSULAR MALAYSIA: Johore, Ulu Segun, Gunung Panti, [500 ft] 150 m, 2 ii 1936, *Corner* SFN30651 (SING); Johore, Ulu Segun, Gunung Panti, 10 iv 1936, *Corner* s.n., (SING); Johore, Sungai Linggui, *Tay, Shah & Ali* 91-00049 (SING); Johore, Sungai Linggui, *Tay, Shah & Ali* 91-00059 (SING).

CONSERVATION STATUS. Endemic to Gunung Panti and Sungai Linggui, likely to be vulnerable.

NOTES. It must be noted that field notes on one specimen examined (*Corner* SFN 30651) say that Ridley has the flower colour quite wrong. Corner describes the pedicels as rose-red, the calyx as pink with reddish pink hairs, and the corolla tube as pale cream, the lower lobes flushed pink and the upper lobes faintly pink (this different corolla colour is included in the description). In this specimen the ovary has a collar of hairs at its tip, as do *C. cupulata* and *C. wallichii*, which Ridley did not mention in his original description.

Cyrtandra lanceolata is easily distinguished from other Peninsular Malaysian species as its flowers are at the base of the stem. It is allied to the Bornean *C. radiciflora* C.B.Clarke.

5. Cyrtandra pendula Blume, Bijdr. Fl. Ned. Ind. 770 (1826). Type: Indonesia, Java, *Blume* 2038c (L). Syn.: *C. rotundifolia* Ridl., J. Straits Branch Roy. Asiatic Soc. 57: 76 (1911). Type: Perak, Temengoh, along Sungai Tampan, *Ridley* 14445 (BM, K, SING).

Herb to 60 cm, the lower part of the stem creeping; stem woody at the base, but fleshier and with red-brown hairs in the younger parts and around the leaf axils. *Leaves* rarely subequal, commonly pseudoalternate, with one member of the pair being reduced to a leafy scale, petioles 8 - 20 cm long, lamina often with white barring above and purple colouring below, narrow ovate to ovate to wide ovate or elliptic, 13 - 23 cm x 7 - 15 cm, apex shortly acuminate to acute, base acute to rounded to cordate, margins crenate or crenate-serrate; the upper surface glabrous or subglabrous; the venation on the lower surface with short dense hairs; lateral nerve pairs 5 - 6. *Inflorescence* borne on a peduncle that extends down from the leaf axils, sometimes almost to the ground, with up to 20 flowers. *Bracts* purple, warty, enclosing base of infloresence. *Peduncle* green or purple, 2 - 20 cm. *Pedicels* very short, no greater than 3 mm. *Calyx* purple, c. 2 cm, externally hairy, internally glabrous; tube c. 13 mm, sometimes bilobed, occasionally the upper of the two lobes divided in two; lobes ridged, these ridges extending to form the narrow lobe tips. *Corolla* yellowish white with purple spotting in the throat, c. 4 cm, narrow whilst within the calyx (for c. 2 cm) then expanding to be broad but somewhat flattened at the mouth creating an oval shape, the two upper lobes larger, 7 x 7 mm, than the three lower, 6 x 5 mm; outer surface hairy, inner surface glabrous. *Filaments* c. 1 cm, glabrous, except for a cluster of hairs at the very tip of the connective. *Anthers* c. 3 mm, with a cluster of hairs at the tip and base. *Gynoecium* c. 3 cm, ovary glabrous, style with short hairs, stigma with two semi-oval lobes. *Disk* c. 2 mm, cupular. *Fruit* 1.5 - 2 x 0.4 - 0.5 cm, very narrow ovate, warty, style and calyx caducous. (Figure 4.7).

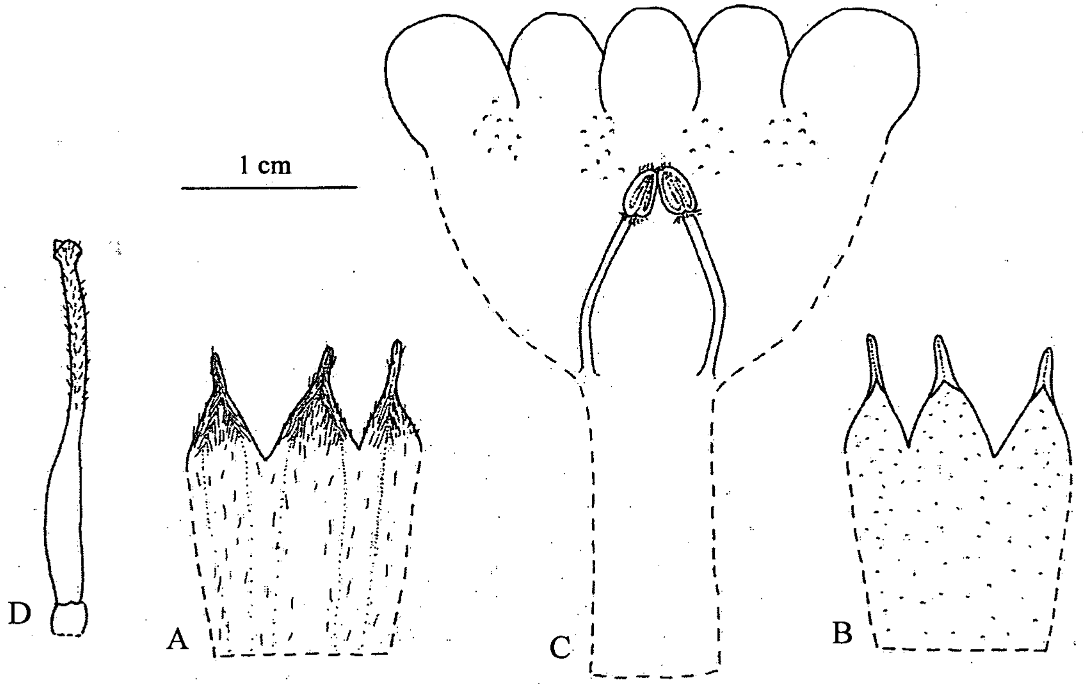

Figure 4.7. A-D. *Cyrtandra pendula* Blume: A, calyx, dissected ventrally, outer surface; B, calyx, dissected ventrally, inner surface; C, corolla, dissected dorsally, showing stamens; D, gynoecium and disk. Drawn from Bramley *et al.* GB37.

ETYMOLOGY. 'pendulus' = pendulous, drooping; referring to the downward-curved (not truly pendulous, but stiff) peduncles of the axillary inflorescences.

ECOLOGY. Mainly lowland forest, often in marshy places and along streams, 0 – 800m.

DISTRIBUTION. Peninsular Malaysia, Indonesia (Java, Sumatra), southern Thailand. (Figure 4.8).

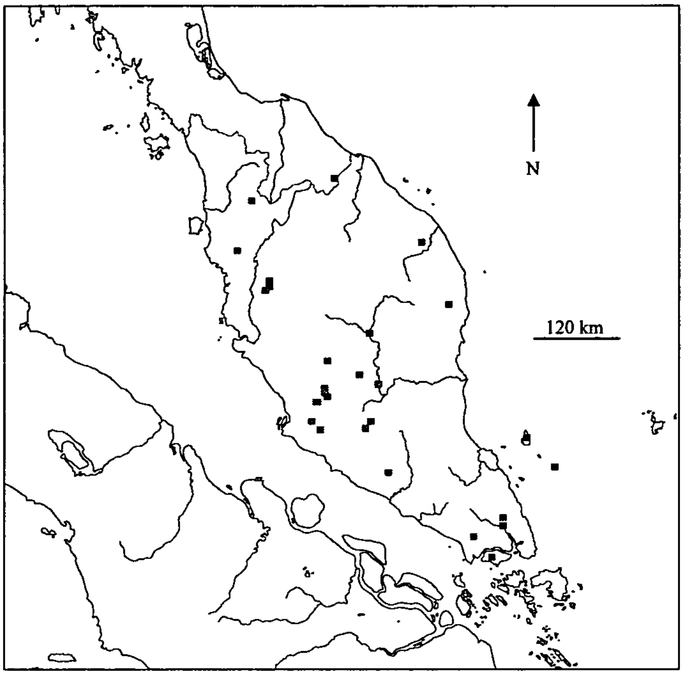

Figure 4.8. *Cyrtandra pendula* Blume distribution map

SELECTION OF SPECIMENS EXAMINED.

PENINSULAR MALAYSIA: Pahang, Bentong rd nr Tranum, 11 viii 1939, *Addison* SFN37215 (K); Negeri Sembilan, Bukit Sutu, 29 x 1885, *Alvins* 1881 (SING); Pahang, foot of Gunung Raya, 13 vii 1924, *Best* 13857 (SING); Selangor, Awana Eco park, 770 m, 29 vii 2002, *Bramley et al.* GB37 (E, KEP, L); Perak, Gunung Pondok, 22 vi 1924, *Burkill* 13913 (SING); Perak, nr Tanjong Rambutan, 4 vi 1930, *Henderson* 23769 (SING); Selangor, Ulu Gombak, 250 m, 3 v 1968, *Mahmud* 813 (L); Pahang, Pulau Tioman, 18 viii 1889, *Ridley* s.n., (SING); Johore, Gunung Pulai, [800 ft] 250 m, 8 xii 1974, *Samsuri Ahmad* SA1043 (SING).

SINGAPORE: Bukit Timah, 1908, *Ridley* s.n. (BM); Bukit Timah, vi 1889, *Ridley* 67 (K).

THAILAND: Narathiwat, Waeng, 250 m, 22 ix 1965, *GP & TS* 1209 [31530] (L); Phangnya, Khao Tala, 50 m, 4 ii 1927, *Kerr* 11819 (BM); Pattani, Bannang Sata, 100 m, 29 vii 1928, *Kerr* 7342 (BM).

CONSERVATION STATUS. Widespread throughout Sundaland, therefore probably at low risk.

NOTES. Common throughout the Malay Peninsula, Sumatra and Java, and easily recognised by its glossy green long-petiolate leaves, sometimes attractively marked with white, and its inflorescence that trails sometimes almost on the ground on a long peduncle. *C. pendula* is a very variable species; because this variation is continuous within the 77 specimens examined it has not been possible to divide the specimens into groups as for *C. cupulata* and *C. wallichii*. Lamina shape is particularly variable; most specimens have an ovate or narrow ovate lamina with a more or less rounded base, but the lamina can also be more elliptic with a cuneate base (*Samsuri* SA1043, SING); cordate (*Burkill* SFN13913, SING); or broadly ovate (almost rotund) with a rounded base (*GP & TS* 1209[31530], L). Specimens also occur with different leaf bases on the same plant e.g. *Best* 13857 (SING). Peduncle length is also variable and probably extends in fruit. There is no correlation between peduncle length, shape of lamina, or geography.

Ridley (1910) described *C. rotundifolia*, which he thought to be a close ally of *C. pendula*, differing in its rounder leaves and greater hairiness. Although specimens with rounder leaves do exist, there is no particular difference in hairiness, and they are found alongside more typical specimens, suggesting this variation is continuous. *C. rotundifolia* is therefore not distinct and is here reduced to synonymy.

Cyrtandra pendula is one of the few examples of *Cyrtandra* species with a distribution spanning different islands. A detailed study throughout its range may identify some congruence between morphology and geography (Burtt, 2001b).

6. Cyrtandra suffruticosa Ridl., Trans. Linn. Soc., ser 2(3): 330 (1893). Type: Peninsular Malaysia. Pahang, Pulau Tioman, 19 viii 1889, *Ridley* s.n. (SING). Syn.: *Cyrtandra falcata* Ridl., J. Straits Branch Roy. Asiat. Soc. 44: 89 (1905). Lectotype (chosen here): Peninsular Malaysia, Selangor, Batu caves, *Ridley* 8219 (SING).

Terrestrial or epiphytic shrub to c. 1.5 m; stems with fine short hairs when young, glabrous and somewhat woody when mature. *Leaves* opposite and most often

anisophyllous, although leaves may be more or less equal at the top of the stem; when anisophyllous, the larger of the pair on a hairy petiole 1 - 3 cm long, the lamina oblong to narrow elliptic to very narrow elliptic, 16 - 27 x 3.7 - 8 cm, apex acuminate, base asymmetric, the longer side acute, the shorter cuneate, margins entire; the upper surface with scattered hair; the lower surface slightly hairier with the midrib and lateral nerve pairs raised, lateral nerve pairs 10-12; the smaller of the pair sessile or on a petiole 1 - 1.5 cm long, lamina elliptic to narrow elliptic, 3 - 7 x 1 - 4 cm, apex acuminate, base acute or obtuse when sessile, margins entire, upper and lower surfaces hairy. *Inflorescence* in axils of leaves, shortly pedunculate, flowers usually up to 6. *Bracts* pale green with red streaks on the outside, dark red on the inner surface, 1.5 - 2 cm long, in a pair, wide ovate, margin entire, hairy. *Peduncles* 2 - 5 mm. *Pedicels* 2 - 5 mm. *Calyx* red, very reduced, c. 2 mm, externally with hair, internally with small gland dots; tube c. 1 mm, lobes five small teeth. *Corolla* white with reddish blotches on the upper lobes and two red stripes extending into the throat on each of the three lower lobes, c. 2.5 cm, outer and inner surfaces glabrous (Ridley, 1893) or with short papillose hairs in the upper part (Burtt, 1999). *Filaments* not seen. *Anthers* not seen. *Gynoecium* c. 1 cm, ovary glabrous, style with short hairs, stigma bilobed. *Disk* c. 2 mm, almost annular but lower on one side and not joined for c. 0.5 mm. *Fruit* green with white spotting, c. 1.5 - 2 x 0.5 cm, sausage shaped, warty, calyx persistent, style semi-persistent.
ETYMOLOGY. 'suffruticosus' = subshrubby, somewhat woody, referring to the habit of the plant.

ECOLOGY. Lowland forest, often epiphytic on trees or growing on rocks.

DISTRIBUTION. Johore, Pahang (Pulau Tioman), Perak, Terengganu. (Figure 4.9).

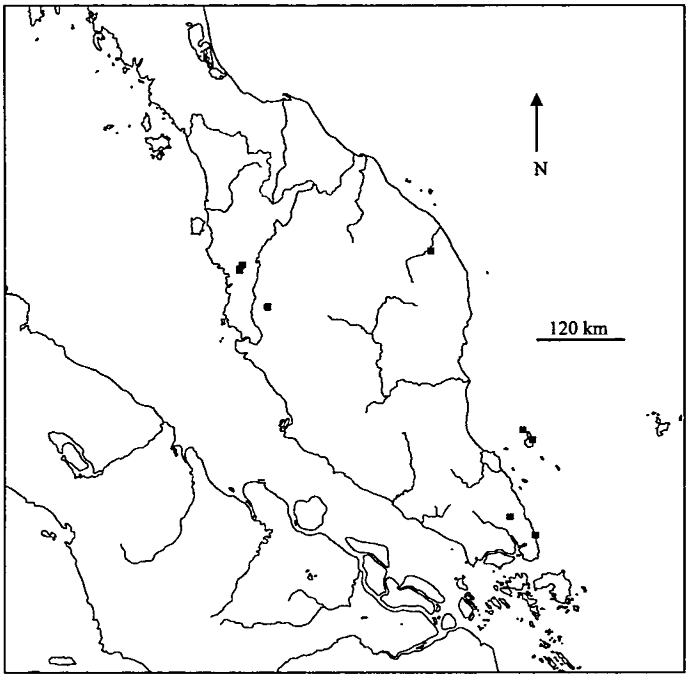

Figure 4.9. *Cyrtandra suffruticosa* Ridl. distribution map

SPECIMENS EXAMINED.

PENINSULAR MALAYSIA: Pahang, Pulau Tioman, vi 1916, *Boden Kloss* s.n. (K); Pahang, Sungei Tawa, Java Bay, Pulau Tioman, 26 vi 1915, *Burkill* 1028 (BM, K, SING); Johore, Sedili river, xi 1932, *Corner* 28416 (SING); Johore, Sungei Berassau, 7 ii 1935, *Corner* 28961 (BM, K, SING); Johore, Sungai Sedili, 13 iv 1935, *Corner* 29267 (K, SING); Pahang, Pulau Tulai, 27 v 1927, *Henderson* 18511 (SING); Perak, Kota Bahru, viii 188?, *King's collector* 569 (SING); Perak, Larut, viii 1883, *King's collector* 4720 (SING); Terengganu, Ulu Brang, vii 1937, *Moysey & Kiah* SFN33655 (BM, K, SING); Perak, Larut, *Scortechini* s.n. (K); Perak, *Scortechini* 142b (SING); Terengganu, Ulu Terengganu, Sekayu waterfalls, 29 viii 1986, *Weber & Anthonysamy* 860829-1/14 (WU 5); Perak, Tupai, *Wray L Jr.* 2845 (SING).

CONSERVATION STATUS. Unknown, but possibly at risk due to the few disjunct localities known.

NOTES. *C. falcata* is reduced to synonymy here. In his original description of *C. falcata*, Ridley (1905) cited *Wray* 2845 and *Scortechini* 142b. However, he also cited these under *C. suffruticosa*, which he had described earlier in 1893. Ridley stated that *C. falcata* is closely allied to *C. suffruticosa*, but has much narrower leaves. No material with consistently narrow leaves matching Ridley's description is discernable among the specimens cited above, which all match *C. suffruticosa.* Since no specimens of *C. falcata* have apparently been collected since it was described, it seems that the name *C. falcata* was applied to specimens with narrower leaves. However, when all the specimens are compared together, it is clear that these narrower leaves fall within the variation of *C. suffruticosa.* No further characters have yet been found that distinguish *C. falcata.*

The corolla colour in the description above comes from observations (and photos) of *Weber & Anthonysamy* 860829-1/14 and notes of *Henderson* SFN18511 and *King's Collector* 4720. Notes on *Burkill* SFN1028 are slightly different, describing brown markings on the upper lobes, and purple spotting in the throat. Ridley (1905) noted that Wray describes the inner corolla as dark claret, but this specimen has not been seen. Ridley described the corolla as glabrous but according to Burtt (1999) and as found in this study, the corolla has short subpapillose hairs in the upper part, and is glabrous below.

Cyrtandra suffruticosa is allied to *C. oblongifolia* (Blume) C.B.Clarke, from Borneo, and belongs to section *Whitia* (Blume) C.B.Clarke, which is a west Malesian group of about ten species (Burtt, 1999). It has a disjunct distribution, occurring in Pahang and Terengganu in the east, and Perak in the west, separated by the Main Range. It is recognisable by its oblong to very narrow elliptic anisophyllous leaves, large wide ovate bracts, the conspicuous flower colour and sausage-shaped fruits.

Corner SFN28416 is an anomalous specimen. It is similar to the other specimens, but its leaves are elliptic and slightly broader (16 - 17 × 7 - 8 cm) and the veins are much more closely packed (12 or 14 compared to 11 or 12 lateral vein pairs) and at a less acute angle. Since it was collected from the same location (Sungei Sedili, Johore) as a more typical specimen (*Corner* 29267, K, SING), it is included in *C. suffruticosa* here.

7. **Cyrtandra stonei** B.L.Burtt, Edinburgh J. Bot. 47: 229 (1990). Type: Peninsular Malaysia, Pahang, Ulu Kali, path to Gunung Lari Tembakau, [5200 ft] 1600 m, 18 iii 1979, *Stone* 14051 (holotype: KLU; isotypes: K, KEP, L [*n.v.*]). Syn. *Cyrtandra dispar* A.DC. var *glabriflora* B.C.Stone, Malaysian Forester 43: 262 (1980). Type as above.

Sub-shrub, c. 1 - 1.5 m tall, stem quadrangular, fleshy, glabrous, the lower part becoming woody. *Leaves* markedly anisophyllous: the major leaf 15 - 22 x 5 - 7 cm on a petiole 3 - 4 cm long, lamina asymmetrically narrow elliptic to oblanceolate, apex acuminate, base asymmetric, the wider side acute and often up to 1 - 2 cm longer, margins very shallowly dentate, upper and lower surfaces glabrous, lateral nerve pairs 9 - 12; the minor leaf 4 - 6 x 1.5 - 2 cm, sessile, lamina narrow ovate to lanceolate, apex acute, margins very slightly dentate. *Inflorescence* axillary, more or less sessile, up to 8 flowered. *Bracts* 1 - 2 cm long, narrow ovate to lanceolate, enclosing inflorescence and smaller bracteoles. *Pedicels* c. 1 cm. *Calyx* white, asymmetric; the upper three lobes fused to form one c. 1.1 cm, narrow ovate with its apex divided into three distinct acuminate tips, the lower two lobes slightly shorter c. 1 cm, divided to the base, narrow ovate; externally the lobes with thickened ridges down the centre, the upper lobe with papillae on the ridges, the lower two glabrous; internally all lobes with scattered papillae. *Corolla* white, somewhat translucent, with a yellow mark in the throat, c. 1.7 cm long, tube narrow at base, then constricted further at c. 5 mm before broadening, all lobes 3.5 - 4 x 3.5 - 4 mm; outer surface glabrous, inner surface with papillae below the upper two lobes and in the throat. *Filaments* c. 5 mm, with glandular hairs especially near the anthers. *Anthers* c. 1 mm. *Gynoecium* c. 1 cm, style with glandular hairs, stigma with two triangular lobes. *Disk* cupular, c. 2 mm high, margin uneven. *Fruit* ovate to globose, fleshy, green, 1.2 - 1.5 x 0.9 cm with a short c. 2 mm apiculus remaining from the otherwise caducous style, calyx semi-persistent. (Figure 4.10).

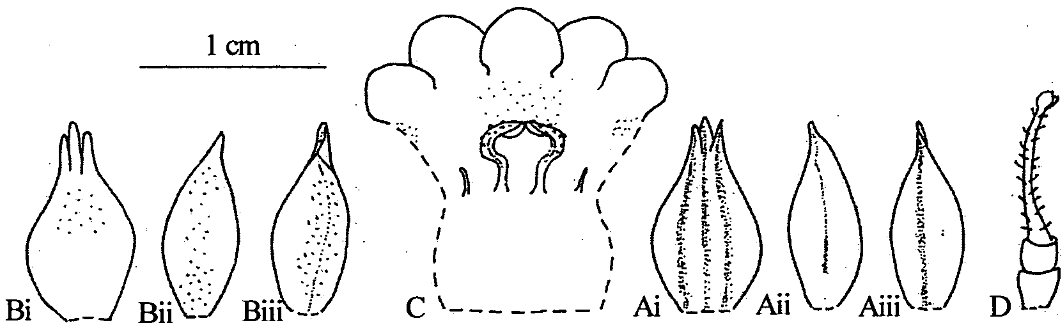

Figure 4.10. A-D. *Cyrtandra stonei* B.L.Burtt: A, calyx, outer surface i) upper lobe ii) lower lobe iii) lower lobe; B, calyx, inner surface i) upper lobe ii) lower lobe iii) lower lobe; C, corolla, dissected dorsally, showing stamens; D, gynoecium and disk. Drawn from Bramley *et al.* GB34.

ETYMOLOGY. Named in honour of B.C. Stone (1933-1994), a distinguished botanist working for many years at KLU.

ECOLOGY. Montane forest, c. 1700m, often in open and secondary vegetation.

DISTRIBUTION. Peninsular Malaysia, Genting Highlands (Pahang). (Figure 4.11).

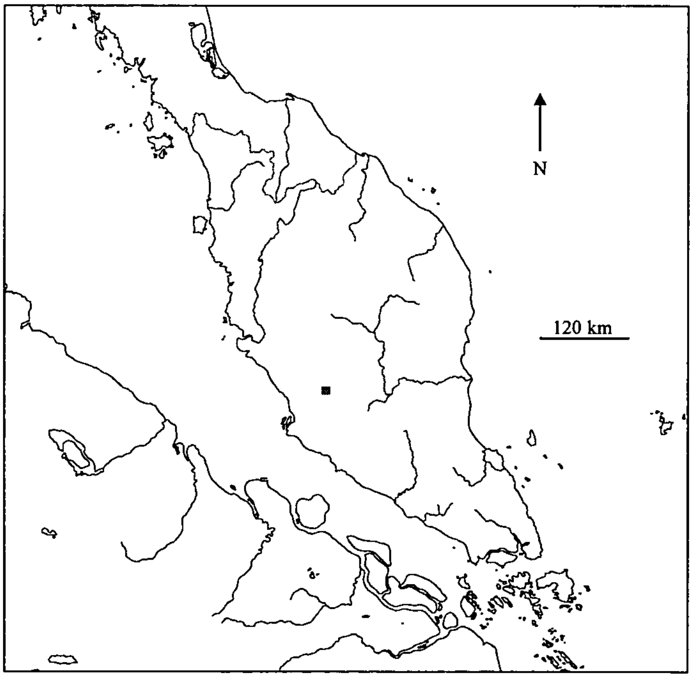

Figure 4.11. *Cyrtandra stonei* B.L.Burtt distribution map.

SPECIMENS EXAMINED.

PENINSULAR MALAYSIA: Pahang, rd to Telekom, Gunung Ulu Kali, 1645 m, 29 vii 2002, *Bramley et al.* GB34 (E, K, KEP, L); Pahang, rd from Ulu Kali to Gunung Chin Chin, 6 v 1999, *Chua et al.* FRI40800 (KEP); Pahang, Bentong, Gunung Ulu Kali, 24 ix 1998, *Chua et al.* FRI40581 (KEP); Pahang, below top of Gunung Ulu Kali, 5 viii 1979, 1700m, *Weber & Vogel* 790805 (WU).

CONSERVATION STATUS. Only collected from the upper montane forest of the Genting Highlands within a narrow altitudinal range, therefore likely to be vulnerable.

NOTES. *Cyrtandra stonei* is the only Peninsular Malaysian representative of section *Dissimiles* C.B.Clarke (see chapter six). This section was originally described by Clarke (1883) and recently lectotypified by Burtt (1990). It is characterised by a zygomorphic calyx (where the upper lobes are fused to form a single lobe, and the lower two divided to the base) and anisophyllous leaves.

Cyrtandra stonei has a very restricted distribution and has not been widely collected. It is easily recognisable in the herbarium as the upper surface of the leaf and the venation dry a very dark colour, but apart from the venation, the lower surface dries to a paler brown. The fruit is fleshier than the usual hardened fruit of west Malesian *Cyrtandra*. In the field the quadrangular stem is noticeable, as well as the glabrous leaves, and the small, quite translucent, white corolla, which has a bright yellow throat.

Cyrtandra stonei grows in areas quite unlike the other Peninsular Malaysian *Cyrtandra* species, which inhabit damp and fairly dark areas in the rain forest. *Cyrtandra stonei* is found at high altitude, growing along the roadside in open vegetation, which includes *Musa* sp. and *Gleichenia linearis* C.B.Clarke.

8. Cyrtandra dispar DC., Prodr. 9: 282 (1845). Type: Peninsular Malaysia, Penang, *Wallich* list no. 807, (lectotype: K (chosen here); isolectotypes: BM, L, SING). Syn. *Cyrtandra frutescens* Wall., Numer. list 807 (1829), pro parte – non Jack.

Shrub 1 - 3 m tall; stems with short hairs when young, maturing to have pale brown bark with a flaky appearance. *Leaves* pseudodistichous, one member of a pair being reduced to a leafy scale, the developed member on a petiole 1.5 - 3 cm long; lamina elliptic to narrow elliptic or obovate, 18 - 40 x 5.5 - 15 cm, asymmetric about the midrib, apex acuminate, base acute and asymmetric, margin biserrate, especially apparent when young; upper surface glabrous to subglabrous; lower surface with red-brown hairs that are denser on the venation than the lamina, all the venation is raised; lateral nerve pairs 12 - 14. *Inflorescence* axillary, sessile or less often shortly pedunculate, 4 or more flowered. *Bracts* clustered around the base of the pedicels, 0.5 - 1 x 0.2 cm, narrowly ovate to lanceolate, margin entire, red-brown hairy and warty on both surfaces. *Peduncles* where present, less than 5 mm long and covered with pale brown flaky bark. *Pedicels* 1 - 2 cm long, hairy. *Calyx* green, 0.7 - 1.2 cm long, externally with short red-brown hair, internally with small gland dots; tube 3 - 6 mm, the upper three lobes divided to c. 3 mm, the lower two to c. 4 mm, the lobes triangular with long fine tips that are also triangular in cross section. *Corolla* white or pale pink with dark red to purple stripes in the throat, 1 - 1.2 cm, broadening towards the mouth, the upper two lobes 2 x 2 mm, the central of the three lower lobes 3 x 3 mm, the outer two 2 x 2 mm; outer surface hairy, inner surface glabrous. *Filaments* c. 4 mm, glabrous. *Anthers* c. 1 mm. *Gynoecium* c. 1 cm, ovary with scattered short hair, style with short hair, stigma bilobed, the two lobes narrowly triangular. *Disk* c. 2.5 mm, unilateral, margin dentate or undulate. *Fruit* green, ellipsoid, 1 - 1.3 x 0.3 - 0.5 cm, warty; calyx and style persistent.

ETYMOLOGY. 'dispar' = unequal, referring to the strongly unequal leaves at a node, with the smaller leaf reduced to a triangular scale.

ECOLOGY. Lowland and hill forest; 100 – 800 (-1700) m.

DISTRIBUTION. Peninsular Malaysia (Kelantan, Penang, Perak), southern Thailand; North and East Sumatra. (Figure 4.12).

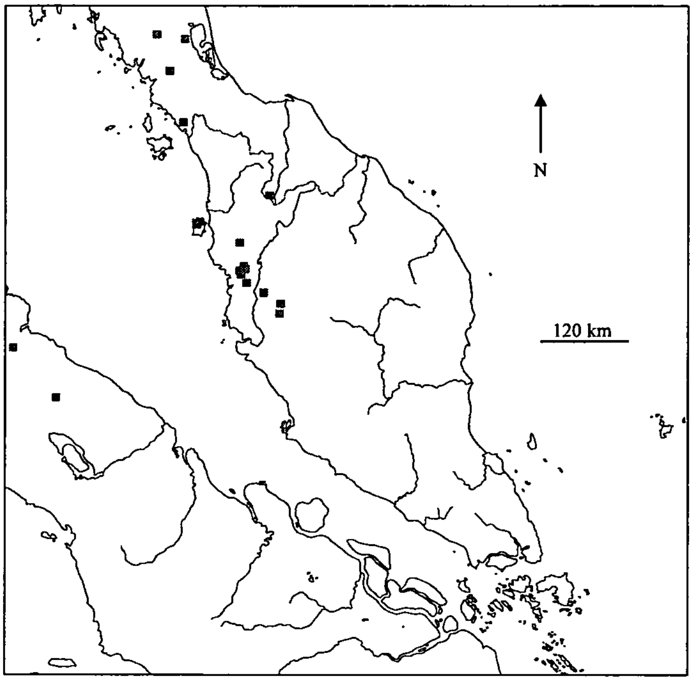

Figure 4.12. *Cyrtandra dispar* DC. distribution map.

SELECTION OF SPECIMENS EXAMINED.

PENINSULAR MALAYSIA: Penang, Government Hill, vii 1893, *Curtis* 1204 (SING); Perak, Gunung Bubu Forest Reserve, 570 m, 15 viii 1966, *Hou* 633 (K, L, SING); Perak, 5 1/4 mile Maxwell Hill rd, 29 x 1969, *Kochummen* FRI2881 (L, SING); Penang, Marriot's rd, iii 1915, *Ridley* s.n. (K); Perak, Thaiping Hills, *Scortechini* 254b (SING); Perak, Gunung Keledang, 18 viii 1986, *Weber* 860818-2/2 (WU); Kelantan, Tanah Merah district, 23 iv 1987, *Weber* 870423-4/1 (WU).

THAILAND: Trang, Khao Chong, 350 m, 13 vi 1974, *Geesink et al.* 7194 (K, L); Betong, Pattani, c. 300 m, 13 viii 1923, *Kerr* 7602 (BM, K).

CONSERVATION STATUS. Not likely to be at high risk as it has a distribution spanning quite a large area.

NOTES. *Cyrtandra dispar* can be distinguished by its pale flaky bark and asymmetric, pseudodistichous, and biserrate leaves. These features are characteristic of sect. *Dispares* C.B.Clarke, in which *C. dispar* is the only representative in the Malay Peninsula. A closely allied species, *C. disparoides*, from Borneo (Sarawak, Hose Mts.), was recently described by Burtt (1978). It is closely related to *C. patula* which differs in habit strongly by its equal leaves (Burtt 1978: 165).

Cyrtandra dispar is confined to the north-west of Malaysia (Perak and Penang), the south of Thailand, and the north and east of Sumatra.

9. Cyrtandra patula Ridl., J. Straits Branch Roy. Asiat. Soc. 86: 303 (1922). Type: Peninsular Malaysia, Negeri Sembilan, Bukit Tangga, xii 1920, *Ridley* s.n. (holotype: K; isotype: SING).

Shrub to 3 m; stems with orange-brown hairs when young, becoming woody and subglabrous in parts, but the stem tips and areas around the leaf axils remaining hairy. *Leaves* opposite and isophyllous, on petioles 2 - 3 cm long, the petioles often ridged at the edge where the lamina has narrowed to form a slight wing; lamina obovate and less commonly narrow elliptic, 27 - 40 x 8 - 12 cm, apex shortly acuminate, base cuneate and narrowly decurrent, margin irregularly biserrate; the upper surface with dense silky hair when young, the hairs becoming scattered as the leaf matures; the lower surface also densely silky hairy when young, these hairs becoming scattered on the lamina except for the raised midrib and lateral nerve pairs which retain a covering of orange-brown hairs; lateral nerve pairs 11 - 14. *Inflorescence* in axils of leaves, shortly pedunculate, with up to 13 flowers. *Bracts* 8 - 15 x 4 - 5 mm, lanceolate to oblanceolate, margin entire, both surfaces hairy. *Peduncles* c. 2 mm. *Pedicels* 1 - 1.5 cm. *Calyx* pale yellow-green, 7 - 9 mm, externally hairy, somewhat warty around the base, internally verrucose; tube c. 5 mm, the upper three lobes c. 2.5 mm, the lower two lobes c. 3.5 mm, lobes triangular with c. 1 mm thickened tips that curve outwards, away from the corolla. *Corolla* off-white with a brown marking in the throat, c. 16 mm, all five lobes 5 x 5 mm; outer surface with orange-brown silky hair, inner surface with papillae in the upper part of the throat. *Filaments* c. 4 mm, sometimes with a few hairs near the base of the anthers. *Anthers* c. 1 mm. *Gynoecium* c. 12 mm, ovary hairy, style with short hairs, stigma with two narrow triangular lobes. *Disk* c. 2 mm, unilateral, margin undulate. *Fruit* 10 - 12 x 3 - 5 mm, sausage shaped, hairy, warty, calyx and style persistent. (Figure 4.13).

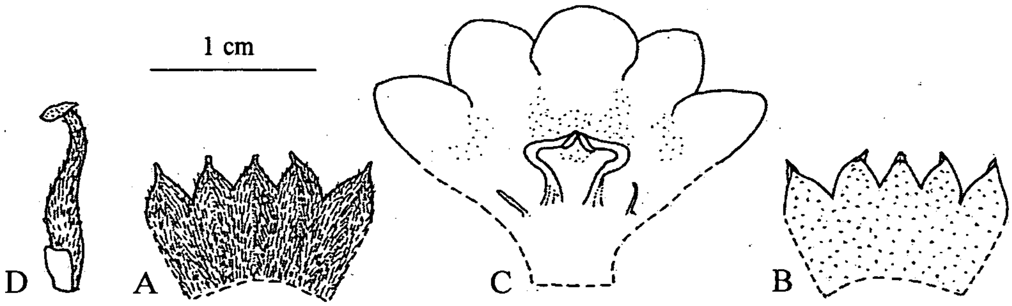

Figure 4.13. A-D. *Cyrtandra patula* Ridl.; A, calyx, dissected ventrally, outer surface; B, calyx, dissected ventrally, inner surface; C, corolla, dissected dorsally, showing stamens; D, gynoecium and disk. Drawn from Bramley *et al.* GB36.

ETYMOLOGY. 'patulus' = spread, outspread; apparently referring to the spreading habit of the plant

ECOLOGY. In hill and lower montane forest, 800 – 1000m, often in muddy wet places and by rocky streams.

DISTRIBUTION. Peninsular Malaysia (western range) and Thailand (the far south). (Figure 4.14).

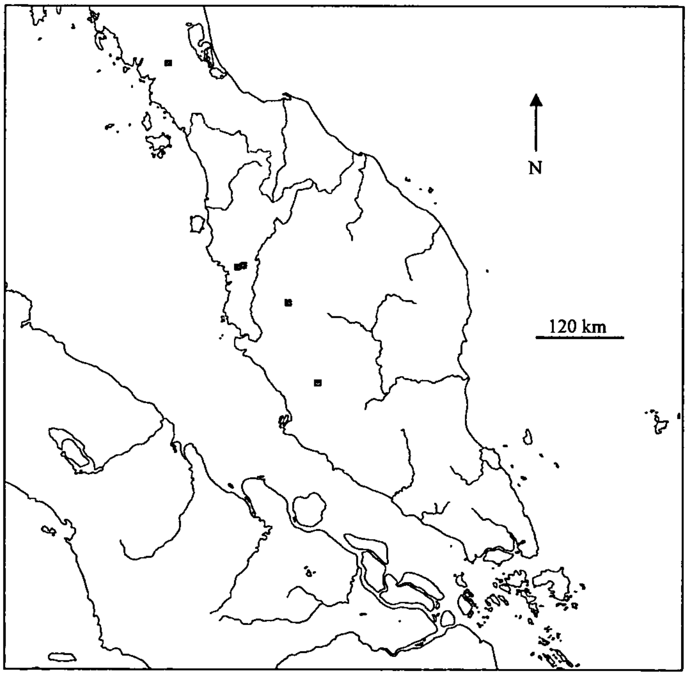

Figure 4.14. *Cyrtandra patula* Ridl. distribution map.

SELECTION OF SPECIMENS EXAMINED.

PENINSULAR MALAYSIA: Perak, Taiping Hills, iii 1911, *Anderson* 124 (SING); Selangor, Awana Eco Park, 770 m, 29 vii 2002, *Bramley et al.* GB36 (E, KEP, K, L); Perak, Ulu Batang Padang, ix 1900, *Ridley* 13667 (SING); Perak, stream near 3rd mile below Maxwell's Hill Post office, 16 ix 1949, *Sinclair & Kiah* SF38772 (SING); Pahang, Ulu Batang Kali, [2500 ft] 800 m, 26 xi 1967, *Whitmore* FRI4553 (K, L, SING).

THAILAND: Surat Thani, Khao Nong, 8 viii 1927, *Kerr* 13223 (BM).

CONSERVATION STATUS. Not widely collected, but its range appears to be quite extensive, and therefore it is probably not at risk.

NOTES. *Cyrtandra patula* is likely to be closely related to *C. dispar* because of the similarities in leaf and flower form. However, it does not appear to have such a wide distribution. It has been poorly collected, often being misidentified as *C. dispar*, but it can be recognised by its equal pairs of large biserrate leaves, as opposed to the pseudodistichous *C. dispar*, and its calyx lobes, which are much broader than the narrow triangular calyx lobes of *C. dispar*. In addition, *C. patula* has a smooth woody stem, compared to the flaky bark of *C. dispar*.

4.3 ADVANTAGES AND DISADVANTAGES OF THIS REGIONAL REVISIONARY APPROACH

The success of this regional approach is somewhat dependent on the size and species richness of the region in question. A 'region' can be defined in a number of ways. In South East Asia the easiest way to define regions is island by island. However, islands the size of Borneo or New Guinea provide a more formidable challenge to islands such as Sumatra or Sulawesi, and these in turn are a more difficult challenge than, for example, Palawan or Peninsular Malaysia.

For this study I chose Peninsular Malaysia for the regional approach. A revision of the Peninsular Malaysian *Cyrtandra* species, with only 12 species recorded before the revision was undertaken, was an ideal size to complete in the short time available. Peninsular Malaysia is not an island but is isolated in the North by a drier climate and therefore different flora, and by sea from the other islands of Sundaland.

Its close proximity to Sumatra also made it appropriate due to the similarities of the floras of the islands of Sundaland (see chapter five). It was also relatively well collected, and accessible for fieldwork.

In continental areas such as South America or Africa, regions are likely to be defined using political rather than geographical boundaries. But treating an area such as South America, using a country based approach is different to the island based approach that can apply in South East Asia. Species distributions do not conform to political boundaries such as country borders, but often do follow geographical boundaries. A country based regional approach would be repetitive, and lead to inaccurate species delimitation because specimens from a fraction of the true range of any species will be examined. A better alternative would be to define regions phytogeographically. If phytogeographic regions proved to be prohibitively large and therefore problematic, especially in terms of species numbers, they could be worked on by a number of taxonomists. This could also apply to the larger islands of South East Asia.

The success of the approach also depends on the nature of the species being treated. Genera that contain species with relatively small distributions and a high degree of local endemic species, such as *Cyrtandra*, are better suited to geographical approaches than genera with wide ranging species.

Regional accounts can be incorporated into regional floras and can be useful for local botanists. Furthermore, regional approaches allow species distributions to be investigated, conclusions to be drawn about the conservation status of species and also the affinities of a region's flora to be assessed. This is particularly useful if the region happens to coincide with a political area (e.g. Peninsular Malaysia), as many conservation policies are implemented nationally.

Regions are convenient areas for fieldwork - perhaps one of the most pressing problems in a genus such as *Cyrtandra* is the need to collect more species. For *Cyrtandra*, targeted collections, most likely to be by region, of specimens for herbaria and silica dried leaf material for DNA sequencing, are needed. With the increased collection of suitable material, molecular phylogenies can be added to, region by region, and could also be used to identify possible monophyletic groups for taxonomic revision (see chapter five).

5 CHAPTER FIVE: REGIONAL APPROACH - ASSESSING THE AFFINITIES OF PENINSULAR MALAYSIAN *CYRTANDRA* USING MOLECULAR PHYLOGENETIC ANALYSES

This chapter forms the second part of the regional approach. Using phylogenetic analyses of ITS sequences it aims to elucidate the affinities of the Peninsular Malaysian *Cyrtandra* species.

5.1 INTRODUCTION

The Malay Peninsula is the extension of Continental Asia pointing southward from Indochina which divides the Andaman Sea and the Strait of Malacca from the South China Sea (Turner, 1995). Politically, it includes the territory of Thailand and Malaysia. Peninsular Malaysia, also known as West Malaysia, has an area of 131,598 km^2, and is 485 miles long. Several mountain ranges run north-south down the Peninsula and the highest peak is Gunung Tahan, 2187 m. It is fringed on the west coast by lowlands and mangrove bordering the sea and on the east coast with sandy plains. Peninsular Malaysia has a predominantly ever-wet tropical climate and supports tropical rain forest vegetation.

Recent estimates suggest that Peninsular Malaysia has 7,660 species of seed plants (Turner, 1995). Deforestation has been a large problem in Peninsular Malaysia. At the turn of the last century (1900s) there was greater than 90% forest cover, but by 1960 there was less than 70%. Now the amount of forest cover seems to have stabilised at 44.5%, as most of the land deemed more suitable for agriculture has been taken (Saw & Soepadmo, 2002).

5.1.1 General Affinities of the Peninsular Malaysian Flora

The wet tropics of the far east, including Peninsular Malaysia, are mostly contained within the phytogeographical area of Malesia. Malesia has a distinctive flora that does not merge gradually with those of adjacent drier regions (Whitmore, 1984).

Van Steenis (1950) defined the Malesian flora with a series of demarcation knots, based on the absence of genera on one side or other of a boundary. The knot applicable to Peninsular Malaysia occurs around the Isthmus of Kra, close to the border between Malaysia and Thailand. This demarcation knot occurs at the boundary between the Malesian and Indo-Chinese flora: there are 375 Malesian genera that do not occur in Indo-China, and 200 genera from Indo-China that do not penetrate into Malesia (Whitmore, 1984).

Within Malesia itself, Peninsular Malaysia's flora is allied to the other areas on the Sunda shelf, in particular Sumatra and Borneo. Peninsular Malaysia, Sumatra, Java and Borneo are often collectively known as West Malesia or Sundaland. Periodic unions of these islands of the Sunda shelf during periods of sea level lowering are likely to have resulted in the similarity of the flora between the countries (Johns, 1995). Vegetation studies on Sumatra (Laumonier, 1990, 1997) show that the Sumatran flora is most similar to that of the Peninsula, sharing 49% of species compared with those of Borneo (45%) or Java (37%). The Peninsula's flora appears to be less rich than other areas of West Malesia: the east Malaysian provinces of Sabah and Sarawak have 27% more species than Peninsular Malaysia, and the estimates for the number of species in Borneo range from 9,000 to 15,000 (Wong, 1998). The estimate of the number of plant species in Sumatra is 10,000 (Whitten *et al.* 1997), c. 24% more species than Peninsular Malaysia, although Sumatra remains undercollected and the flora poorly known (Kiew, 2002). These differences in species numbers are partly due to area, as Peninsular Malaysia is smaller than both Sumatra (472,610 km^2) and Borneo (744,108 km^2), and therefore might be expected to have fewer species.

In terms of endemism there are also differences between the islands of west Malesia. The Malay Peninsula has 22 endemic genera; Sumatra 10 endemic genera (although this not likely to be accurate [Kiew, 2002]), and Borneo 63 endemic genera (Wong, 1998).

Within the Gesneriaceae subfamily *Cyrtandroideae*, there are c. 16 genera in Peninsular Malaysia, including 3 endemic genera found only on limestone (Kiew, Weber & Burtt, 1998). The genera seem to follow two main distribution patterns. The first, and least common pattern is a mainly Eurasian distribution, exemplified by *Didymocarpus*, which extends from Sino-Himalayan areas southwards through Thailand and Vietnam with a few species reaching the Malay Peninsula (Burtt, 1998b). The second is a mainly Malesian distribution, although some genera do reach mainland Asia such as *Henckelia* (c.180 species) which ranges from tropical South India and Sri Lanka to New Guinea and from south Thailand to Borneo, but has its greatest species concentration in west Malesia, especially in Peninsular Malaysia, where there are around 100 specific names (Weber & Burtt, 2000). This apparent radiation in Peninsular Malaysia is rare among the genera of the subfamily *Cyrtandroideae* - most genera seem to have their main radiations in other areas of Malesia. For example, *Aeschynanthus*, which has a similar number of species (c.160), and is distributed similarly to *Henckelia*, has only 15 species in Peninsular Malaysia, and has its main radiation in New Guinea (Weber & Mendum, 2003).

Cyrtandra also follows the Malesian pattern. As seen in chapter four, the northern limits of *Cyrtandra* on the Thai-Malay Peninsula are in southern Thailand, and the genus is not particularly well represented in Peninsular Malaysia. Taking this information into account, we could reasonably expect the origin of the Peninsular Malaysian *Cyrtandra* flora to have been in other Sundaland areas.

Corner (1960) recognised three special floristic areas in the Malay Peninsula (Wong, 1998).
A: the Riau pocket - localised in the southeast Pahang-East Johore area, which shares species with Central Sumatra and the Riau islands south of Singapore and northwest Borneo.
B: the west coast region in which there is much similarity to the Sumatran flora
C: an enclave of southward invasion by Burmese-Thai floral elements

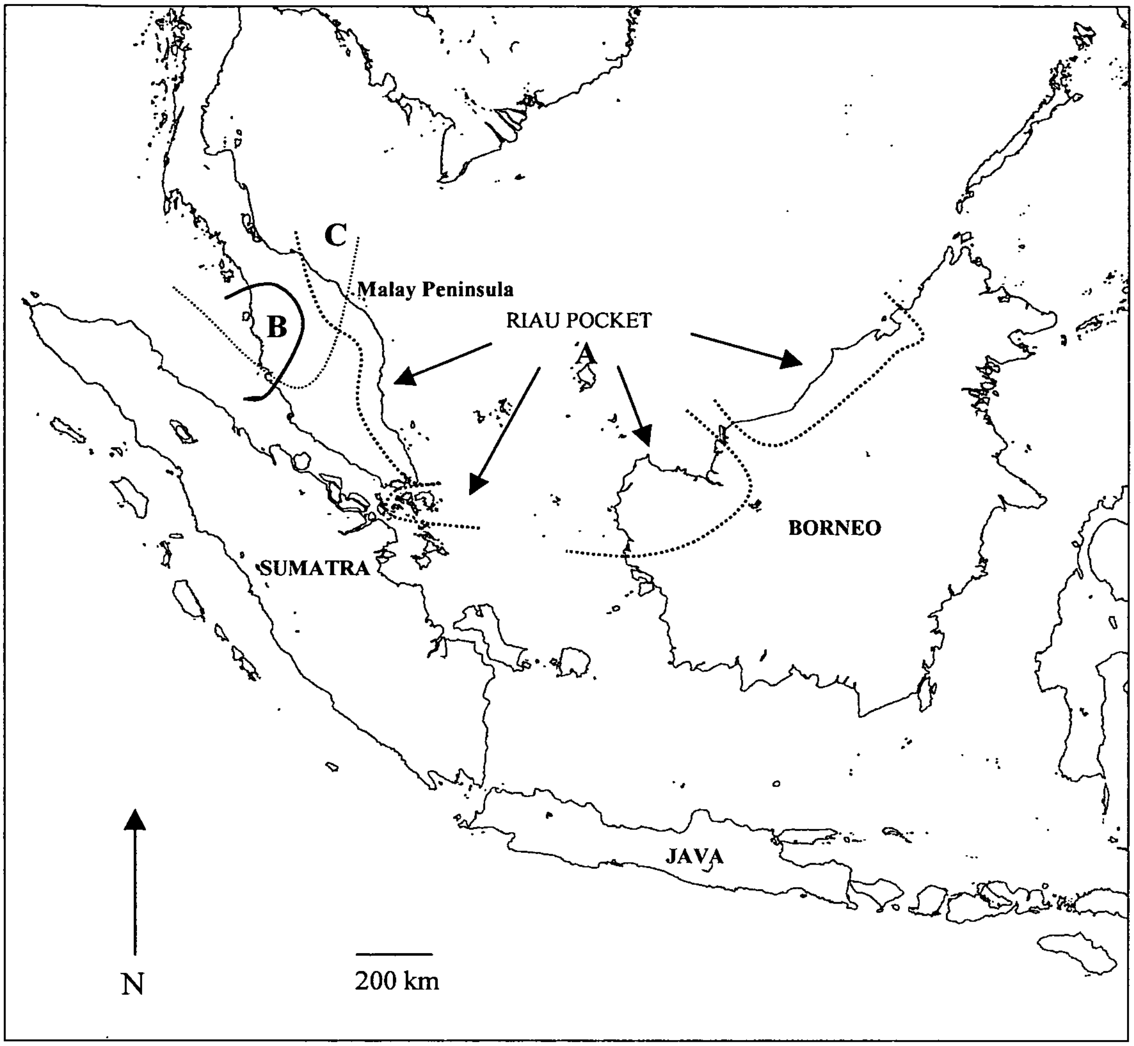

Figure 5.1. Map of Sundaland illustrating Corner's special floristic areas A (Riau pocket), B (West Coast area with Sumatran affinity) and C (enclave of southward invasion from Asia).

The taxonomic revision of the Peninsular Malaysian *Cyrtandra* in chapter four briefly discussed the morphological affinities of each species, and it seems that some follow the patterns described in Corner's floristic areas A (e.g. *C. wallichii* (C.B.Clarke) B.L.Burtt and *C. suffruticosa* Ridl.) and B (e.g. *C. stonei* B.L.Burtt, *C. dispar* DC., *C. patula* Ridl.).

Using an ITS phylogeny with accessions of Peninsular Malaysian species and additional species from Borneo, this chapter aims to elucidate the affinities of the *Cyrtandra* of Peninsular Malaysia, and hence whether they provide evidence for Corner's special floristic areas. I hypothesise that the molecular data will corroborate the affinities between Sumatran, Bornean and Peninsular Malaysian species from Corner's areas A and B, suggested by the morphological data detailed in chapter four. Additional species from Kalimantan (Borneo) have been added to provide a better representation of the genus from Borneo, since the other Bornean species included were collected in Sabah.

As in chapter three, the absence or presence and type of foliar sclereids present in the Peninsular Malaysian species has been considered, in this case using notes made by Professor Bokhari, shown in appendix 13 (Bramley *et al.*, 2004b).

In order to provide confidence in the use of ITS data for reconstructing the phylogenetic history of *Cyrtandra*, a smaller sample of *Cyrtandra* species have been sequenced for the *trn*L region of the chloroplast genome. Methods and the results of the phylogenetic analyses of these sequences are included in this chapter, after the discussion of the ITS phylogeny.

5.2 MATERIALS AND METHODS

5.2.1 Outgroup and Ingroup Taxa

As in chapter three, the chosen outgroup was *Aeschynanthus pulcher*. The ingroup contains 55 accessions: 38 of these follow chapter three, and an additional 16 accessions include 11 sequences representing six of the nine *Cyrtandra* species from Peninsular Malaysia and five sequences representing four Kalimantan species.

5.2.2 DNA Extraction, PCR and Sequencing Protocol

DNA extraction, PCR and sequencing protocols follow chapter three.

5.2.3 Analysis of Sequence Data

Sequences were imported into Sequence Navigator (Version 1.0.1, Perkin Elmer, Applied Biosystems Division, Foster City, CA, USA) and aligned manually. Alignment of the 55 ITS sequences analysed resulted in a 583-bp long data matrix. Sequence characteristics were calculated using PAUP Version 4.07b (Swofford, 2001) except for the transition/transversion ratio, which was determined using MacClade Version 3.07 (Maddison & Maddison, 1997). (Table 5.1).

Phylogenetic trees were generated using PAUP Version 4.07b (Swofford, 2001) and Mr Bayes (version 2.01; Huelsenbeck & Ronquist, 2001). Maximum parsimony (MP) analyses involved a heuristic search strategy with 10,000 random stepwise addition sequence replicates and TBR branch swapping with the option 'collapse branches if minimum length is zero' selected. Further searches (with options MULTREES and steepest descent on) using the trees stored in the memory from the initial search as the starting trees were carried out for tree optimisation, but no additional trees were found. Only combined ITS1 and ITS2 data were subjected to analyses. Individual gap characters were treated as missing data and gaps were coded as additional characters according to the simple coding method of Simmons and Ochoterena (2000). To investigate the effects of the additional gap characters, a sensitivity analysis (Wheeler, 1995) was carried out without them. Ambiguous regions that allowed alternative alignment interpretations were excluded (bp 147-152, 277-284, 296-309, 330-334, 364-368, 375-377, 383-385, 506-513). An analysis including these regions was carried out in order to test their effects. A successive reweighting analysis was carried out using the average value of the rescaled consistency index for each character in order to select a phylogram identical in topology to the reweighted tree for display.

Bootstrap values (Felsenstein, 1985) were calculated from a 10,000 replicate analysis using a heuristic search strategy with simple addition of the taxa, MULTREES option off and TBR branch swapping. Decay indices (Bremer, 1988) were determined by running the programme AutoDecay (Eriksson, 1998) in conjunction with PAUP version 4.07b (Swofford, 2001).

Parameters and assumptions used in the maximum likelihood (ML) searches were selected using the program Modeltest (Posada & Crandall, 1998) and based on the the Akaike Information Criterion (AIC), the model selected was TIM (Rodriguez et al., 1990) with a gamma distribution.

ML heuristic search parameters were simple addition sequence of taxa with TBR branch swapping, MULTREES and COLLAPSE. An ML analysis was performed using Bayesian methods and a general time reversible (GTR) model with a gamma distribution in MrBayes. For this analysis four simultaneous Monte Carlo Markov Chains (MCMC) were run for 1,000,000 generations, saving a tree every 100 generations.

5.3 RESULTS

5.3.1 Sequence Characteristics

The average length of ITS1 and ITS2 in total was 495 bp (table 5.1). Alignment of all taxa required the insertion of 59 gaps of 1-28 bp length, 26 in ITS1 and 33 in ITS2, 21 of which were potentially phylogenetically informative. The length of aligned ITS1 and ITS2 regions (in total) were 583 bp. Due to alignment ambiguities (where alternative alignments were possible) 52 sites were excluded (14 sites in ITS1 and 38 sites in ITS2). Of the remaining 552 unambiguously aligned sites, 41.3% were constant, 37% were phylogenetically informative, and 21.7% were autapomorphic (table 5.1).

Pairwise comparisons of individual taxa across both spacer regions revealed 0-18.5% sequence divergence within the ingroup, and 13-19.3% divergence between ingroup and outgroup analysed, both ranges differing slightly from those found in chapter three (ingroup 0-18.9%; ingroup and outgroup 13.7-20.1%). Atkins *et al.* (2001) found a maximum sequence divergence of 15.7% within the ingroup.

Among the Peninsular Malaysian *Cyrtandra*, combined ITS1 and ITS2 sequences showed 0.45-13.3% divergence (table 5.2). The most divergence between Peninsular Malaysian collections occurred between *C. cupulata* Ridl. and *C. dispar* DC. The species within section *Dissimiles* (chapter six) had sequence divergence ranging from 3.1% to 9.1%, with the lowest divergence between *C. anisophylla* C.B.Clarke and *C. stonei* B.L.Burtt, and the highest between *C. anisophylla* and *C. trisepala* C.B.Clarke. Within the ingroup, maximum sequence divergence was between *C. ferruginea* Merrill (from the Philippines) and *C. chrysea* C.B.Clarke (from Borneo). The lowest sequence divergence between different species was 0.22%, between *C. stenoptera* Bramley & Cronk and *C. trichodon* Ridl. (from Sumatra).

Table 5.1: Sequence characteristics (ITS1 and ITS2)

Parameter	**ITS1 and ITS2**
Length range (total) (bp)	473-527
Length mean (total) (bp)	495
Length range (ingroup) (bp)	473-527
Length mean (ingroup) (bp)	495
Length range (outgroup) (bp)	498
Aligned length (bp)	583
G+C content range (%)	52.7-61.6
G+C content mean (%)	57.9
Number of excluded sites (%)	8.92
Sequence divergence (ingroup) (%)*	0-18.5
Sequence divergence (in/outgroup) (%)*	13-19.3
Number of indels (total)*	21
Size of indels (total)*	1-10
Number of sites after exclusion*	552
Number of variable sites*	324
Number of constant sites (%)*	41.3
Number of informative sites (%)*	37
Number of autapomorphic sites (%)*	21.7
Transitions (min-max)*	491-497
Transversions (min-max)*	277-286
Mean No.Transitions/Mean no. transversions*	1.72

*Based on alignment excluding ambiguous sequence sites

Table 5.2. Sequence divergence figures (ITS1 and ITS2)

GROUP	ITS1 and ITS2 Sequence divergence (%)
Ingroup/Outgroup	13-19.3
Ingroup	0-18.5
Peninsular Malaysian species	0.45-13.3
Dissimiles species	3.1-9.1
Dissimiles & east Wallace	8-18.1

5.3.2 Phylogenetic patterns

Parsimony analysis of unambiguously aligned ITS sequences yielded 12 most parsimonious trees of 821 steps when the gaps were added to the data matrix (consistency index [CI] = 0.57; retention index [RI] = 0.69). Reweighting yielded a single most parsimonious tree. Figure 5.2 is a phylogram, showing branch lengths, of one of the 12 most parsimonious trees. Sensitivity analyses all resulted in an identical strict consensus topology.

The strict consensus tree (figure 5.3) displays bootstrap (BS) values and decay indices (DI). Figure 5.4 is a maximum likelihood tree with Bayesian majority rule consensus percentages assigned to nodes where applicable. Peninsular Malaysian *Cyrtandra* are present in numerous different clades on the strict consensus tree (figure 5.3). In order to be consistent with chapter three, these clades will be referred to as i) group one (Peninsular Malaysian, Sumatran and Bornean as well as *C.* sp. Lantuyang from Mindoro) ii) group two (section *Dissimiles*) iii) group three (Peninsular Malaysian and Sumatran shrubby), and in addition, iv) group four (*wallichii* and *cuprea*).

In group one (BS89, DI+5, Bayesian 75), the Peninsular Malaysian collections *C.* aff. *wallichii* GB32 and FRI44491 are sister to the Sumatran *C. rhyncanthera* C.B.Clarke. The Malaysian collection of *C. pendula*, a species that is distributed from Java, across Sumatra to and within the Malay Peninsula, appears as

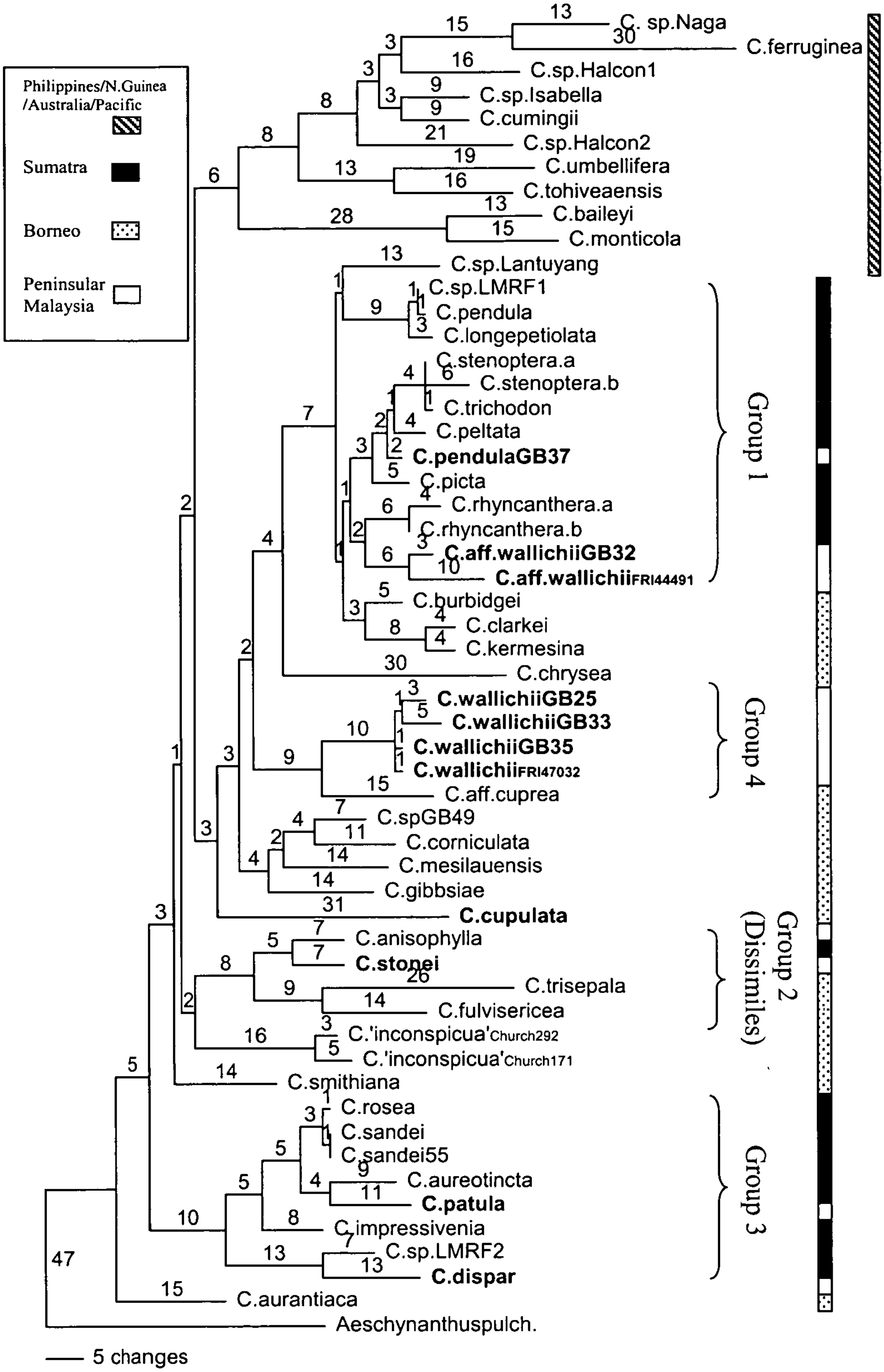

Figure 5.2. Phylogram, one of twelve most parsimonious trees based on parsimony analysis of ITS sequence data and the alignment gap matrix. Numbers indicate branch lengths. Species from Peninsular Malaysia are in bold. Bars show the geographical distribution of the species.

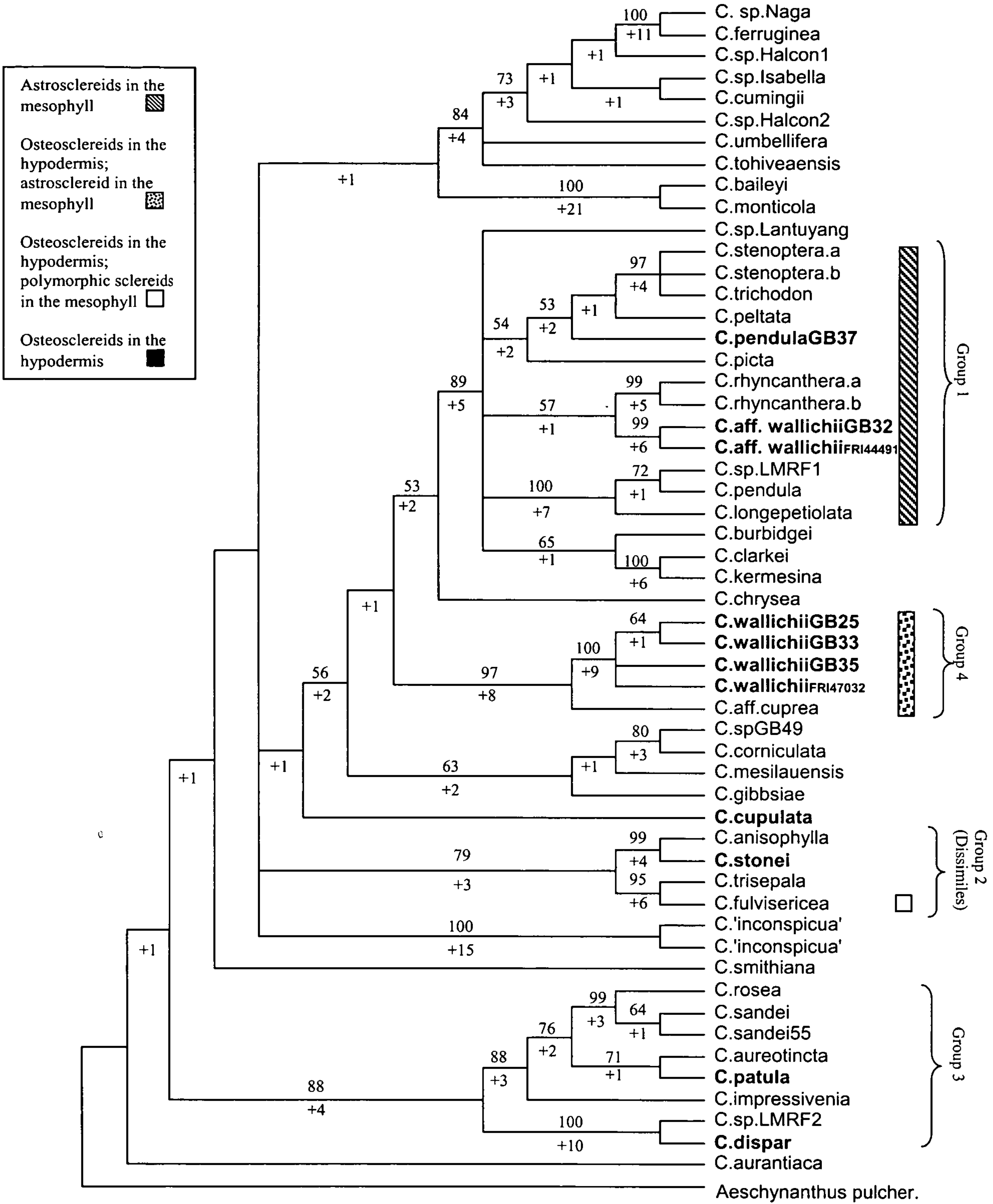

Figure 5.3. Strict consensus tree of twelve most parsimonious trees of 821 steps based on parsimony analyses of ITS sequence data and alignment gap matrix. Numbers above the branches are Bootstrap values, numbers below are Decay Indices. Species from Peninsular Malaysia are in bold. Bars denote the pattern of foliar sclereids.

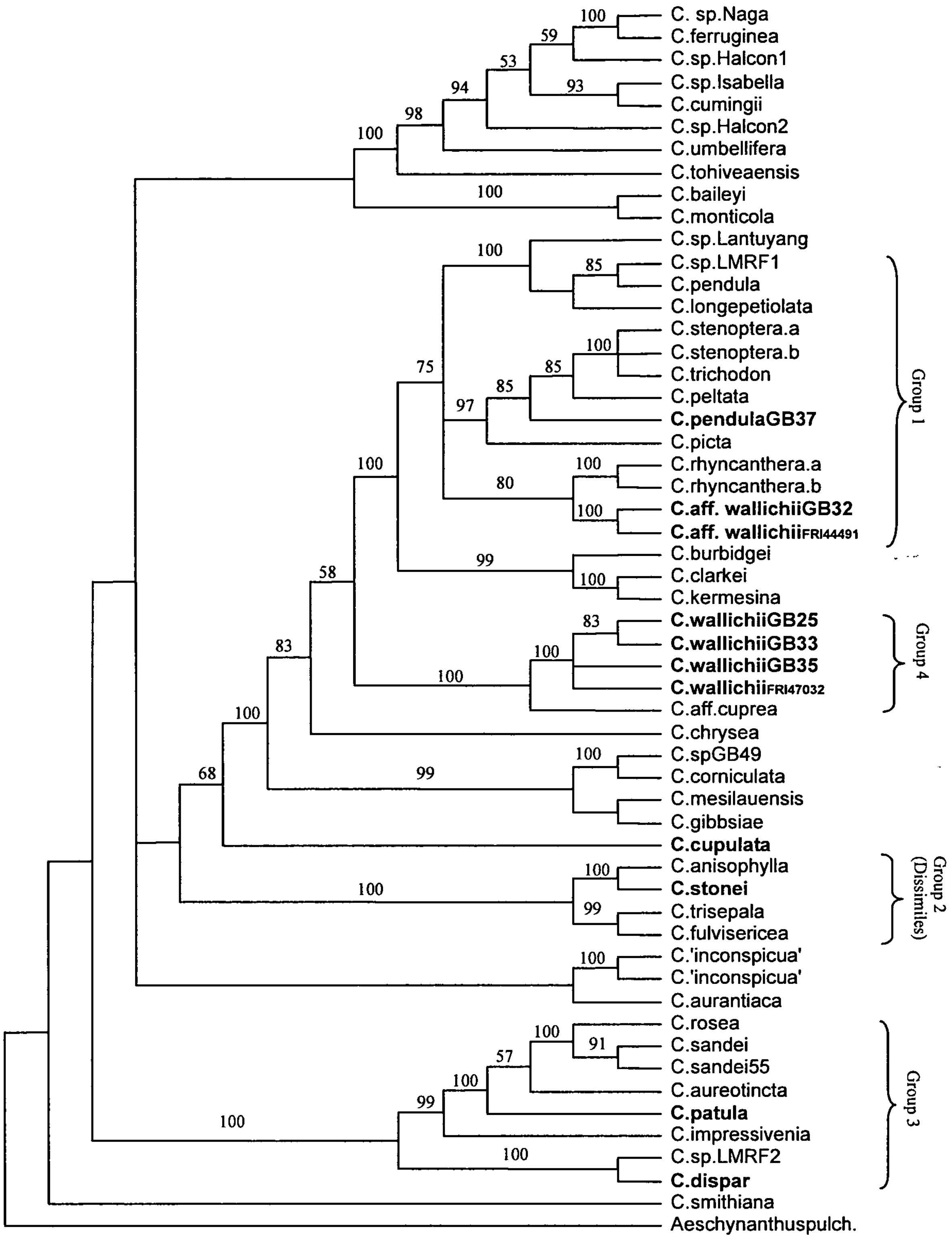

Figure 5.4. ML tree. Values on nodes are the Bayesian majority rule consensus percentages. Species from Peninsular Malaysia are in bold.

sister to different Sumatran species, *C. picta* Blume and *C. peltata* Jack, to the Sumatran collection of *C. pendula*, which is sister to *C.* sp. LMRF1 and *C. longepetiolata*.

Group two (*Dissimiles*) is well supported (BS79 DI+3 Bayesian 100). *Cyrtandra stonei* is in this clade, as would be expected, its closest relative being the Sumatran *C. anisophylla* (Bramley *et al.* 2004b; chapter 4 of this thesis).

Group three remains much as described in chapter three, strongly supported (BS88 DI +4 Bayesian 100), with the addition of two Peninsular Malaysian species, *C. dispar* and *C. patula*. *Cyrtandra patula* is sister to the Mount Kerinci endemic *C. aureotincta*, and *C. dispar* to *C.* sp. LMRF2.

The multiple accessions of *C. wallichii* form a small strongly supported group (BS100 DI +9 Bayesian 100) with their closest relative appearing to be a collection from Kalimantan that bears an affinity to *C. cuprea*. The *C. wallichii* accessions, collected from different locations in Peninsular Malaysia, show a small amount of variation between them (0.45-1.55% sequence divergence).

One Peninsular Malaysian species, *C. cupulata*, is on a long branch sister to the largest clade containing Bornean and Sumatran species (including group one). There is no bootstrap or Bayesian support for its position, but a decay index of +1.

The species from Kalimantan also appear in various groups. As expected, *C. trisepala* C.B.Clarke (chapter six) is in group two, the *Dissimiles* clade. *Cyrtandra* sp. GB49 (aff. *C. prostrata*) is most closely related to *C. corniculata* B.L.Burtt from Sabah (BS80 DI+3 Bayesian 100). *Church* 171 and *Church* 292 appear sister to each other (BS100 DI+15 Bayesian 100): they are likely to be the same species, and have been preliminarily identified as *C. inconspicua* B.L.Burtt *ined.*

As in chapter three, the *Cyrtandra* from areas outside of Sundaland (the Philippines, Australia, New Guinea, the Pacific and Taiwan) form a separate clade to *Cyrtandra* from Sundaland, with the exception of *C.* sp. Lantuyang, from Mindoro, the Philippines.

The ML tree topology (figure 5.4) is very similar to the MP trees, but the ML tree provides more resolution in the deeper nodes, and the positions of *C. smithiana* B.L.Burtt and *C. aurantiaca* B.L.Burtt are altered. The Bayesian analysis also gave a similar tree, but all deeper nodes collapse making *Cyrtandra* a polytomy; this tree is not shown but the Bayesian majority rule consensus percentages are plotted on the ML tree in figure 5.4. The majority of nodes supported in the MP analysis are also supported in the Bayesian analysis.

5.4 DISCUSSION

5.4.1 Affinities and origins of the Peninsular Malaysian *Cyrtandra* Flora

Peninsular Malaysia is on the fringe of the *Cyrtandra* distribution, and has far fewer species of *Cyrtandra* (nine species; see chapter four of this thesis), than its two neighbouring islands, Borneo (c. 120 species) or Sumatra (c. 49 species) than might be expected: it seems there has not been radiation of lineages. This is reflected in the phylogeny, in which the Peninsular Malaysian species are scattered throughout the major clades, with no two different Malaysian species being sister to each other. It can also be said with some confidence that the origin of the genus is not likely to have been on mainland Asia. This suggests a migration of several lineages from Sumatra and Borneo to the peninsula and a small degree of speciation e.g. *C. stonei* (group two), and *C. patula* (group three), from Sumatran relatives. *Cyrtandra dispar* (group 3), has dispersed from Sumatra to the peninsula, widening its distribution.

As suggested in the introduction, the Peninsular Malaysian *Cyrtandra* species seem to have either an affinity with Bornean or Sumatran species. These are discussed in four groups below.

5.4.1.1 a) Endemic Peninsular Malaysian species with a Sumatran affinity

Cyrtandra patula, *C. stonei*, and *C.* aff. *wallichii* are all sister to Sumatran species, and are all found on the west side of the Peninsula only (see distributions in chapter four). *Cyrtandra stonei* is endemic to the Genting Highlands; *C. patula* occurs in the western Main range and in southern Thailand, and *C.* aff. *wallichii* has been collected from the Cameron Highlands and Kelantan. This highlights a link between species distributed on the west side of the Peninsula and Sumatran species. Indeed, the wider sister groups of *C. patula* and *C.* aff. *wallichii* are also Sumatran. This pattern follows the observation and recognition by Corner (1960), of a distinct floristic area along the west coast of Peninsular Malaysia where there is much similarity to the Sumatran flora. This has also been recognised and predicted in general and in specific genera or families e.g. Ridley (1937); Dipterocarpaceae (Ashton, 1992); *Aeschynanthus* (Mendum, pers. comm.).

5.4.1.2 b) Sumatran/Javan species that have extended their range to Peninsular Malaysia

There are two Peninsular Malaysian *Cyrtandra* species that also occur in Sumatra and/or Java, and therefore provide further evidence for Corner's west coast floristic area. The first is *C. pendula*, a rare example of a *Cyrtandra* species found in Java, Sumatra and the Malay Peninsula. It is not found in Borneo, which perhaps suggests that it spread to the Peninsula via Sumatra. The phylogeny includes two accessions of *C. pendula*, one from Sumatra, and one from Peninsular Malaysia (*C. pendula*GB37). Unexpectedly, they appear in two different positions in the phylogeny, as sister to different Sumatran species. The most credible position is that of the Sumatran *C. pendula*, which is sister to *C. longepetiolata* and *C.* sp. LMRF1. The unexpected position of *C. pendula*GB37 might lead to speculation that a morphologically cryptic species exists within *C. pendula*. Alternatively it might suggest a hybridisation event has occurred, and that *C. pendula*GB37 has a different copy of the ITS region to the Sumatran *C. pendula*.

The second Peninsular Malaysian species that is also found in Sumatra is *C. dispar*, which is distributed in the north, east and possibly west of Sumatra. The Peninsular Malaysian accession of *C. dispar* appears as sister to *C.* sp. LMRF2 that vegetatively bears an affinity to *C. dispar*, but the voucher specimen is sterile making a definite identification difficult. *Cyrtandra dispar* appears to have migrated across to the north west of the Malay Peninsula - it is found in Penang, Perak, Kelantan and southern Thailand.

5.4.1.3 c) Endemic Peninsular Malaysian species with Bornean affinity

Cyrtandra wallichii, widespread in Peninsular Malaysia, appears in the phylogeny as sister to an accession from Kalimantan that bears an affinity to *C. cuprea* B.L.Burtt. It is likely to be part of a Bornean lineage, and therefore to have reached the Peninsula by way of migration from Borneo. Indeed, the accessions of *C. wallichii* and *C.* aff. *cuprea* are basal to a larger group of Bornean and Sumatran species. *Cyrtandra cuprea* shares a number of morphological characters with *C. wallichii*, such as a large silky hairy corolla, and a membranous calyx through which the corolla seems to break on maturation (see chapter four). It belongs to a group containing other Bornean species, *C. erectipila* B.L.Burtt and *C. subgrandis* B.L.Burtt, all sharing the same sclereid pattern of astrosclereids in the mesophyll and osteosclereids in the hypodermis (Burtt, 1978). *Cyrtandra wallichii* could be representative of Corner's Riau Pocket floristic area, with later migration throughout the Malay Peninsula.

5.4.1.4 d) Endemic Peninsular Malaysian species with no obvious affinities

The Peninsular Malaysian endemic *C. cupulata* does not appear to be closely related to any of the species within the sample. It appears on a long branch, in an unsupported position, basal to *C. mesilauensis, C. gibbsiae* and *C. corniculata* clade and the large clade containing most of the Bornean species.

In regard to further exploring the Riau pocket floristic area and its relevance to *Cyrtandra*, it would have been interesting to sequence *C. suffruticosa*, but unfortunately the ITS region could not be amplified from the material available. *C.*

suffruticosa is from the east coast of the Peninsula and Pulau Tioman, although it has also been recorded from a small area on the west coast (see chapter four). Studies on the flora of Pulau Tioman, an island lying about 20 miles from the mainland of the Peninsula (Stone, 1977) and comments on the flora of the East coast of the Peninsula (Ridley, 1893) have suggested an affinity with the Bornean flora.

5.4.2 Historical explanations for present day distributions

Palaeogeography suggests that lower sea levels in Pleistocene climate fluctuations exposed parts of the Sunda shelf that are now submerged, revealing land bridges between the Malay peninsula, Sumatra and Borneo (Voris, 2000). This is likely to have allowed migration between the areas. The climate fluctuations also meant drier times, causing rain forest to retreat into refuge areas such as the Barisan range of Sumatra, and some of the large rivers draining the Sunda shelf probably also provided refugia along their banks (Gathorne-Hardy *et al.*, 2002). These periods of greater exposure of the Sunda shelf seems to explain the similarities of floras and Corner's floristic areas of the west coast and Riau pocket. This can be seen in a number of families such as the Dipterocarpaceae, where relict distributions of some species certainly reflect a more extensive former community of particular habitats (Ashton, 1982).

Gathorne-Hardy *et al.* (2002), and Meijaard (2003) speculate that Peninsula Malaysia was predominantly an area of savanna during the drier climatic periods with the possible exception of rain forest refuge sites that may have occurred along rivers. Gathorne-Hardy *et al.* (2002) discussed termite, fossil and palynological data and showed that there appears to have been more refuge sites on Sumatra and Borneo, so perhaps the suggestion that there were fewer rain forest refugia on Peninsular Malaysia could explain the lack of endemic *Cyrtandra* species there compared to Borneo or Sumatra. In addition, drier climatic periods could explain the isolation of species such as *C. stonei*, which, in such periods, is likely to have become restricted to the peak of Gunung Ulu Kali in the Genting Highlands, to which it is now endemic.

5.4.3 Section *Dissimiles* and its sister taxa

The phylogeny does not give clear evidence to allow the identification of the sister taxa of section *Dissimiles*. In the strict consensus tree, section *Dissimiles* forms part of a large polytomy, but from the phylogram (figure 5.2), a candidate sister taxon is *C. inconspicua*, an unpublished species from Kalimantan. However, sampling of the genus needs to be more thorough before we can conclude anything with confidence.

5.5 PHYLOGENETIC ANALYSES OF THE *trn*L-F REGION

5.5.1 Introduction

This short section attempts to provide confidence in the use of ITS for reconstructing the phylogenetic history of *Cyrtandra* by performing analyses of the *trn*L-F region of the chloroplast genome. If the ITS phylogeny is an approximation of true phylogenetic history, it should be congruent with a phylogeny produced using *trn*L-F sequences from the independent, maternally inherited chloroplast genome. Due to time limitations, the sample sequenced for *trn*L-F is a subsample of the species sequenced for ITS.

The advantages of the chloroplast genome for phylogenetic reconstruction in angiosperms are shown by its wide use (Soltis & Soltis, 1998). Nuclear genes, are often members of multigene families whereas chloroplast regions are only present as single copies (Soltis & Soltis, 1998). It is also inherited uniparentally, usually through the maternal line in angiosperms, therefore allowing the detection of hybridisation events. The *trn*L-F region is frequently used in phylogenetic reconstruction (e.g. Bakker *et al.*, 1999; Fernandez *et al.*, 2001; Plana, 2002) and consists of the *trn*L intron, the small *trn*L 3' exon and adjacent *trn*L-F spacer. In the family Gesneriaceae the *trn*L-F region has been suggested to be evolving at a rate five times slower than ITS (Möller *et al.*, 1999). In *Cyrtandra* it might therefore be expected to resolve more fully the more basal nodes of the genus, that appear unresolved in the ITS phylogenies.

5.5.2 Materials and Methods

5.5.2.1 Outgroup and ingroup taxa

Following the previous analyses, *Aeschynanthus* was used as the outgroup genus. In this case three accessions of *Aeschynanthus* were used: *A. bracteatus*, *A. longiflorus* and *A. sp.* Sequences were obtained from M. Möller (RBGE).

5.5.2.2 DNA extraction, PCR and sequencing protocol

DNA had previously been extracted from the samples sequenced (see chapter three and appendix 3). The complete *trn*L-F region was amplified using the Polymerase Chain Reaction (PCR) with the primers (all Taberlet *et al.*, 1991) '*trn*L c' (forward) CGA AAT CGG TAG ACG CTA CG, and '*trn*L f' (reverse) ATT TGA ACT GGT GAC ACG AG. The PCR mixture and PCR program are described in appendix 5. Following successful amplification, the PCR product was purified using the QIAquick PCR purification kit (Qiagen Ltd., Crawley, W.Sussex, UK).

Sequencing primers were identical to those used for PCR but in addition, to ensure that the whole *trn*L-F region was sequenced in both directions, the internal primers '*trn*L d' (reverse) GGG GAT AGA GGG ACT TGA AC and '*trn*L e' (forward) GGT TCA AGT CCC TCT ATC CC were used (Taberlet *et al.* 1991).

The purified PCR products were sequenced as in appendix 6.

5.5.2.3 Analysis of sequence data

Sequences were imported into Sequence Navigator (Version 1.0.1, Perkin Elmer, Applied Biosystems Division, Foster City, CA, USA) and aligned manually. Alignment of the 26 *trn*L-F sequences resulted in an 894 bp long matrix. Sequence characteristics were calculated using PAUP Version 4.010b (Swofford, 2001) except for the transition/tranversion ratio, which was determined using MacClade Version 3.07 (Maddison and Maddison, 1997).

Phylogenetic trees were generated using PAUP Version 4.07b. Maximum parsimony analyses involved a heuristic search strategy with 10,000 random stepwise addition sequence replicates and TBR branch swapping with the option 'collapse branches if minimum length is zero' selected. Only the combined intron and spacer were subjected to analyses. Individual gap characters were treated as missing data and gaps were coded as additional characters according to Simmons & Ochoterena (2000). To investigate the effects of the additional gap characters, a sensitivity analysis (Wheeler, 1995) was carried out without them.

Bootstrap values (Felsenstein, 1985) were calculated from a 10,000 replicate analysis using a heuristic search strategy with simple addition of the taxa, MULTREES option off and TBR branch swapping. Decay indices were determined by running the programme AutoDecay (Eriksson, 1998) in conjunction with PAUP version 4.07b (Swofford, 2001).

5.5.3 Results

5.5.3.1 Sequence characteristics

The average length of the *trn*L-F region was 852 bp. Alignment of all taxa required the insertion of 18 gaps of which five were phylogenetically informative. The *trn*L-F region shows little variation: 91% of sites were constant, 3.4% phylogenetically informative and 5.6% autapomorphic.

Pairwise comparisons of individual taxa across both intron and spacer regions showed that within the ingroup, sequence divergence (see table 5.4) ranged from 0-1.68%, and from 1.54-3.8 % between the ingroup and the outgroup. The Peninsular Malaysian species showed divergence of 0.35-1.66%, with the maximum divergence between *C. patula* and *C. stonei*. Within section *Dissimiles*, sequence divergence was 0.01-1.07%, with the most divergence between *C. fulvisericea* and *C. stonei*. The maximum sequence divergence in each group of species shown in table 5.4 is approximately 5-9 times slower than sequence divergence in ITS.

Table 5.3. Sequence characteristics (*trn*L-F region)

Parameter	***trn*L-F**
Length range (total) (bp)	839-866
Length mean (total) (bp)	852
Length range (ingroup) (bp)	839-857
Length mean (ingroup) (bp)	851
Length range (outgroup) (bp)	850-866
Aligned length (bp)	894
G+C content range (%)	34.3-35.6
G+C content mean (%)	35.2
Number of excluded sites (%)	0
Sequence divergence (ingroup) (%)	0-1.68
Sequence divergence (in/outgroup) (%)	1.53-3.8
Number of indels (total)	18
Size of indels (total)	1-15
Number of sites after exclusion	n/a
Number of variable sites	81
Number of constant sites (%)	91
Number of informative sites (%)	3.44
Number of autapomorphic sites (%)	5.56
Transitions (min-max)	37-38
Transversions (min-max)	54-56
Mean no. transitions/Mean no. transversions	0.69

Table 5.4. Sequence divergence figures (*trn*L-F region).

GROUP	*trn*L-F Sequence divergence (%)
Ingroup/Outgroup	1.54-3.8
Ingroup	0-1.68
Peninsular Malaysian species	0.35-1.66

5.5.3.2 Phylogenetic patterns

Parsimony analysis of unambiguously aligned *trn*L-F sequences yielded eight most parsimonious trees of 92 steps when the gaps were added to the data matrix (CI = 0.96, RI= 0.94). Figure 5.5 is a phylogram, showing branch lengths, of one of the eight most parsimonious trees. Analyses excluding the gap matrix resulted in a less resolved topology, with the two accessions of *C. pendula* and *C. longepetiolata* forming part of the large polytomy, not appearing as sister species.

The strict consensus tree shows bootstrap and decay indices (figure 5.6). The tree does not show much resolution, most of the species appearing in a large polytomy (BS 66 DI +1). Sister to the polytomy is the well-supported species pair *C. mesilauensis* and *C. gibbsiae* (BS 84, DI +2). Within the large polytomy there are four distinct groups: *C. clarkei* and *C. kermesina* (BS 63, DI +1); *C. aureotincta*, *C. patula* and *C. impressivenia* (a subsample of 'group three' described in chapters three and earlier in this chapter; BS 90, DI +2); two accessions of *C. pendula* and *C. longetiolata* (BS 63 DI +1); and section *Dissimiles* (BS 87 DI +2). *C. smithiana* appears as basal to section *Dissimiles* but is weakly supported (BS 55 DI +1).

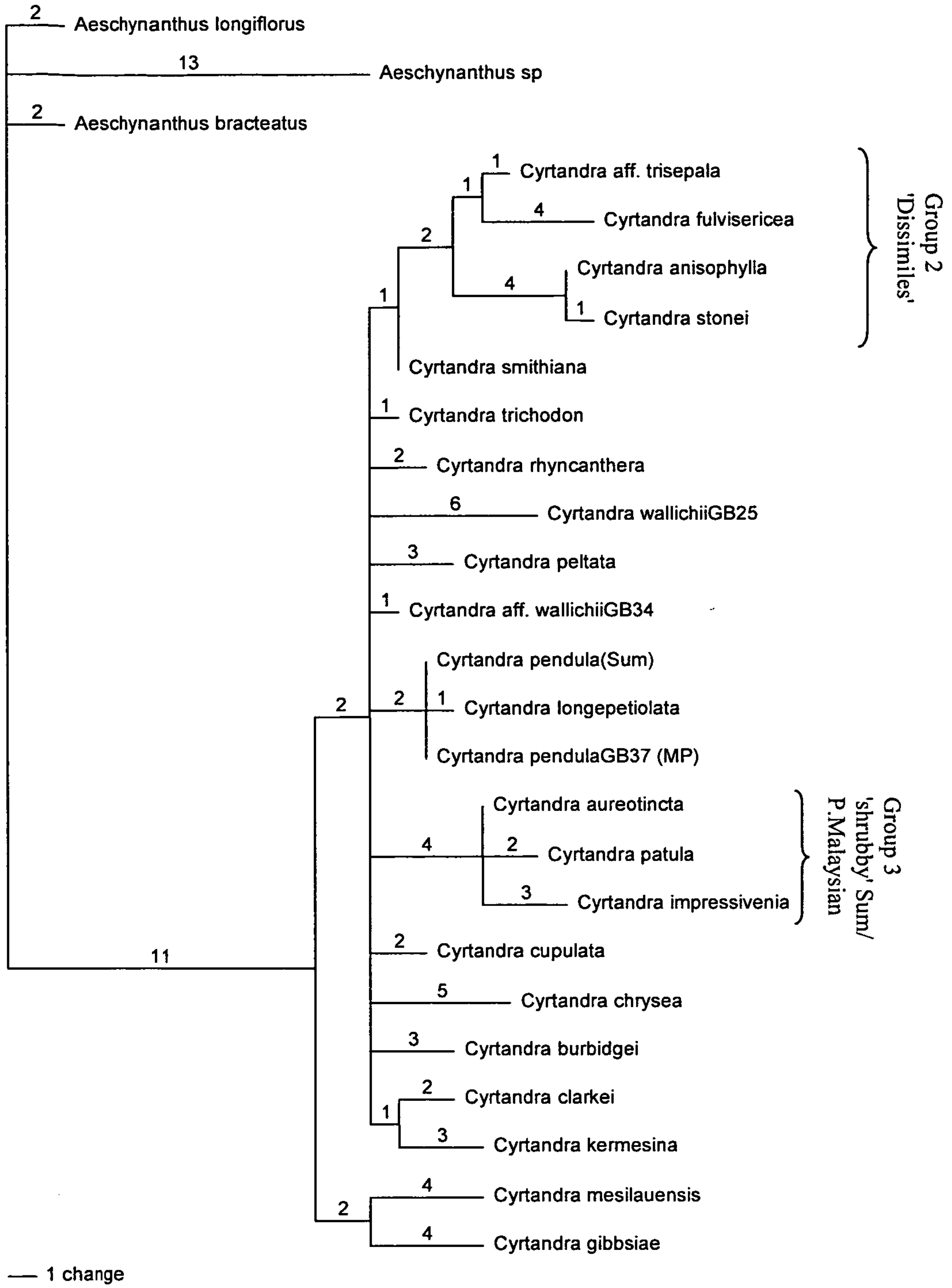

Figure 5.5. Phylogram, one of eight most parsimonious trees based on parsimony analyses of *trn*L-F sequence data and the alignment gap matrix. Numbers indicate branch lengths.

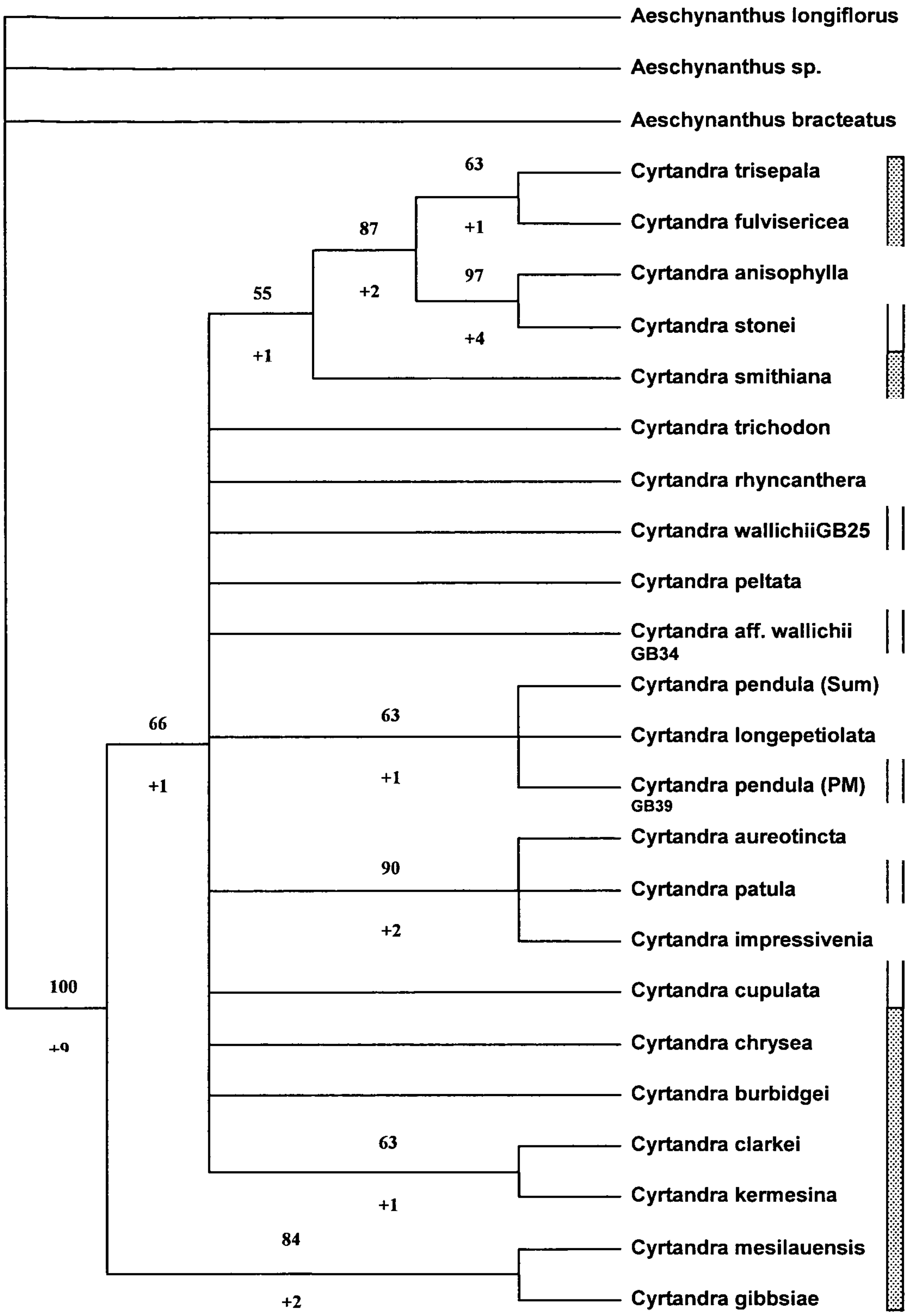

Figure 5.6. Strict consensus tree of one of eight most parsimonious trees of 92 steps, based on parsimony analysis of *trn*L-F sequence data and the alignment gap matrix. Numbers above the branches are Bootstrap values, numbers below are Decay Indices. Bars denote the geographical distribution of the species: spotted = Borneo; black=Sumatra; white=Peninsular Malaysia.

5.5.4 Discussion

5.5.4.1 Congruence with the ITS phylogeny

Although the sample sequenced for the *trn*L-F region was a subset of the sample sequenced for ITS, it is still possible to examine congruence between the data sets by comparing the topology of the phylogenies produced.

Although *Cyrtandra* shows much less divergence in *trn*L-F sequences than ITS, some of the major groups that appeared in the ITS phylogeny are also represented in the *trn*L-F phylogeny. These are group three, the predominantly shrubby Sumatran clade, and section *Dissimiles*. Elements of group one are also present, since the *C. pendula* accessions and *C. longepetiolata* group, and in addition, two further species pairs, in both cases Bornean, are present (*C. mesilauensis* and *C. gibbsiae*; *C. clarkei* and *C. kermesina*).

The two *C. pendula* accessions have identical *trn*L-F sequences, both appearing in a small clade with *C. longepetiolata* in the *trn*L-F phylogeny. This matches the position of the Sumatran *C. pendula* in the ITS phylogeny. The somewhat unexpected relationship between *C. pendula*GB37, and *C. peltata* and *C. trichodon*, suggested by the ITS phylogeny, is not supported by the *trn*L-F phylogeny. This suggests that it is unlikely that the different positions of *C. pendula* in the ITS phylogeny can be explained by the existence of a morphologically cryptic species. It is more tempting to speculate that a hybridisation event has occurred, and that different copies of ITS were sequenced from the two *C. pendula* accessions, one maternal (from *C. pendula*) and one paternal (from another species). This problem can be highlighted using chloroplast DNA since it is only inherited maternally.

In conclusion, the data suggest that there is congruence between the ITS and *trn*L-F data, and therefore that confidence can be held in the observations made using the ITS phylogeny in chapter three and earlier in this chapter.

5.6 ADVANTAGES AND DISADVANTAGES OF THIS MOLECULAR PHYLOGENETIC REGIONAL APPROACH

A regional approach to molecular phylogenetic analyses is valuable from the point of view of identifying phytogeographic regions and providing evidence for such areas of floristic similarity. The resulting phylogenies also allow historical distributions and biogeography to be considered.

The main difficulty with this approach is with sampling - which species should be included from other areas within the distribution of a genus in order to assess the affinities of a genus from a particular region? In *Cyrtandra* this is not presently an issue due to a shortage of material suitable for DNA extraction. A more appropriate problem is acquiring sequences for all a region's species.

This approach highlights the need to increase our collection of material for DNA extraction. It also demonstrates the importance of including multiple accessions of the same species, especially those that occur in more than one region, such as *C. pendula*, in order to uncover possible cryptic species or detect possible hybridisation events.

Both this chapter and chapter three show how molecular phylogenies can help in the identification and confirmation of monophyletic groups within a genus. This often corroborates previously known morphological evidence as shown in the example of *Cyrtandra* section *Dissimiles*, and can lead to a revision being undertaken with more confidence in the monophyly of a group (chapter six).

6 CHAPTER SIX: REVISION OF THE SPECIES OF *CYRTANDRA* (GESNERIACEAE) SECTION *DISSIMILES* C.B.Clarke

This chapter represents a monographic and phylogenetic taxonomic approach to *Cyrtandra* taken in this thesis. It is a taxonomic revision of *Cyrtandra* section *Dissimiles* C.B.Clarke, a monophyletic group recognised in both the molecular phylogenetic chapters (three and five) of this thesis.

6.1 INTRODUCTION

In the last overall treatment of *Cyrtandra*, Clarke (1883) recognised 164 species, which he divided into 13 sections, and in doing so is the only botanist to attempt a sectional classification of the whole genus (Burtt, 2001b). However, the species groups forming all the sections proposed in Clarke's treatment would not now be classified together (Burtt, 1990). Hence, Clarke's sections have been abandoned and currently, there is no satisfactory infrageneric classification for the genus.

Other attempts at sectional classification have been based on *Cyrtandra* species from particular geographical areas: for example, Hillebrand (1888) proposed that the Hawaiian species could be assigned to five sections, to which St John (1966, 1987) added a further two. Currently, the 50 Hawaiian *Cyrtandra* species are classified into six sections, based on Hillebrand's (1888) original arrangement (Wagner *et al.*, 1990, 1999).

In addition, Schlecter (1923) created 26 sections in his treatment of the genus in New Guinea. In West Malesia, Burtt (1990) has adopted some of Clarke's names for groups of species that are linked by distinct suites of morphological characters. In total, there are 40 validly published sectional names existing in *Cyrtandra* (Burtt, 2001b). However, most species are not assigned to sections (e.g. Atkins & Cronk, 2001; Burtt, 1970, 1978, 1990; Bramley & Cronk, 2003/chapter two of this thesis; Bramley *et al.*, 2004b/chapter four of this thesis). Recently, work has begun to describe individual sections, starting with Bornean species groups (e.g. Hilliard *et al.*, 2003).

Section *Dissimiles* C.B.Clarke is one of the morphologically well-marked groups recognised by Burtt (1990). The molecular phylogenetic analyses in chapters three and five suggest that the section can also be defined by molecular synapomorphies. Contrary to usual practice where a section is named after its type species such as section *Decurrentes* C.B.Clarke where *C. decurrens* is the type species, *C. dissimilis* was placed by Clarke (1883) in section *Whitia* (Blume) C.B.Clarke. Section *Dissimiles* therefore required lectotypification (Burtt, 1990). Burtt chose *C. trisepala* C.B.Clarke, as it was the only species to be illustrated by Clarke and clearly shows the characters defining the section. Clarke (1883) had also included a number of species that do not belong in the section, such as *C. calycina* Benth. (New Guinea), and *C. incisa* C.B.Clarke (Philippines), a decision perhaps understandable given the inadequate material he had to study.

There are eleven species recognised in this treatment of section *Dissimiles*; one species is new, and one species is reduced to synonymy. Section *Dissimiles* is centred on Borneo, with two outlying species in Sumatra (*C. anisophylla* C.B.Clarke and *C. beccarii* C.B.Clarke) and one in Peninsular Malaysia (*C. stonei* B.L.Burtt).

No single morphological character defines section *Dissimiles*, indeed many of the characters occur individually in other groups within the genus; it is a combination of characters that is unique to this group. The most distinctive characters are:
i) anisophylly - in most cases the leaves in a pair are not equal in size. One member of the pair develops fully, but the other remains small and stunted, often resembling a stipule. Very occasionally specimens are found with leaf pairs in which both members are more or less equal in size.
ii) calyx - the calyx is zygomorphic: the upper three lobes are fused to form one but the tips remain free, and the lower two lobes are completely divided to the base. A typical *Cyrtandra* calyx is more regular, taking the form of a tube either with five

more or less even lobes, or with three upper lobes that are shaped differently from the two lower lobes (see chapters two and four).

iii) corolla - the corolla is small (generally less than 2 cm long), predominantly white but sometimes with a greenish or pinkish tinge, quite fleshy and almost translucent or with translucent lines.

Other features common to the species within the section are not as diagnostic, but collectively help to assign species to the section. The species all share a glandular hairy style, and they have a typical leaf venation pattern in which only the midrib and lateral nerve pairs are visible, and sometimes a marginal vein. There is a strong tendency for the two upper lobes of the corolla to be shorter and with a much shallower division between them than the lower three lobes, and the corolla wall often bulges outwards immediately behind the two upper lobes, resulting in an internal hollow in front of which the anthers lie. This hollow is often filled with glandular hairs. The stamens have glandular hairs or glands on the filaments and connectives. The fruit is characteristically fleshier than it is in other western Malesian *Cyrtandra* species, where it is hard (sclerocarpous). Further characters define groups of allied species within the section, such as toothed leaf margins and flaky bark; these are discussed in the species notes.

6.2 KEYS AND DESCRIPTIONS

The following keys and descriptions present the 11 *Cyrtandra* species here recognised in section *Dissimiles*.

In the keys and descriptions:

i) Measurements are given for leaves presumed to be mature, and their shape is described following Hickey (1979). The larger member of a pair is referred to as the major leaf, and the smaller member as the minor leaf.

ii) All measurements of floral characters were taken from herbarium material that had been rehydrated and softened in spirit, or from spirit collections.

iii) All details of plant heights and colours in the descriptions are taken from the collectors' notes on specimen labels.

iv) All locations follow the American National Imagery and Mapping Agency's (NIMA) GEOnet Names Server (http://164.214.2.59/gns/html/index.html

v) All measurements refer to length unless stated otherwise.

vi) *Cyrtandra* flowers are protandrous, therefore flowers examined are either immature, or in the male phase (the stamens dehiscing and gynoecium not at mature length), or the female phase (the stamens having recoiled back into the corolla tube after dehiscence, and the gynoecium at full length) of development. Effort has been made to describe both male and female organs when mature, however, when this was not possible it is noted.

vii) All specimens cited have been seen by the author, unless stated otherwise.

Cyrtandra J.R. & G.Forst., *Char. gen. pl.* 5 (1776)

Cyrtandra sect. **Dissimiles** C.B.Clarke in A. & C. DC., Monogr. phan. 5: 249. 1883.
Lectotype: *C. trisepala* C.B.Clarke (Burtt, 1970).

Terrestrial or epiphytic perennial herbs, shrubs or small trees. *Leaves* simple, petiolate, opposite; the leaves in a pair very occasionally subequal, most commonly anisophyllous (one member of a pair very reduced in size); the lamina hairy to glabrous above, below either glabrous or somewhat hairy with only the midrib and lateral nerve pairs visible and slightly raised, sometimes connected by a skirting marginal vein. *Inflorescence* in the upper leaf axils; sessile, subsessile or pedunculate; flowers few to many in pair-flowered cymes. *Bracts*[1] often partly enclosing the inflorescence. *Calyx* zygomorphic, the upper three lobes fused to form one, the apex divided into three tips; the lower two lobes divided to the base; calyx apparently persistent or caducous in fruit. *Corolla* five-lobed, lobes often subequal, slightly bilabiate with the two upper lobes usually distinguishable from the three lower; usually white with a greenish or pinkish tint, the throat often marked with yellow, red, brown or purple, often with translucent lines. *Fertile stamens* 2. *Staminodes* 3, if present. *Gynoecium* ovary superior, hairy or glabrous; placentation

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[1] The term "bracts" is used here for the first pair of bracteoles (prophylls) of the axillary cyme. In *Cyrtandra* these are usually more prominent than the subsequent bracteoles.

parietal; style with glandular hairs, stigma with two median lobes. *Disk* cupular. *Fruit* a somewhat fleshy berry, more or less globose to ovate or conical.

6.2.1 Key

1a. Margins of the major leaf in a pair distinctly serrate to shallowly serrate or dentate..2
1b. Margins of the major leaf in a pair more or less entire..7

2a. Bark tessellate or roughened with a tendency to become flaky near the tops of stems..3
2b. Bark smooth or striate or wrinkled in places...4

3a. Bark tessellate; outer surface of bracts glabrous; the fused upper lobe of the calyx narrowly obovate, apex divided into three rounded tips each c. 2 mm long with short thickened points at the very top; corolla white or cream with a yellow palate...**8. C. impar**
3b. Bark roughened especially near the tops of stems; outer surface of bracts with short hairs; the fused upper lobe of the calyx almost lanceolate or narrowly elliptic, apex divided into three very narrow triangular tips, each c. 1.5 - 2 mm long, thickened; corolla pink with red marks on the floor of the tube.........**9. C. rubropicta**

4a. Lower surface of the major leaf in a pair glabrous...5
4b. Lower surface of the major leaf in a pair with some hairs especially covering the venation...6

5a. Major leaf in a pair 15 - 22 x 5 - 7 cm; bracts narrowly ovate to lanceolate, 1 - 2 cm long; the fused upper lobe of the calyx narrowly ovate, the apex divided into three thickened acuminate tips, each one c. 1.5 - 2 mm long (Peninsular Malaysia)..**6. C. stonei**
5b. Major leaf in a pair 15 - 29 x 6.5 - 12 cm; bracts broadly ovate, c. 1 cm long; the fused upper lobe of the calyx obovate, the apex divided into three rounded tips, each one c. 1 mm (Sumatra)..**4. C. anisophylla**

6a. Fused upper lobe of the calyx widely obovate, the apex divided into three wide rounded tips, c. 3 - 5 x 3 - 6 mm, not thickened; corolla up to 3 cm; margins of major leaf serrate, the serrations widely spaced, either quite shallow or up to 2 mm deep; the lower leaf surface with a few rough hairs on the midrib and lateral nerve pairs..**7. C. weberi**

6b. Fused upper lobe of the calyx obovate, the apex divided into three rounded triangular tips, c. 3 mm long, thickened with a c. 1 mm point at the very top; corolla c. 1.6 cm; margins of major leaf with very shallow serrations in the upper half; the lower leaf surface with dense rough hair on the midrib and lateral nerve pairs...**11. C. bryophila**

7a. Lower surface of new leaves hairy to densely hairy; lower surface of mature leaves hairy to sparsely hairy..8

7b. Lower surface of new leaves occasionally with some hair but usually glabrous; lower surface of mature leaves glabrous...10

8a. Bark with a tendency to become flaky near the tops of the stems; larger leaf in a pair lorate, 13 - 17 x 2 - 2.8 cm..**10. C. iliasii**

8b. Bark smooth or striate on all areas of stem; larger leaf in a pair narrowly elliptic to oblanceolate, c. 10 - 28 x 3 - 10 cm...9

9a. Outer surface of calyx glabrous or with a few hairs at the tips; the minor leaf in a pair lanceolate, the tip always erect; the fused upper lobe of the calyx narrowly obovate to oblanceolate, the apex divided into three rounded tips, each c. 1 mm, usually not thickened...**1. C. trisepala**

9b. Outer surface of calyx with tufts of silky hair at the tips; the minor leaf in a pair usually narrowly elliptic to lanceolate, the upper third to half deflexed, or occasionally lanceolate, the tip remaining erect; the fused upper lobe of the calyx elliptic, the apex divided into three narrow triangular tips, thickened, each c. 1 - 2 mm...**3. C. fulvisericea**

10a. Inflorescence pedunculate, peduncles 0.5 - 2 cm;
pedicels up to 1 cm (Sumatra)..**5. C. beccarii**
10b. Inflorescence very shortly pedunculate, peduncles less than 0.5 cm;
pedicels 3 mm or less (Borneo)..11

11a. The minor leaf in a pair sessile, 1 - 1.5(2) x 0.2 - 0.5 cm, lanceolate, not sheathing the axil, tip erect; bracts 1 - 1.3 x 0.3 - 0.4 cm, lanceolate, chartaceous...**1. C. trisepala**
11b. The minor leaf in a pair either sessile or petiolar; when sessile either linear to narrow ovate, lamina 1.5 - 4 x 0.3 - 1.5 cm, partially sheathing the stem, or, lamina 1.5 - 4 x 1.5 - 3 cm, ovate, almost completely sheathing the stem, in both cases the tip deflexed; when on a petiole less than 0.5 cm long, lamina 3 - 4 x 1 - 2 cm, elliptic; bracts 1 - 3 cm long, leathery..**2. C. multibracteata**

1. Cyrtandra trisepala C.B.Clarke in A. & C. DC., Monogr. phan. 5: 249. 1883. Type: MALAYSIA, Sarawak, Gunung Gading, xii 1866, *Beccari* 2452 (holotype: FI, [photo E]; isotype: K). Syn: *Cyrtandra producta* Kraenzl., Mitt. Inst. Bot. Hamburg. 7: 95 (1927). Syntypes: Bukit Raya [Raja], *Winkler* 893 (HBG [*n.v.*]), *Winkler* 880 (HBG [*n.v.*]), *Winkler* 968 (E, HBG [photo]).

Small shrub or epiphyte to c. 2.5 m, stems woody, bark pale, striate, young growth sometimes with hair especially in the axils, older growth glabrous. *Leaves* very occasionally occurring in more or less equal pairs, most often pairs markedly anisophyllous: the major leaf with a more or less glabrous petiole 1 - 1.5 cm (much darker in colour than the main stem on drying), lamina 12 - 19 x 3 - 7 cm, narrow elliptic to oblanceolate, apex acuminate 1 - 1.5 cm, base asymmetric, one side shorter and acute, the longer side more rounded, margins entire, upper surface glabrous, lower surface with scattered adpressed hair or occasionally glabrous, minutely bumpy, lateral nerve pairs (8 - 12); the minor leaf sessile 0.8 - 1.5(2) x 0.2 - 0.5 cm, lanceolate, stipuliform, chartaceous, thickened at the midrib and the base, margins entire, outer surface warty with some hair, inner surface with a tuft of hair at the base. *Inflorescence* axillary, very shortly penduncluate. *Peduncle* less than 3 mm.

Bracts 0.8 - 1.3 x 0.3 - 0.4 cm, lanceolate, similar to the minor leaf, chartaceous, outer surface more or less glabrous or occasionally with scattered hair, inner surface with a tuft of hair at the base. *Bracteoles* slightly longer and wider, numerous. *Pedicels* c. 1 mm. *Calyx* fused upper lobe 9 - 12 x 3 - 6 mm, narrow obovate to oblanceolate, the apex divided into three rounded tips c. 1 mm long, not thickened, margins entire or occasionally irregularly dentate in the upper half; the two lower lobes 8 - 10 x 2 - 3 mm, narrow oblanceolate to almost lorate, apex rounded and not thickened, margins entire; outer surface of calyx glabrous or with very few hairs at the tips, inner surface somewhat granular in texture. *Corolla* white with a greenish or pink to purple tinge, c. 17 mm; tube c. 13 mm, the upper two lobes c. 3 x 4 mm with a c. 1.5 mm central sinus, the lower three lobes 4 x 5 - 6 mm, the corolla wall bulging outwards immediately behind the upper lobes resulting in an internal hollow in front of which the anthers lie; outer surface of corolla with short hairs on the backs of the lobes, inner surface glabrous except for the hollow which is filled with glandular hairs. *Filaments* c. 5 mm, with glandular hairs that also occur along the connective margins. *Anthers* c. 1.5 mm. *Gynoecium* c. 9 mm (immature), ovary glabrous, style with glandular hairs, stigma bilobed. *Disk* 2 mm, cupular, margins undulate. *Fruit* 1.2 - 1.3 x 0.3 - 0.5 cm, narrow ovate, verrucose, sometimes scarcely so.

ETYMOLOGY. The epithet '*trisepala*' refers to the distinctive zygomorphic calyx of this species, which is also characteristic of section *Dissimiles*, in which the upper three lobes are fused, and the lower two divided to the base, resulting in a three lobed calyx rather than the typical five lobed calyx usually found in *Cyrtandra.*

ECOLOGY. 50 - 500 m; lowland forest, often near streams or on rocks in the streambed.

DISTRIBUTION. Western Sarawak and Kalimantan, extending into central Sarawak (Figure 6.1).

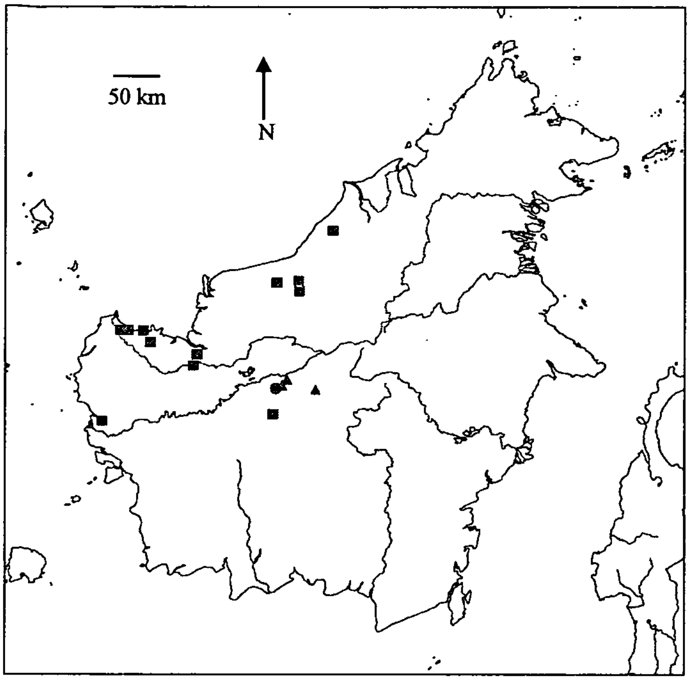

Figure 6.1: Distribution of *C. trisepala* C.B.Clarke: group one specimens (■); group two specimens (●); group three specimens (▲).

SPECIMENS EXAMINED.

Cyrtandra trisepala is a variable species, differing especially in the degree of hairiness of the leaves, in the number of lateral nerve pairs and in the entirety of the calyx margins. To ease identification, the specimens are cited in informal groups, each with a short explanatory paragraph.

Group one: specimens in this group can be more or less completely glabrous, but it is also common to find some hair on the new growth and the lower surfaces of more mature leaves. The upper lobe of the calyx has three rounded, non-thickened tips, and is generally quite narrow with entire margins. The habit of *Webb* CW3644 differs from the other specimens, being a treelet to 5 cm dbh, rather than a shrub of up to 2.5 m in height. Furthermore, *George* S38284 has 11 - 12 lateral nerve pairs rather than 8-9, the typical number for group one, and its new growth and lower leaf surfaces are more hairy than on the other specimens in the group.

WEST KALIMANTAN. Pontianak, 13 iii 1931, *Mondih* 2b (K, L, SING); Ulu Juwoi Deras, nr visitor lodge, nr Juwoi Ulu, 0° 6.1' S 112° 36' E, 290 m, 14 vi 1998, *Webb* CW3644 (A).

SARAWAK. Gunung Subis, 24 iv 1972, *Anderson* 31761 (L); Lundu district, valley between Gunung Perigi and Gunung Gading, 6 viii 1962, *Burtt & Woods* B2709 (E); Santubong foothills, 1° 45' N 110° 15' E, 75 m [250 ft], 19 iii 1967, *Chew* CWL1432 (K); Bau, Gunung Kawa, 12 viii 1978, *George* S38284 (K, L); Bukit Iju, Ulu Sungei Arip, Balingian, 5 viii 1965, *Jugah Kudi* S23713 (K, L); Simpang Tiga, Ulu Mayeng, Kakus, 50 m, 5 x 1963, *Ilias Paie* S19255 (K, KEP); path to Gunung Silantek, Ulu Sungei Silantek Kiri 85th mile, Sri Aman, 180 m, 21 viii 1980, *Ilias Paie* S42470 (E, K, KEP, L); Gunung Lesong, Lingga, 1° 16' N 111° 09' E, 500 m, 26 xi 1981, *Lee* S43231 (E, K, L); Bukit Mersing, Tau range, 2° 30' N 113° 6' E, 305 m [1000 ft], 31 v 1956, *Purseglove* P5221 (E, K, L, SING).

Group two: this group contains just one specimen, *Church* 2288. It is distinct in that it is a woody scrambler to 4 m, its leaves are oblanceolate with an unusual slightly dentate margin in the upper third, and it has a much greater number of lateral nerve pairs (14-17).
WEST KALIMANTAN, Serawai, south of Uut Labang, 0° 36' 6.1 S 112° 38' 56.2 E, 750 m, 7 x 1995, *Church et al.* 2288 (A, E, K).

Group three: specimens in group three differ from those in groups one and two by the combination of greater hairiness, generally more lateral nerve pairs (10-12), usually irregularly dentate calyx margins and greater hairiness of the outside of the corolla lobes (although flowers have only been seen in bud). The specimens in this group represent *C. producta* Kraenzl. (synonymised here), these being Kraenzlin's type specimen and similar collections from near the type location: *Jarvie et al.* 5869, *Burley et al.* 824 (although this collection differs in its calyx, which has entire margins, and a longer upper lobe, c. 12 x 3.5 versus 7 - 9 x 3 - 4 mm).
WEST/CENTRAL KALIMANTAN. Headwaters of Sungei Kahayan, 5 km NW of Tumbang Sian logging camp, 0° 35 S 113° 25 E, 150 m, 26 iv 1988, *Burley et al.* 824 (E, KEP, L); Kalteng, Samba, 0° 46' 52 S 112° 51' 15.7 E, 205 m, 1 ii 1995, *Jarvie & Ruskandi* 5869 (E); Bukit Raya [Raja], 0° 40' S 112° 46' E, 1400 m, 20 xii 1924, *Winkler* 968 (E).

NOTES. *C. trisepala* is most recognisable by its rather delicate, lanceolate minor leaf, the tip of which remains erect, and its calyx, which is also quite delicate, and has an upper lobe with three rounded non-thickened tips.

Cyrtandra producta is synonymised here. Kraenzlin's type specimen (*Winkler* 968) and *Jarvie & Ruskandi* 5869 (see group three) seem conspecific, differing from *C. trisepala* sensu stricto by the greater hairiness of the leaves and parts of the inflorescence, and the margins of the calyx that are irregularly dentate rather than entire. However, one specimen from the type area, *Burley et al.* 824, shares the greater hairiness of the leaves and parts of the inflorescence, but has a calyx with entire margins. In addition there are specimens from other groups in the type area (e.g. group two; *Church et al.* 2288) making the boundary between *C. producta* and *C. trisepala* blurred and unjustifiable.

2. Cyrtandra multibracteata C.B.Clarke in A. & C. DC., Monogr. phan. 5: 249. 1883. Type: MALAYSIA, Sarawak, Belaga, *Beccari* 3777 (holotype: FI [photo]).

Shrub to 2.5 m, stems woody, bark striate, new growth occasionally a little hairy, becoming glabrescent, sometimes a few hairs remaining in the leaf axils. *Leaves* markedly anisophyllous: the major leaf with a petiole 1 - 3.5 cm long, lamina 16 - 33 x 5 - 17.5 cm, asymmetrically narrow obovate to oblanceolate or narrow elliptic to elliptic, apex usually shortly acuminate, sometimes more distinctly acuminate, but extending no more than 1.5 cm, base asymmetric, the shorter side narrowing towards the petiole and more acute than the more rounded longer side, margins more or less entire, upper surface glabrous, lower surface more or less glabrous with minute bumps almost visible to the naked eye, lateral nerve pairs 6 - 8(9) or 8 - 11; the smaller leaf either sessile or petiolar; when sessile, either lamina c. 1.5 - 4 x 0.3 - 1.5 cm, stipuliform, upright, linear or narrow ovate, the lower half to three quarters appressed to and partially sheathing the stem and the upper part deflexed, or lamina 1.5 - 4 x 1.5 - 3 cm, ovate, the lower third to half almost completely sheathing the stem and the upper part deflexed, in both cases the apex acuminate and margins entire, the lower surface warty around the thickened midrib and base, the upper surface glabrous; when petiolar, lamina 3 - 4 x 1 - 2 cm, elliptic, apex and base acute, margins entire, upper and lower surfaces glabrous, lateral nerve pairs c. 4, petiole to 0.5 cm. *Inflorescence* axillary, very shortly pedunculate. *Peduncles* less than 5 mm long, stout. *Bracts* c. 1 - 3 cm long, leathery, thickened at the midrib, partly enclosing the inflorescence, keel-shaped or flattened, ovate to narrow ovate, apex acute or rounded, base thickened, outer surface glabrous or sometimes with scattered hairs, base warty, inner surface with a tuft of hair at the base, often warty. *Bracteoles* smaller, narrower, numerous. *Pedicels* 2 - 3 mm, stout. *Calyx* fleshy, the fused upper lobe c. 12 - 15 x 6 - 7 mm, elliptic to narrow obovate, the apex divided into three tips, each c. 0.5 - 1.5 mm long, bluntly triangular with a small thickened point at the very top; the lower two lobes 12 - 13 x 2.5 - 4 mm, oblanceolate, apex somewhat rounded but thickened with a small point at the very tip; outer surface of calyx glabrous except for a few short hairs on the thickened tips, inner surface covered with small glands. *Corolla* white sometimes with a pink or purplish tint, the throat sometimes marked with yellow or purple, 17 - 18 mm; tube 13 - 14 mm, the two upper lobes 3 - 5 x 3 - 5 mm, with a c. 1 mm central sinus, the three lower lobes 4 - 5 x 4 - 5.5 mm, the corolla wall bulging outwards immediately behind the lobes resulting in an internal hollow in front of which the anthers lie; outer surface of corolla glabrous, inner surface with glandular hairs in the throat, especially within the pouch in the roof of the tube, otherwise glabrous. *Filaments* with scattered short glandular hairs also occurring along the connectives. *Anthers* 1.5 - 2 mm. *Gynoecium* c. 14 mm, ovary glabrous, style with glandular hairs, stigma bilobed. *Disk* c. 1.5 mm, cupular, margin undulate. *Fruit* 1 - 1.5 x 0.3 - 0.5 cm, conical, surface papillose/verrucose or smooth, calyx often persisting in fruit.

ETYMOLOGY. The bracts in this species are numerous and their thick, leathery texture makes them quite distinctive, hence the epithet '*multibracteata*'.

ECOLOGY. 50 - 1500 m; lowland to lower montane forest, commonly found growing on rocks in the middle of streams.

DISTRIBUTION. Sarawak, Kalimantan (central and from one location in East Kalimantan): Figure 6.2.

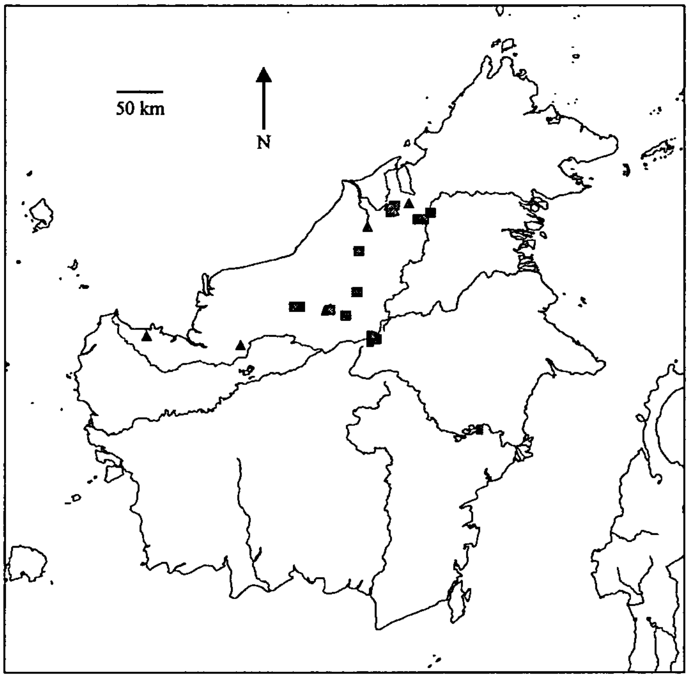

Figure 6.2: Distribution of *C. multibracteata* C.B.Clarke: group one specimens (■); group two specimens (▲).

SPECIMENS EXAMINED.

Due to the variability of *C. multibracteata*, specimens are cited under informal groups, the characteristics of which are explained in a short note preceding the list of specimens. The division of the specimens into groups shows that there is no geographical patterning associated with the morphological variation (Figure 6.2).

Group one: this represents *C. multibracteata* as exemplified by the type specimen. The plants are substantial in all parts - the leaves are typically elliptic or narrow obovate, but occasionally narrow elliptic or oblanceolate, 16 - 33 x 6 - 17.5 cm; the bracts are 1.5 - 3 cm long. Within this group there is variation in the minor leaf morphology: sometimes the minor leaf sheaths the whole of the axil, a character that is very distinctive in the herbarium, but is not consistent as specimens occur with both leaf types e.g. *Kudi* S23843. *Burtt* B5173 is an anomaly as it has an abnormal calyx with a wider shape more like *C. fulvisericea*, but it is glabrous rather than silky hairy.

EAST KALIMANTAN, around Jelini, along Sungei Belayan, northwest of Tabang, 0° 14' S 116° 36' E, 100-150 m, 7 i 1979, *Murata et al.* B1169 (L).

SARAWAK. Ulu Sungei Sedampa, headwaters of Batang Balleh, Kapit district, 1° 34' N 114° 30' E, 460 m [1500 ft], 2 vii 1969, *Anderson & Ilias Paie* S28351 (E, K, L); headwaters of Sungei Sedampa, tributary of Balleh river, Kapit district, 1°35' N 114°32' E, 16 vii 1969, *Anderson* S28864 (E); Sungei Balang, a trib. of headwaters of Balleh river, Kapit district, 1° 36' N 114° 30' E, 17 vii 1969, *Anderson & Ilias Paie* S28885 (E, K, L); Sungei Dema, Belaga district, 2° 27' N 114° 13' E, 30 viii 1978, *Burtt* B11364 (E); S. Hose mountains, 2° 8' 20 N 113° 43' E, 4500 ft, 13 vi 1980, *Burtt* B12875 (E); Bukit Mabong, SE end of Hose mountains, c. 2° N 114° E, 1500 m, 5 viii 1967, *Burtt & Martin* B4801 (E); Route from Bakelalan to Gunung Murud above Sungei Kernap, 4° N 115° 38' E, 1340 m [4400 ft], 23 ix 1967, *Burtt & Martin* B5173 (E); Pelagus rapids, 2° 10' N 113° E, 21 vii 1962, *Burtt & Woods* B2595 (E); Gunung Api, Ulu Melinau, 1065 m [3500 ft], 7 ix 1970, *Chai & Lehmann* S30089 (E, K, L); along valley of Sungai Keyan, a branch of Ulu Sungei Kakus, Bintulu district, 50-100 m, 9 xi 1963, *Hirano & Hotta* 509 (E); Bukit Raya, Kapit, 2° 10' N 113° 07' E, 6 x 1965, *Jugah Kudi* S23843 (K, KEP, L, SING); Gunung Mulu N.P., 4° 03' N 114° 56' E, 5 v 1977, *Lee* S38859 (K, L); Gunung Mulu, tributary of Sungei Paku, 470 m [1550 ft], 5 x 1977, *Lewis* 286 (K); Kalabit highlands, Gunung Murud, Belapan river-Dapo river, 3° 52' N 115° 30' E, 1100 m, 2 iv 1970, *Nooteboom & Chai* 1852 (L); Kalabit highlands, Batu Lawi, 3° 52' N 115° 23' E, 1250 m, 29 iv 1970, *Nooteboom & Chai* 2309 (K, KEP, L); nr Long Kapa, Mount Dulit (Ulu Tinjar), less than 300 m, 31 vii 1932, *Richards* 1047 (K, L); Bukit Raya, Kapit district, 3 iv 1969, *Smith* S27745 (E, K, L, SING); Sungei Sedupak, Ulu Sungei Balleh, 1° 25' N 114° 30' E, 500 m, 14 iv 1986, *Yii et al.* S52069 (K, KEP, L); Bukit Batu Tiban, Ulu Sungei Balan, 1° 32' N 114° 35' E, 400 m, 29 iv 1986, *Yii et al.* S51686 (E, K, KEP, L).

Group two: this represents a large number of specimens that are smaller in stature than the type specimen; they generally have shorter, narrower leaves, 16 - 24 x 5 - 8 cm; smaller bracts 1 - 1.2 x 0.6 - 1 cm; fewer lateral nerve pairs, 6 - 8, but share the other inflorescence characters, e.g. calyx and corolla morphology, with group one. Since the characters are not wholly diagnostic it has only been possible to make this informal distinction by placing specimens in either group one or group two.

SARAWAK. Gunung Matang. 10 miles west of Kuching, 700 m [2300 ft], 28 iii 1965, *Anderson* S20972 (E, K); 670 m [2200 ft], 8 vii 1976, *Laijanai & Banyeng* S37035 (K, KEP, L); 1893, *Ridley* s.n. (K).

Gunung Mulu N.P. Stream tributary of Sungei Melinau about 2 miles above gorge camp, 4° 5' N 114° 50' E, 25 vi 1962, *Burtt & Woods* B2285 (E); Gunung Mulu N.P., around camp 2, 500 m, 3 viii 1978, *Jermy* 14260 (E); Gunong Mulu N.P., 4° 01' N 114° 52' E, 500 m, 27 ix 1976, *Lee* S38067 (E, K, L).

S. Hose mtns, Sungei Melinau, camp 1, 2° 6' N 113° 38' 15 E, 18 iv 1980, *Burtt* B12912 (E); SE end Hose mountains, Ulu Melinau falls, 2° 6' N 113° 42' E, 1035 m [3400 ft], 18 viii 1967, *Burtt & Martin* B4953 (E); SE end Hose mountains, hill west of Ulu Melinau falls, 2° 6' N 113° 42' E, 1220 m [4000 ft], 22 viii 1967, *Burtt & Martin* B5056 (E).

Sungei Sipayan, Bukit Pagon, Limbang. 28 vii 1984, *Awa & Lee* S47505 (KEP); 28 vii 1984, *Awa & Lee* S47529 (K, KEP).

Dulit range, 160 m, 5 x 1983, *Awa & Yii* S46609 (K, KEP); Sungei Jelok, nr Bukit Sengkajang, Lanjak-Entimau PF, Lubok Antu district, 640 m [2100 ft], 18 iii 1974, *Chai* S34020 (E, K, KEP, L); Upper Rejang river, 1929, *Clemens* 21645 (K); Sungei Iban, Linau, Belaga, 11 xi 1982, *Lee* S45509 (K, KEP);

Ulu Mujong, above N.Temiai, Balleh, 300 m, 11 iv 1964, *Unyong* S19639 (E, K, SING).

NOTES. *Cyrtandra multibracteata* is a very variable species, especially in its leaf morphology, both of the minor and major leaves. It seems to be distributed across Sarawak, and has been collected from a handful of locations in East Kalimantan, showing an apparently disjunct distribution, although this is perhaps due to the under-collection of the Kalimantan flora. Group one is more recognisable and distinctive than group two because of its very thick leathery bracts and larger obovate leaves. Group two is more similar to *C. fulvisericea* but lacks the fulvous hair on new and older growth, and has a narrower upper lobe of the calyx, the surface of which is glabrous or has only scattered hair compared to the tufts of silky hair found at the thickened tips of *C. fulvisericea* calyx lobes.

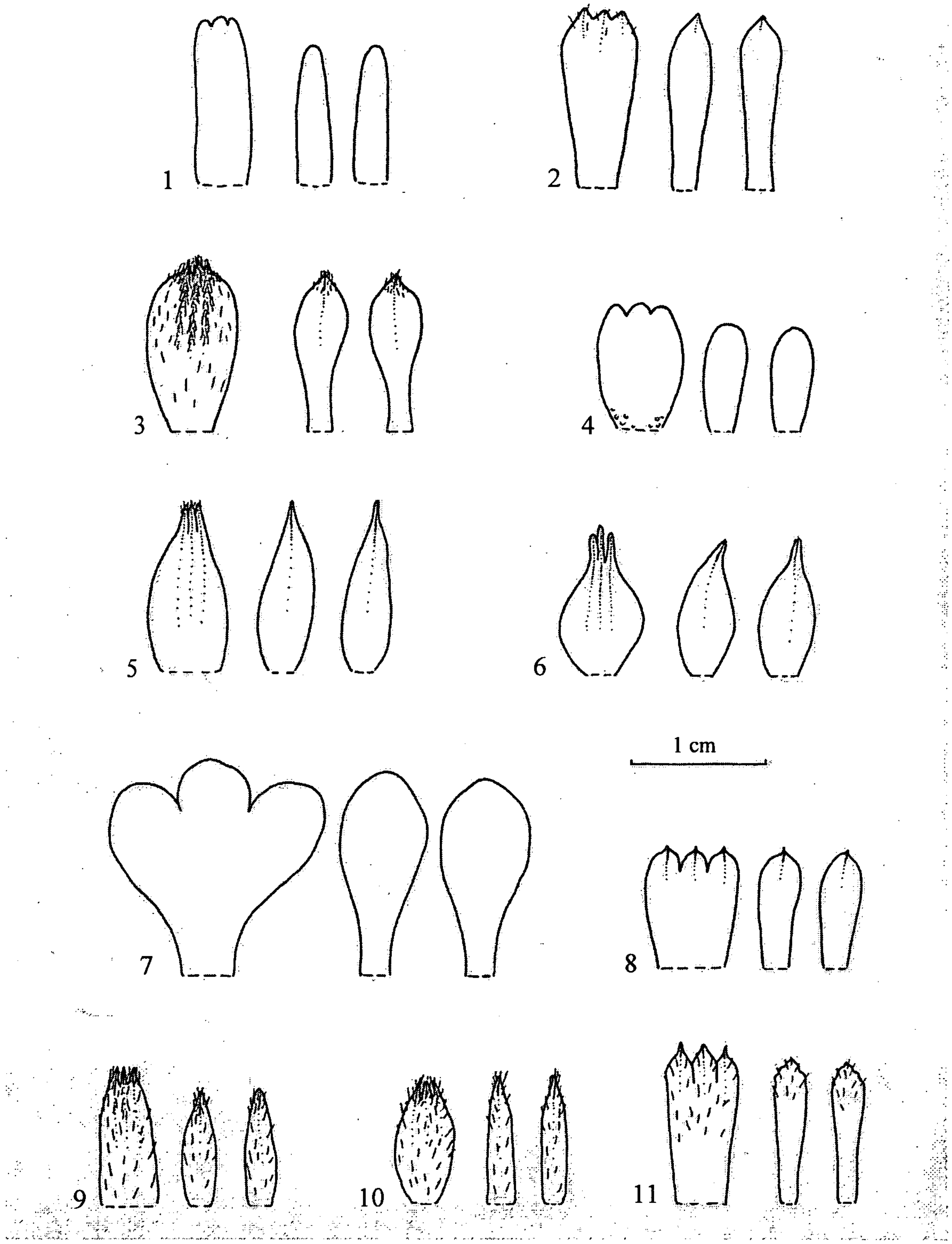

Figure 6.3: 1-11. Dissected calyces of the 11 species of section *Dissimiles* (all drawn to the same scale). For each species the outer surfaces of the fused upper lobe and the two completely divided lower lobes are illustrated. Numbers follow the account.

3. Cyrtandra fulvisericea Bramley *sp. nov.* Type: MALAYSIA. Sabah, Mount Kinabalu, Marai Parai Gigisan creek, 1370 m [4500 ft], 27 iii 1933, *Clemens* 32402 (holotype: BM; isotypes: A, L).

C. multibracteatae et C. trisepalae affinis; differt a C. multibracteata foliis oblanceolatis vel angustis ellipticis, caulibus foliisque juvenilibus pilis fulvis sericeis tectis; differt a C. multibracteata et C. trisepala lobo supero elliptico calycis cum tribus apicibus incrassatis pilis fulvis sericeis (in C. multibracteata lobum superum ellipticum ad anguste obovatum calycis cum tribus apicibus incrassatis glabris vel sparsis pilis; in C. trisepala lobum superum angustum obovatum calycis cum tribus apicibus rotundis parce pilosis).

Shrubs to 3 m, stems woody, bark striate, when young usually clad with soft fulvous hair, often densely so, the hair thinning on older growth but remaining in the axils and usually on the petioles. *Leaves* in pairs, very occasionally more or less equal in size, but most often markedly anisophyllous; the major leaf with an often densely hairy petiole 1 - 2 cm long, lamina 10 - 28 x 3.5 - 10 cm, narrow elliptic or oblanceolate, apex acuminate for 1 - 1.5 cm, base acute, sometimes asymmetrically so, the slightly shorter side more acute than the longer, when young the lower surface very silky hairy, this hair thinning with age, the older leaves bearing scattered hair especially concentrated on the midrib and the lateral nerves, texture minutely bumpy, upper surface more or less glabrous, margins more or less entire, lateral nerve pairs (6)7 - 11(12); the minor leaf variable, sessile, most often the lamina 1 - 3.5 x 0.2 - 1 cm, upright, narrow elliptic to lanceolate, the lower half to two thirds appressed to and partly sheathing the stem, the upper part deflexed, the apex acuminate up to 1 cm, the base thickened around the midrib, margins entire, the lower surface with short hairs, warty especially around the base, the upper surface glabrous apart from a tuft of hair at the base, slightly warty, or, rarely the lamina 1 - 1.5 x 0.4 - 0.6 cm, lanceolate, the midrib thickened especially towards the base, the apex erect, margins entire, surfaces as other form. *Inflorescence* axillary, more or less sessile or very shortly pedunculate. *Peduncles* up to 3 mm long, stout. *Bracts* 1 - 2 x 0.6 - 1 cm, ovate, outer surface warty and hairy, especially along the midrib, inner surface with a tuft of long silky hair at the base. *Bracteoles* smaller and narrower, inner surface with a tuft of long silky hair at the base. *Pedicels* 2 - 3 mm. *Calyx* fused upper lobe 9 - 12 x 4 - 6 mm, elliptic, the apex divided into three thickened narrowly triangular tips, each 1 - 2 mm long; the two lower lobes, 9 - 12 x 1.5 - 3.5 mm, narrow elliptic to lanceolate to oblanceolate; outer surface of calyx with tufts of silky hair at the tips, the hair sometimes extending for 2 mm, the rest of the lobe subglabrous or with scattered hair, inner surface with glands and sometimes a tuft of silky hair at the base. *Corolla* white sometimes tinged with pale pink, with a yellow mark in the throat sometimes leading to a red or purple blotch, 14 - 18 mm; tube 11 - 12 mm, the upper two lobes 4 - 5 x 3 - 5 mm, with a 1 - 2 mm central sinus, the lower three lobes 3.5 - 6 x 4 - 7 mm, the corolla wall bulging outwards immediately behind the lobes resulting in an internal hollow in front of which the anthers lie; outer surface of corolla with hairs on the backs of the lobes, otherwise glabrous, inner surface glabrous except for a patch of glandular hairs within the pouch in the roof of the tube, occasionally the glandular hairs covering a larger area either side of the pouch. *Filaments* c. 5 - 7 mm, with some glandular hairs, these also occurring along the margins of the connective. *Anthers* c. 1.5 mm. *Gynoecium* 0.8 - 1 cm (immature), ovary glabrous, style with glandular hairs, stigma bilobed. *Disk* c. 1.5 mm, cupular, margin undulate. *Fruit* 0.8 - 1.2 x 0.3 - 0.5 cm, conical, surface often markedly verrucose, calyx persistent in fruit.

ETYMOLOGY. '*fulvisericea*' refers to the fulvous silky hair that covers young growth, sometimes remaining on older growth, and is especially prevalent on the lower surface of the leaves, the stems and in the axils.

ECOLOGY. 100 - 3000 m; lowland to upper montane forest, often on logs or rocks and boulders near streams in or on the streambed.

DISTRIBUTION. Sabah, Central Sarawak and the border with East Kalimantan (Figure 6.4).

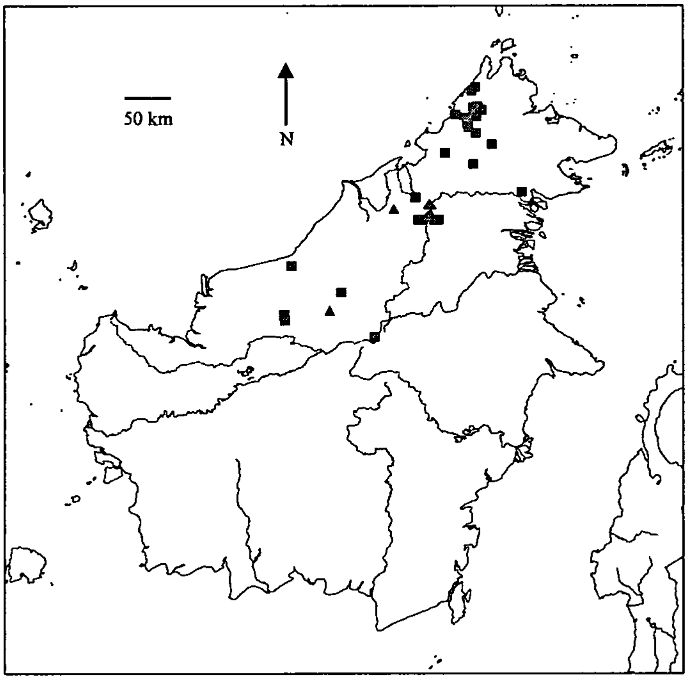

Figure 6.4: Distribution of *C. fulvisericea*: group one specimens (■); group two specimens (▲).

SPECIMENS EXAMINED.

In order to highlight the variation within *C. fulvisericea*, the specimens are cited in informal groups, each with a brief explanatory paragraph.

Group one: this group represents the typical *C. fulvisericea*: the young growth, axils, stems and petioles are clad with fulvous silky hair, and the minor leaf is usually deflexed in the upper third to half. The majority of the specimens originate from Mount Kinabalu and Sabah, but there are also representative collections from Sarawak, Brunei and East Kalimantan.

SABAH. Mount Kinabalu N.P.. Kadamaian river, 1830 m [6000 ft], 12 vi 1933, *Carr* Sing Field No. 27589 (SING); Mahandui river, 1220 m [4000 ft], 3 iii 1933, *Carr* Sing Field No. 26330 (SING); Kadamaian river, 1980 m [6500 ft], 21 vi 1933, *Carr* Sing Field No. 27722 (SING); Ulu Ligwagu & Ulu Mesilau, 6° N 116° 35' E, 1220 m [4000 ft], 3 ix 1961, *Chew et al.* RSNB1431(E, K); Ulu Liwagu & Ulu Mesilau, 6° N 116° 35' E, 1525 m [5000 ft], 3 ix 1961, Chew et al. RSNB 1439 (K); Ulu Liwagu & Ulu Mesilau, 6° N 116° 35' E, 1220 m [4000 ft], 2 ix 1961, *Chew et al.* RSNB2654 (E, K); Ulu Liwagu & Ulu Mesilau, 6° N 116° 35' E, 1525 m [5000 ft], 6 ix 1961, *Chew et al.* RSNB2813 (E, K, L); Mesilau river, 150 m [500 ft], 21 i

1964, *Chew et al.* RSNB4051 (E, K); Bembangan river, 1525 m [5000 ft], 25 ii 1964, *Chew et al.* 4537 (K); Mesilau cave, 13 iii 1964, *Chew et al.* 4688 (K); 23 v 1964, *Chew et al.* RSNB6011 (E, K, L, SING); Dallas, 11 viii 1931, *Clemens* 26061 (BM, L, SING); Dallas, 1220 m [4000 ft], 1 ix 1931, *Clemens* 26253 (BM, SING); Dallas, 760 m [2500 ft], 27 xi 1931, *Clemens* 27286 (BM, L); Tenompok, 1525 m [5000 ft], 8 ii 1932, *Clemens* 28288 (A, L, SING); Tenompok, 1675 m [5500 ft], 11 iii 1932, *Clemens* 28810 (A, BM, L, SING); Penibukan, 1220 - 1525 m [4000-5000 ft], 16 i 1933, *Clemens* 31127 (BM); Penibukan, canon east of camp, 1220 - 1525 m [4000-5000 ft], 24 i 1933, *Clemens* 31349 (BM); Penibukan, 1220 - 1525 m [4000-5000 ft], ii 1933, *Clemens* s.n. (BM); Silau basin, 1830 - 2135 m [6000-7000 ft], 18-19 v 1932, *Clemens* s.n. (BM); near summit trail, Mt Kinabalu, 6° 04' N 116° 33' E, 2000 m, 28 vii 1998, *Cronk et al.* CBHM16 (E); southern slope of Mount Kinabalu eastern route, above right bank of the eastern attributary of Sungei Mesilau, nr Mesilau cave, 1980 m, 29 viii 1963, *Fuchs & Collenette* 21395 (K, L); Liwagu trail, 1600 m, 16 i 1969, *Kokawa* 6220 (L); along Sungei E. Mesilau from Mesilau camp to Mesilau cave, 1600-2000 m, 21 i 1969, *Kokawa & Hotta* 4055 (L); Along Sungai Mamut, 1200-1400 m, 15 ii 1969, *Kokawa & Hotta* 5775 (L); Mesilau, 1370 m [4500 ft], 23 vii 1963, *Sinanggul* SAN38366 (K, L); Ranau, Boundary Rentis, 1554 m, 22 i 1976, *Stevens et al.* 610 (A, E, KEP, L); Ranau, Boundary Rentis, 1463 m, 22 i 1976, *Stevens et al.* 653 (A, E, L).

SABAH. Above Kallang waterfall nr Telom, 5° 10' N 115° 55' E, 900 m, 22 ii 1980, *Argent* 1345 (E, L); Crocker range, Km 4.25 on Kota Kinabalu - Tambunan rd, 5°51' N 116° 17' E, 1220 m, 17 ix 1983, *Beaman & Beaman* 7005 (E, L); Tambunan district: Crocker range, Km 59.5 on Kota Kinabalu-Tambunan rd, 5° 46' N 116° 21' E, 1400 m, 2 xi 1983, *Beaman et al.* 7375 (E, L); Tambunan district, Crocker range, in ravine on E side of Kota Kinabalu-Tambunan rd at km 55, 55.5° 49' N 116° 20' E, 1600-1700 m, 3 iv 1984, *Beaman et al.* 9164 (L); Tambunan district: Crocker range, in ravine on E side of Kota Kinabalu, 5° 49' N 116° 20' E, 1600-1700 m, 3 iv 1984, *Beaman et al.* 9165 (E); Silau-Silau path, 6° 04' N 116° 33' E, 1550 m, 27 vii 1998, *Cronk et al.* CBHM4 (E); Mesilau park, on bank of River Mesilau, 5° 58' N 116° 37' E, 1900 m, 27 vii 1998, *Cronk et al.* CBHM13 (E); Nungbok Mountain, 1160 m

[3800 ft], 8 iii 1954, *Darnton* 474 (BM); rd through northern edge of Crocker range N.P. towards Kota Kinabalu, 5° 45' N 116° 21' E, 1500-1600 m, 15 x 1999, *Davies et al.* SJD99046 (E); Sungai Milian, 22 xi 1986, *Jimpin* SAN118736 (K, KEP); Gunung Trusmadi, Tambunan, 22 viii 1988, *Jimpin* SAN125568 (K, KEP); Sosopodon, Kundasan, 1220 m [4000 ft], 18 ix 1966, *Kiah* S3 (L, SING); Km 55 Jalan Nabawan/Sepulut, Ulu Sungei Nabawan, 23 ii 1990, *Krispinus* SAN128397 (KEP); Sungei Setiawan, Sepulut, 18 v 1986, *Krispinus* SAN113852 (KEP); Gunong Alab, 5° 51' N 116° 22' E, 1650 m, 3 viii 1998, *Mendum & Lamb* 14 (E); roadside between Gunung Alab and Kota Kinabalu, 5° 51' N 116° 22' E, 650 m, 3 viii 1998, *Mendum & Lamb* 17 (E); roadside between Gunung Alab and Kota Kinabalu, 5° 51' N 116° 22' E, 1500 m, 3 viii 1998, *Mendum & Lamb* 18 (E); Sinsuron rd, 5° 40' N 116° 22' E, 850-900 m, 4 viii 1998, *Mendum & Lamb* 27 (E); Tawau Kalabakan forest reserve, 7 iv 1996, *Pereira et al.* JTP294 (KEP, K); Gunung Trusmadi, Tambunan, 13 viii 1988, *Sumbing & Fidilis* SAN125485 (K, KEP).

SARAWAK. Balang/Balleh watershed, extreme headwaters of Balleh river, Kapit district, foothills of Bukit Batu Tibang, 1° 35' N 114° 33' E, 945 m [3100 ft], 6 vii 1969, *Anderson* S28454 (E, L); Summit ridge of Bukit Tibang on Indonesian border, headwaters of Balleh river, Kapit district, 1° 35' N 114° 35' E, 1525 m [5000 ft], 12 vii 1969, *Anderson & Ilias Paie* S28677 (E); Bukit Mersing, 2° 30' N 113° 6' E, 1100 m, 5 x 1963, *Ashton* S19157 (E); route to Batu Lawi, Bario, 1250 m, 1 viii 1985, *Awa et al.* S50487 (K, L); Ulu Sungei Kapit, 110 m, 25 ii 1975, *Chai* S36019 (E, K, KEP, L); Sungei Apa, tributary of Sungei Sut in between Bukit Goram and Bukit Bakak, Ulu Kapit, 335 m, 3 iii 1975, *Chai* S36200 (E); W. Koetai, Kian river, 700 m, 25 x 1925, *Endert* 4578 (K, L); Batu Laga plateau, Batang Rejang, 2900 m, 12 ix 1984, *Mohtar* S48249 (K, KEP, L); Ulu Segun, Bintulu, 230 m [750 ft], 24 viii 1968, *Ilias Paie* S27214 (E, L, SING); Bukit Batu Tibang, Balang/Balleh ridge, Kapit district, 1° 35' N 114°33' E, 915 m [3000 ft], 8 vii 1969, *Ilias Paie* S28447 (E, K, L).

BRUNEI. Temburong, Gunung Pagon, around helipad, 4° 18' N 115° 20' E, 1480 m, 1 iv 1993, *Coode* 7592 (K).

EAST KALIMANTAN, between Long Bawan and Panado. 3° 52' N 115° 42' E, 1000 m, 11 vii 1981, *Geesink* 9018 (L); 3° 52' N 115° 42' E, 1800 m, 19 vii 1981, *Geesink* 9120 (E, L).

Group two: this applies to a group of specimens from around Gunung Mulu and Gunung Murud in the far east of Sarawak, and one specimen from the Hose Mountains in central Sarawak. These specimens are distinct because they retain more of the fulvous silky hair on the lower surface of their mature leaves than group one, the parts of the inflorescence are generally more hairy, and the tip of the minor leaf remains erect (except *Burtt* B5074 where is it deflexed).

SARAWAK. S.E. end of Hose mtns, hillside west of Ulu Melinau falls, 2° 6' N 113° 42' E, 1220 m [4000 ft], 23 viii 1967, *Burtt & Martin* B5074 (E); route from Bakelalan to Gunung Murud above Sungei Konap, 4° N 115° 38' E, 1340 m [4400 ft], 23 ix 1967, *Burtt & Martin* B5168 (E); route from Bakelalan to Gunung Murud nr camp 3, 3° 5' N 115° 32' E, 1770 m [5800 ft], 28 ix 1967, *Burtt & Martin* B5280 (E); route from Bakelalan to Gunung Murud below camp 4, 3° 56' N 115° 32' E, 1830 m [6000 ft], 4 x 1967, *Burtt & Martin* B5375 (E); Long Ugong to Long Semagoh, 4° 10' N 115° 35' E, 18 x 1967, *Burtt & Martin* B5566 (E); S. slope of W. ridge of Mulu, upper tributaries to Sungei Tapin, 4° 05' N 114° 55' E, 1700-1800 m, 26 iii 1978, *Nielsen* 880 (E).

Affiliated specimens

A number of specimens are clearly affiliated to *C. fulvisericea* but do not quite match - they are listed below.

SABAH. Mount Kinabalu, Marai Parai, Upper Kinitaki gorge, 1675 m [5500 ft], 29 iii 1933, *Clemens* 32432 (A, BM); Kota Belud, Tenompok, 1465 m [4800 ft], 5 xi 1959, *Meijer* SAN20333 (K, L); Sungei Saburan, Sepulut, 16 x 1984, *Musi* SAN106959 (K, L).

SARAWAK. Kapit, Sungei Bena area, 1° 56' N 113° 8' E, 23 iv 1980, *Burtt* 12953 (E); Kalabit highlands, Mt Murud east, path to top, 1700 m, 4 iv 1970, *Nooteboom &*

Chai 1914 (L); Kalabit highlands, 2 hrs north of Pa Lunggan, 1100 m, 10 iv 1970, *Nooteboom & Chai* 2074 (KEP, L).

NOTES. *Cyrtandra fulvisericea* is characterised by the soft, silky fulvous hair that covers the young growth, often remaining on the lower surface of the leaves and in the axils, its hairy bracts, and the distinctive shape and indumentum of the upper lobe of its calyx. It is, however, variable in the major leaf shape and minor leaf morphology. It includes specimens that fall between *C. trisepala* and *C. multibracteata*, species that are, in their strict forms, easy to distinguish, but appear to have an intermediate group of specimens between them. This species is likely to require further study in the field, and more investigation into characters such as the form of the minor leaf, the extent of the fulvous hair, and the calyx morphology before the boundaries between its less distinctive forms and *C. multibracteata* and *C. trisepala* can be completely clarified.

For the most part the specimens are from Sabah (group one), especially Mount Kinabalu, but the range does extend to Sarawak. Within Sarawak there is a group of specimens (group two) that are generally more hairy and distinctive because of their minor leaves, the tips of which, rather than becoming deflexed for the upper third to half, remain erect. The group two specimens are not however distinct in other characters, the calyx morphology in particular being extremely similar to that of group one specimens, so the features by which they at first seem distinct must be considered to be part of the variation within *C. fulvisericea.*

4. Cyrtandra anisophylla C.B.Clarke in A. & C. DC., Monogr. phan. 5: 249. 1883. Type: SUMATRA. West Sumatra, Mount Singgalang, 1700 m, vi-vii 1878, *Beccari* s.n. (holotype: FI [*n.v.*]; isotype: K).
Erect shrub to 2 m. *Leaves* markedly anisophyllous: the major leaf with a c. 2 cm petiole, lamina 15 - 29 x 6.5 - 12 cm, elliptic to narrowly obovate to oblanceolate, apex obtuse to shortly acuminate, base asymmetric, one side up to 2 cm shorter and more acute than the longer, margins serrate for the upper three quarters of the lamina, the serrations quite widely spaced, upper and lower surfaces glabrous, lateral nerve

pairs 9 - 13, connected by a faint skirting vein c. 4 mm from the margin; the minor leaf sessile 1.5 - 3 x 1 - 1.5 cm, ovate, the basal part sheathing the stem, the upper part deflexed, apex acuminate, margins entire, upper and lower surfaces glabrous. *Inflorescence* axillary, more or less sessile, with many flowers clustered together. *Bracts* c. 1 cm long, green tinged brownish, overlapping and covering inflorescence, broadly ovate, margins entire, outer surface somewhat verrucose at base, inner surface hairy. *Bracteoles* smaller, more numerous. *Pedicels* 2 - 3 mm. *Calyx* fused upper lobe c. 9 x 6 mm, obovate, the apex divided into three rounded tips c. 1 mm; the lower two lobes slightly shorter c. 8 x 3 mm, apices rounded; outer surface of calyx glabrous, verrucose at base, inner surface with glandular and eglandular hairs. *Corolla* off-white, c. 8 mm, completely enclosed by calyx (intact lobes not seen); outer surface of corolla with glandular hairs on the backs of the lobes, inner surface with short glandular hairs under the two upper lobes and in the throat. *Filaments* c. 4 mm, with sessile glands. *Anthers* c. 1 mm. *Gynoecium* c. 6 mm, ovary glabrous except for a few short glandular hairs near the tip where it passes into the style, style with short glandular hairs, stigma bilobed. *Disk* c. 1.5 mm high, cupular, margin undulate. *Fruit* 5 - 10 x 5 - 12 mm, more or less globose, somewhat fleshy, verrucose, sometimes apiculate due to the persistent style.

ETYMOLOGY. '*anisophylla*' = unequal leaves, referring to the anisophyllous leaf pairs.

ECOLOGY. 450 - 2000 m, lowland to upper montane forest.

DISTRIBUTION. Sumatra: Aceh, North Sumatra, West Sumatra, Jambi (Kerinci), (Figure 6.5).

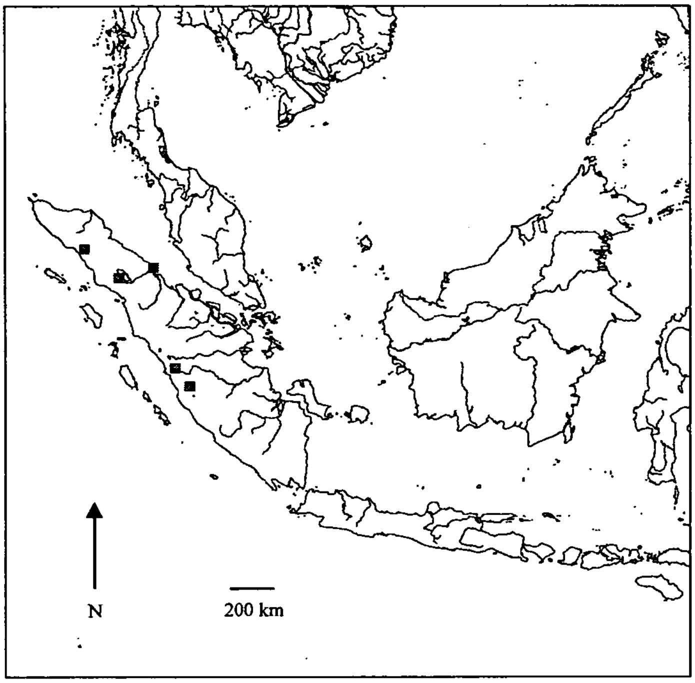

Figure 6.5: *Cyrtandra anisophylla* C.B.Clarke distribution map.

SPECIMENS EXAMINED.

SUMATRA. Jambi, Mount Kerinci, 1 iii 1954, *Alston* 13972 (BM); North Sumatra, south of Sidikalang, nr Parbuluan, 28 iii 1954, *Alston* 14856 (BM); North Sumatra, Asahan, Aek Salabat, 450 m, 15 - 26 vii 1936, *Boeea* 9591 (A); 1500 m, 4 iii 1920, *Bünnemeyer* 8405 (L); Jambi, Mount Kerinci, 1300 m, 7 iii 1920, *Bünnemeyer* 8554 (L); Jambi, Mount Kerinci, 1440 m, 20 iii 1920, *Bünnemeyer* 9011 (L); 2000 m, 19 iv 1920, *Bünnemeyer* 9585 (BO, K); West Sumatra, north slope of Gunung Talang, 1900 m, 15 xi 1988, *Nagamasu* 3515 (L); Jambi, Mount Kerinci, 1950 m, vii 1979, *Ohsawa* et al. A-176 (BO); Jambi, Mount Kerinci, 1800 - 2000 m, 27 vii 2000, *Radhiah & Cronk* 109 (E); Aceh, Gunung Leuser Nature Reserve, 1250 m, 26 vi 1979, *de Wilde & de Wilde-Duyfjes* 18992 (K, L).

NOTES. *Cyrtandra anisophylla* is a common and widespread species in Sumatra, occurring at a range of altitudes. It must not be confused with its closest ally *C. beccarii* C.B.Clarke, also from Sumatra, that has the same leaf type but bears a pedunculate rather than sessile inflorescence like that of *C. anisophylla*, and an upper calyx lobe with three narrow triangular tips, different to the three rounded tips of *C. anisophylla*. A second allied species is *C. stonei* B.L.Burtt, apparently endemic to the Genting Highlands of Peninsular Malaysia. *Cyrtandra stonei* has a sessile inflorescence like *C. anisophylla*, but an upper calyx lobe with three narrow triangular tips, and narrow ovate to lanceolate bracts like *C. beccarii*.

5. Cyrtandra beccarii C.B.Clarke in A. & C. DC., Monogr. phan. 5: 249. 1883. Type: SUMATRA. West Sumatra, Mount Singgalang, 1700 m, vi-vii 1878, *Beccari* 327 (holotype: FI [*n.v.*]; isotypes: K, L).

Shrub to 3 m, stems woody, bark glabrous. *Leaves* markedly anisophyllous: the major leaf with a glabrous petiole 1 - 2 cm long, lamina 15 - 24 x 4 - 8 cm, narrowly elliptic or oblanceolate, apex shortly acuminate, base asymmetric, the shorter side narrower and more acute than the longer, margins entire, both upper and lower surfaces glabrous, the midrib raised below, lateral nerve pairs 10 - 12; the minor leaf very shortly petiolate, tending to fall easily, lamina 1 - 3 x 0.4 - 1.2 cm, narrow elliptic, margins entire, both upper and lower surfaces glabrous. *Inflorescence* axillary, pedunculate. *Peduncles* 0.5 - 2 cm. *Bracts* c. 15 x 4 - 6 mm, narrow ovate to lanceolate, tips thickened, margins slightly undulate, outer surface with short hair and a granular texture, inner surface with short hair. *Bracteoles* shorter, surfaces as bracts. *Pedicels* up to 1 cm. *Calyx* fused upper lobe c. 13 x 5 mm, narrow ovate, the apex divided into three narrow triangular tips, each c. 2 mm, thickened along the median line and at the very top, this thickening extending down the lobe as slightly raised ridges; the lower two lobes c. 13 x 2 mm, lanceolate, narrowing to a thickened point, this thickening extending down the centre of the lobes; outer surface glabrous except for a few short hairs near the tips, inner surface gland dotted. *Corolla* white, c. 15 mm; tube c. 11 mm, the upper two lobes c. 3 x 2 mm with a 1 mm central sinus, the lower three lobes c. 4 x 3 mm; outer surface of corolla with some short hairs on the backs of the lobes, inner surface with glandular hairs on the roof of the tube underneath the two upper lobes, otherwise glabrous. *Filaments* with scattered glandular hairs, these also occurring on the connectives. *Anthers* c. 1.5 mm. *Gynoecium* c. 1 cm, ovary with some short glandular hairs near the tip, style with glandular hairs, stigma bilobed. *Disk* c. 2 mm, cupular, margin undulate. *Fruit* 12 - 13 x 6 - 11 mm, ovate to subglobose.

ETYMOLOGY. This species is named after Odoardo Beccari (1843-1920), the great Italian naturalist who eventually became director of the Florence Botanic Garden and Herbarium. He made many expeditions to SE Asia, and collected the type specimen of *C. beccarii*, and many other species that were described by Clarke (1883).

ECOLOGY. 1100 - 1850 m, lower to upper montane forest.

DISTRIBUTION. Sumatra: North Sumatra, West Sumatra (Figure 6.6).

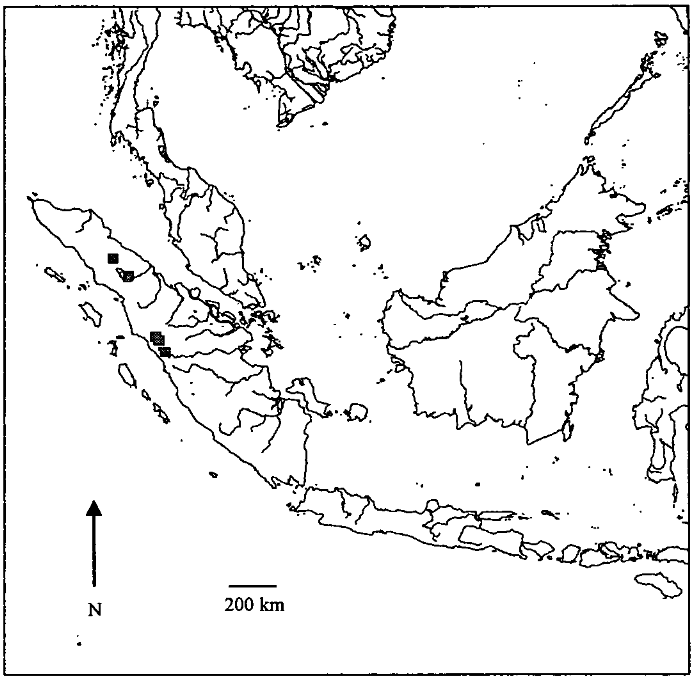

Figure 6.6.: *Cyrtandra beccarii* C.B.Clarke distribution map.

SPECIMENS EXAMINED.

SUMATRA. West Sumatra, west side of Gunung Merapi, 2200 m, 22 vi 1953, *van Borssum* 2187 (K); West Sumatra, Gunung Talaman, 0° 4' N 99° 59' E, 1850 m, 27 v 1917, *Bünnemeyer* 885 (L); West Sumatra, Tanang Taloe, 0° 14' N 99° 59' E, 1100 m, 17 vi 1917, *Bünnemeyer* 1123 (L); North Sumatra, B(e)rastagi woods, 16 ii 1921, *Ridley* s.n. (K); North Sumatra, Gunung Batu Lopang, 2° 40' N 98° 56' E, 1400-1500 m, 8 vii 1972, *De Wilde & De Wilde-Duyfjes* 13511 (L).

NOTES. *Cyrtandra beccarii* is one of two species of section *Dissimiles* present on Sumatra. Its closest ally is *C. anisophylla*, and the type collections are both from the same location, Mount Singgalang. It is easy to distinguish from *C. anisophylla* due to its pedunculate inflorescence and calyx morphology. *Cyrtandra anisophylla* has a subsessile inflorescence, the apex of the upper lobe of its calyx is divided into three blunt tips, and the lower lobes have rounded tips; the upper lobe of the calyx of *C. beccarii* is divided at the apex into three narrow triangular tips, and the lower calyx lobes have pointed tips. *Cyrtandra stonei*, as yet known only from the Genting Highlands of Peninsular Malaysia is also a close ally, sharing its calyx and bract morphology with *C. beccarii*, but bearing a sessile rather than pedunculate inflorescence.

6. Cyrtandra stonei B.L.Burtt, Edinburgh J. Bot. 47: 229 (1990). Type: Malay Peninsula, Pahang, Ulu Kali, path to Gunung Lari Tembakau, 1600 m [5200 ft], 18 iii 1979, *Stone* 14051 (holotype: KLU, isotypes: K, KEP, L). Syn. *Cyrtandra dispar* A.DC. var *glabriflora* B.C.Stone, Malaysian Forester 43: 262 (1980). Type as above.

Sub-shrub, c. 1 - 1.5 m tall, stem quadrangular, fleshy, glabrous, the lower part becoming woody. *Leaves* markedly anisophyllous: the major leaf with a petiole 3 - 4 cm long, lamina 15 - 22 x 5 - 7 cm, asymmetrically narrow elliptic to oblanceolate, apex acuminate, base asymmetric with one side of the lamina narrowing towards the petiole before the other, the wider side acute and often up to 1 - 2 cm longer, margins very shallowly dentate, upper and lower surfaces glabrous, lateral nerve pairs 9 - 12; the minor leaf sessile or with a petiole less than 5 mm long, lamina 4 - 6 x 1.5 - 2 cm, narrow ovate to lanceolate, apex acute, margins very slightly dentate, upper and lower surfaces glabrous. *Inflorescence* axillary, more or less sessile, up to 8 flowered. *Bracts* 1 - 2 cm long, narrow ovate to lanceolate, enclosing inflorescence. *Bracteoles* smaller and narrower. *Pedicels* c. 1 cm. *Calyx* white, fused upper lobe c. 11 x 6 mm, narrow ovate, the apex divided into three distinct acuminate tips, each c. 1.5 - 2 mm, thickened, this thickening extending to form slightly raised ridges down the lobe, outer surface with papillae scattered across the ridges, inner surface with scattered papillae; the lower two lobes c. 10 x 4 mm, narrow ovate, outer surface glabrous, inner surface with scattered papillae. *Corolla* white, somewhat translucent, with a yellow mark in the throat, c. 17 mm, tube narrow at base, then constricted further at c. 5 mm before broadening; tube c. 13 mm, all lobes 3.5 - 4 x 3.5 - 4 mm;

outer surface of corolla glabrous, inner surface with papillae below the upper two lobes and in the throat. *Filaments* c. 5 mm, with glandular hairs, these also occurring along the connectives. *Anthers* c. 1 mm. *Gynoecium* c. 1 cm, style with glandular hairs, stigma with two triangular lobes. *Disk* cupular, c. 2 mm high, margin uneven. *Fruit* green, 1.2 - 1.5 x 0.9 cm, ovate to globose, fleshy, with a short c. 2 mm apiculus remaining from the otherwise caducous style, calyx semi-persistent.

ETYMOLOGY. Named in honour of B.C. Stone (1933-1994), a distinguished botanist working for many years at KLU.

ECOLOGY. Upper montane forest, c. 1700 m, often in open and secondary vegetation.

DISTRIBUTION. Peninsular Malaysia: Genting Highlands (Pahang). Figure 6.7.

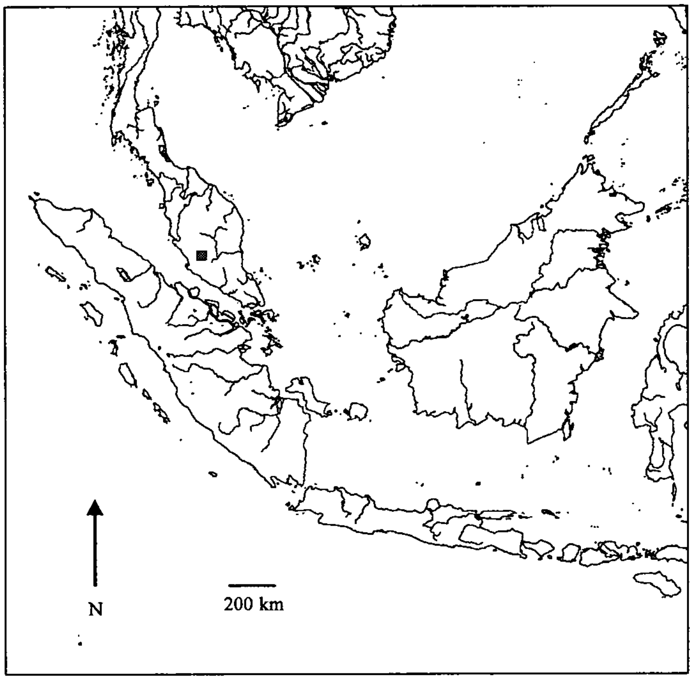

Figure 6.7.: *Cyrtandra stonei* B.L.Burtt distribution map.

SPECIMENS EXAMINED.

MALAY PENINSULA: Pahang, rd to Telekom, Gunung Ulu Kali, 1645 m, 29 vii 2002, *Bramley et al.* GB34 (E, K, KEP, L); Pahang, rd from Ulu Kali to Gunung Chin Chin, 6 v 1999, *Chua et al.* FRI40800 (KEP); Pahang, Bentong, Gunung Ulu Kali, 24 ix 1998, *Chua et al.* FRI40581 (KEP); Pahang, below top of Gunung Ulu Kali, 5 viii 1979, 1700m, *Weber & Vogel* 790805 (WU);.

NOTES. *Cyrtandra stonei* is the only Peninsular Malaysian representative of section *Dissimiles* C.B.Clarke, and is endemic to the Genting Highlands. It is allied to the two Sumatran members of the section, *C. anisophylla* and *C. beccarii*, sharing bract and calyx morphology with *C. beccarii*, and a sessile inflorescence with *C. anisophylla*. It could be suggested that *C. stonei* is the result of the dispersal from Sumatra to Peninsular Malaysia of *C. anisophylla* or *C. beccarii* (with subsequent evolution), an event that is plausible since periods of lower sea levels in history exposed land between Sumatra and the Malay Peninsula (see chapter five). There are a number of western Peninsular Malaysian species that have a close affinity to Sumatran species, and some species, for example *C. dispar* DC., have a distribution spanning both countries.

Cyrtandra stonei has a narrow distribution and has not been widely collected. In the field the quadrangular stem is noticeable, as well as the glabrous leaves, and the small, quite translucent, white corolla, which has a bright yellow throat.

Cyrtandra stonei grows in areas quite unlike other *Cyrtandra* species, which inhabit damp and fairly dark areas in the rain forest. It was found at high altitude, growing along the roadside in open vegetation, which included *Musa* sp. and *Gleichenia linearis* C.B.Clarke.

7. **Cyrtandra weberi** B.L.Burtt in Edinburgh J. Bot. 47: 232 (1990). Type: MALAYSIA: Sabah, Mount Kinabalu, Kiau view trail, 1100 m, 21 ix 1979, *Weber* 790921-1/6 (holotype: WU).

Woody herb or shrublet, to (4 ft) c. 1.2 m, stems somewhat fleshy when young, becoming woody, bark increasingly striate with age, glabrous. *Leaves* markedly anisophyllous: the major leaf with a petiole 1 - 5.5 cm long, lamina 8.5 - 21 x 3.5 - 8.5 cm, narrow elliptic, apex shortly acuminate, base usually asymmetric, the shorter side acute to rounded, the longer side most often rounded but more acute when the base is less distinctly asymmetric, margins serrate, the serrations quite widely spaced, very slight or up to 2 mm deep, the tips blunt, upper surface when young with scattered short quite rough hairs, a few hairs remaining on older leaves, lower surface with short quite rough hairs on the midrib and primary nerve pairs, lateral nerve pairs 8 - 10; the minor leaf sessile or with a petiole less than 5 mm long, lamina 1.5 - 8 x 0.6 - 3.5 cm (size proportional to size of major leaf), narrow ovate, apex acute to shortly acuminate, base thickened around the midrib, margins serrate, the serrations less conspicuous than those on the major leaf, upper and lower surfaces glabrous, lateral nerve pairs up to 5 - 6. *Inflorescence* axillary, shortly pedunculate. *Peduncle* 2 - 5 mm. *Bracts* 14 - 20 x 14 - 18 mm, ovate, margins sometimes a little undulate, outer surface glabrous, inner surface glabrous. *Bracteoles* shorter and narrower. *Pedicels* 3 - 5 mm, extending to 1 cm as fruit matures. *Calyx* fused upper lobe 17 - 19 x 15 - 17 mm, wide obovate, the apex divided into three wide rounded tips 3 - 5 x 3 - 6 mm, delicate and not thickened; the two lower lobes divided to the base 15 - 17 x 6 - 8 mm, oblanceolate, apex rounded; outer surface of calyx glabrous, inner surface with an even covering of sessile glands. *Corolla* white, with a yellow or orange mark in the throat, up to 3 cm long (lobes not seen intact); outer surface of corolla glabrous, inner surface with glandular hairs densely covering the upper and lower throat but not extending onto the lobes. *Filaments* c. 12 mm (mature but not yet dehisced), with scattered glandular hairs, these more densely covering the connectives. *Anthers* c. 3 mm. *Gynoecium* c. 16 mm (immature), ovary glabrous, style with scattered glandular hairs, stigma bilobed. *Disk* 1 - 1.5 mm, cupular, margin undulate. *Fruit* 1 - 1.2 x 0.6 - 0.7 cm, ovate, glabrous.

ETYMOLOGY. Named after Professor Anton Weber of Vienna University, who has contributed much to the understanding of Gesneriaceae.

ECOLOGY. 1100 - 2895 m, lower to upper montane forest.

DISTRIBUTION. Restricted to Mount Kinabalu, Sabah.

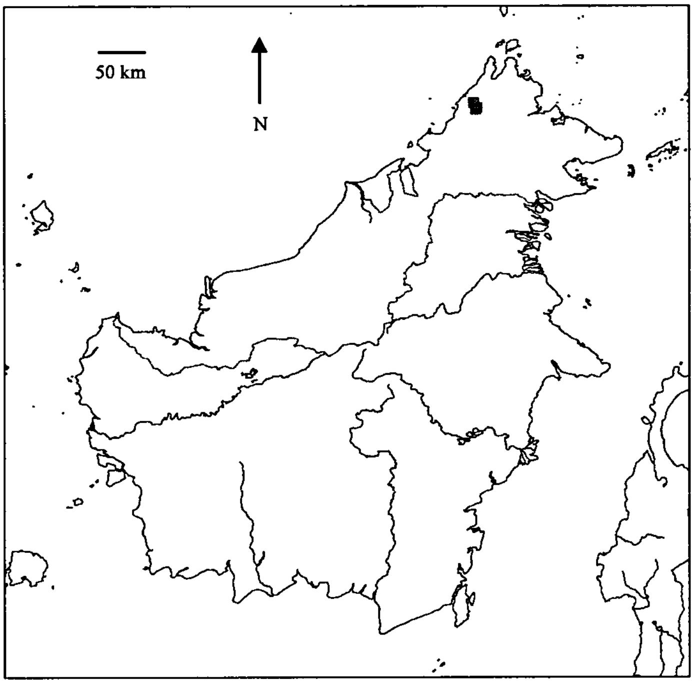

Figure 6.8.: *Cyrtandra weberi* B.L.Burtt distribution map.

SPECIMENS EXAMINED.

SABAH. Bembangan river, 1585 m [5200 ft], 19 iv 1964, *Chew et al.* RSNB4956 (E, L).

Mount Kinabalu N.P. Marai Parai, Upper Kinitaki gorge, 1525 m [5000 ft], 29 iii 1933, *Clemens* 32427 (BM); Columbon river, 2895 m [9500 ft], 30 vi 1933, *Clemens* 33758 (BM, L); Columbon river, 1370 m [4500 ft], 19 vii 1933, *Clemens* 33993 (BM); head of the Kinataki river, 2440 - 2745 m [8000-9000 ft], ii 1933, *Clemens* 35020 (BM); northen face of Kinabalu in Goking's valley, 2715 m, 6 ix 1963, *Fuchs* 21476 (A, L).

NOTES. *Cyrtandra weberi* is easily distinguishable from the other species of section *Dissimiles* from Mount Kinabalu (*C. fulvisericea*) because of its serrate leaf margins and its calyx, which is much larger (17 - 19 mm versus 9 - 12 mm) than any of the other species of the section, and in addition has a distinctive upper lobe with an apex that is divided into three non-thickened, delicate, glabrous, rounded tips.

Within *C. weberi*, there is morphological variation: *Fuchs* 21476, *Clemens* 33758 and *Clemens* 35020 are all larger and more substantial and shrubby, with thicker stems and a larger minor leaf, 3.5 - 8 x 1.5 - 3.5 cm, being especially distinctive.

RSNB 4956, *Clemens* 32427 and *Clemens* 33993 are all smaller, more delicate and more herbaceous, with a sessile minor leaf, 1.5 - 2.5 x 0.6 - 1 cm. However, this variation is unlikely to suggest the existence of infraspecific taxa, since it corresponds to altitudinal differences - the larger specimens were collected between 2440 and 2895 m and the smaller specimens between 1370 and 1585 m.

8. Cyrtandra impar Kraenzl., in Mitt. Inst. Bot. Hamburg. 7: 97 (1927). Type: West Kalimantan, Bukit Bidang Menabai, 700 m, 26 xii 1924, *Winkler* 1070 (holotype: HBG [*n.v.*]).

Shrub to 1 m, stems a little branched from the more or less creeping base, bark tessellate. *Leaves* markedly anisophyllous: the major leaf with a short 0.5 - 1 cm flaky barked petiole, lamina 17 - 29 x 5 - 13 cm, oblanceolate, apex acuminate 0.5 - 2 cm, base decurrent, sometimes slightly asymmetrically so, on smaller leaves the margins of the upper three quarters serrate, the serrations upward pointing and up to 2 mm long, on larger leaves the margins of the upper third serrate, the serrations more shallow, up to 1 mm long, upper surface glabrous, lower surface glabrous with a prominent midrib and slightly less prominent lateral nerve pairs, lateral nerve pairs 10 - 16; the minor leaf sessile, the lower part appressed to and sheathing the stem then the upper part becoming deflexed, or the upper part remaining erect and more stipuliform; when the upper part deflexed, the lamina 3 - 3.5 x 1.2 - 1.8 cm, the apex acuminate, c. 1 cm, the base adpressed to the stem; when erect the lamina 2 - 3 x c. 1.5 cm, the apex acute, the base somewhat auriculate either side of the thickened, almost corky base of the midrib; margins of both forms with slight serrations, upper and lower surfaces of both forms glabrous. *Inflorescence* axillary, more or less sessile. *Bracts* 1 - 1.8 cm long, ovate, margins sometimes slightly serrate, outer surface warty around the base, minutely gland dotted, inner surface minutely gland-dotted with a tuft of silky hairs at the base. *Bracteoles* numerous, the same size or slightly smaller than the outer bracts, outer surface minutely gland-dotted, inner surface minutely gland dotted with a tuft of silky hairs at the base. *Pedicels* c. 3 mm. *Calyx* fused upper lobe c. 10 - 12 x 6 - 7 mm, narrow obovate, the apex divided into three rounded tips, each c. 2 mm long with a short thickened point at the very top; the two lower lobes c. 9 - 12 x 3 mm, the apex rounded with a short thickened point at the very tip; outer surface of calyx minutely gland-dotted, sometimes with short hairs near the apex, inner surface minutely gland-dotted with silky hair at the base. *Corolla* white or cream with a pale yellow palate, c. 16 mm; tube c. 11 mm, the two upper lobes c. 5 x 5.5 mm with a 2 mm central sinus, the three lower lobes c. 5 x 6 mm, more spreading, the corolla wall bulging outwards immediately behind the upper lobes resulting in an internal hollow in front of which the anthers lie; outer surface of corolla glabrous, inner surface glabrous except for red glandular hairs in the bulge on the roof of the tube. *Filaments* c. 7 mm, with sessile glands on the upper half below the anthers, the connective fringed with a few red glandular hairs. *Anthers* c. 3 mm. *Gynoecium* c. 12 mm (immature), ovary glabrous, style with glandular hairs, stigma bilobed. *Disk* c. 2 mm, cupular, margin undulate. *Fruit* immature, c. 8 x 4.5 cm, warty.

ETYMOLOGY. The epithet '*impar*' means unequal, and refers to the anisophyllous leaf pairs.

ECOLOGY. 550 - 1065 m, lowland to lower montane forest.

DISTRIBUTION. Only represented by a few collections from parts of West Kalimantan and the Poi range of western Sarawak (Figure 6.9).

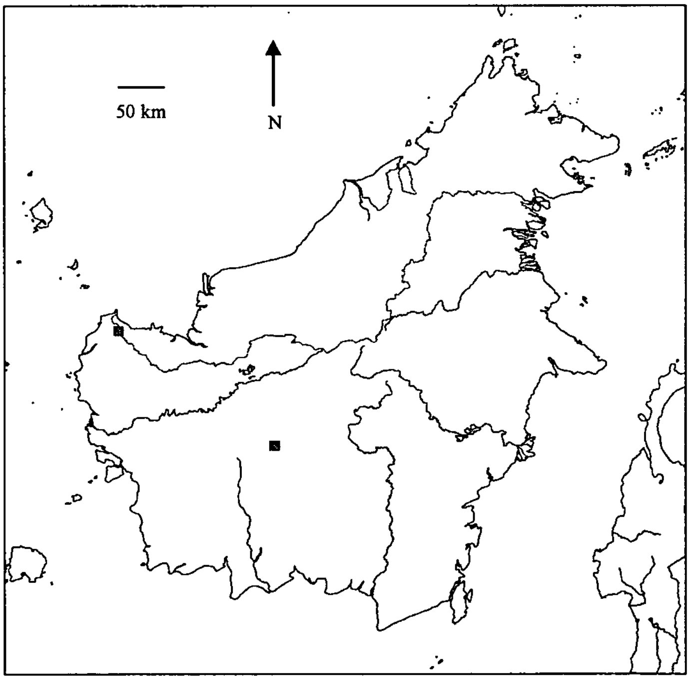

Figure 6.9.: *Cyrtandra impar* Kraenzl. distribution map.

SPECIMENS EXAMINED.

SARAWAK. Gunung Berumput, Poi range, 1° 41' N 109° 39' E, 1065 m [3500 ft], 13 viii 1962, *Burtt & Woods* B2811 (E).
WEST KALIMANTAN. Serawai, Sungai Merah, 0° 33' 40 S 112° 37' 32.7 E, 550 m, 11 ii 1995, *Church et al.* 1891 (E).
NOTES. *Cyrtandra impar* is one of a group of four closely allied species, the other three members of the group being *C. rubropicta*, *C. iliasii* and *C. bryophila*. The group is characterised by its serrate leaf margins, and three of the species show a tendency for roughened bark. However, *C. impar* is distinctive because of its tessellate bark, which is much more flaky than that of other two species. It shares its white corolla with yellow palate with *C. bryophila* and *C. iliasii*, rather than the pink marked with red corolla of *C. rubropicta*. *Cyrtandra impar* is also distinct from *C. rubropicta* because of the absence of red colouring of the underside of the leaves and the calyx. Each species has a different calyx shape. *Cyrtandra impar* has a typically shrubby habit compared to the epiphytic or scrambling herbs *C. rubropicta*, *C. iliasii* and *C. bryophila*.

The specimens seen are slightly variable: *Burtt & Woods* B2811 has a deflexed minor leaf and its major leaves are smaller in stature with margins that are more distinctly serrate. The type specimen and *Church et al.* 1891 have much larger major leaves, the margins of which are less distinctly serrate, and the minor leaf is more stipuliform, remaining erect.

9. Cyrtandra rubropicta Kraenzl., Mitt. Inst. Bot. Hamburg. 7: 98 (1927). Type: West Kalimantan, Schwaner Gorge, Bukit Bidang Menabai, 700 m, 12 xii 1924, *Winkler* 783 (HBG [*n.v.*]).
Epiphyte or scrambler, epiphytic up to c. 9 m; stems woody, bark rough, almost becoming flaky, when young with some hair around the petioles and axils.
Leaves markedly anisophyllous: the major leaf with a short, stout, 0.5 - 1 cm petiole, lamina 13 - 21 x 4 - 6.5 cm, oblanceolate, almost narrow oblanceolate, apex acuminate, c. 1.5 cm, base acute, sometimes slightly asymmetrical, margins serrate in the upper three quarters of the lamina, the serrations pointing upward at c. 45°, up to 2 mm deep with blunt tips, upper surface with some hairs at the base of the midrib

when young, otherwise glabrous, lower surface glabrous, the midrib and lateral nerve pairs prominently raised, lateral nerve pairs 12 - 14, connected by a skirting vein c. 2 - 3 mm in from the margins; the minor leaf sessile, often caducous, lamina 1.5 - 2 x 0.5 - 1.5 cm, either the lower half sheathing and remaining pressed to the stem, the upper part deflexed, or, the base not so adpressed to the stem, the upper part not deflexed, in both cases the margins sometimes slightly serrate, the upper and lower surfaces glabrous, the midrib thickened near the base. *Inflorescence* axillary, more or less sessile. *Bracts* c. 12 - 13 x 9 mm, ovate, quite fleshy, margins undulate, outer surface gland dotted, with scattered short hairs especially concentrated along the midrib, warty at the base, inner surface gland dotted, with long adpressed hairs at the base and much shorter upward pointing hairs covering the remaining surface. *Bracteoles* 9 - 11 x 3 - 6 mm, narrow ovate, both outer and inner surfaces gland-dotted and with short hairs, the inner surface with a tuft of longer hair at the base. *Pedicels* c. 2 mm. *Calyx* bright red, fused upper lobe c. 10 - 11 x 3.5 - 4.5 mm, almost lanceolate or narrow elliptic, the apex divided into three very narrow triangular tips, each c. 1.5 - 2 mm, thickened; the two lower lobes c. 7 - 10 x 2 mm, lanceolate; outer surface of calyx with adpressed delicate hairs, these slightly shorter at the calyx tips, inner surface with gland dots. *Corolla* pink with red marks on the floor of the tube, c. 15 mm; tube c. 11 mm, the upper two lobes c. 3 x 3.5 mm with a c. 1.5 mm central sinus, the lower three lobes c. 4 x 4.5 mm; outer surface of corolla with short hairs on the backs of the lobes, inner surface with a few glandular hairs in the roof of the tube at the base of the upper lobes, otherwise glabrous. *Filaments* with sessile glands on the upper half and a few glandular hairs on the connectives. *Anthers* c. 1.5 mm. *Gynoecium* immature, ovary glabrous, style with glandular hairs and some longer eglandular hairs near the top of the developing ovary, stigma bilobed. *Disk* c 1.5 mm, cupular, undulate. *Fruit* 9 x 7 mm, ovate, warty.

ETYMOLOGY. '*rubropicta*' refers to the plant's red colouring, often noted to occur on the calyx, corolla and the underside of the leaves.

ECOLOGY. The only recorded altitude is c. 1370 m [4500 ft]; epiphytic in lower montane forest.

DISTRIBUTION. Hose mountains of Sarawak, extending south into West Kalimantan (Figure 6.10).

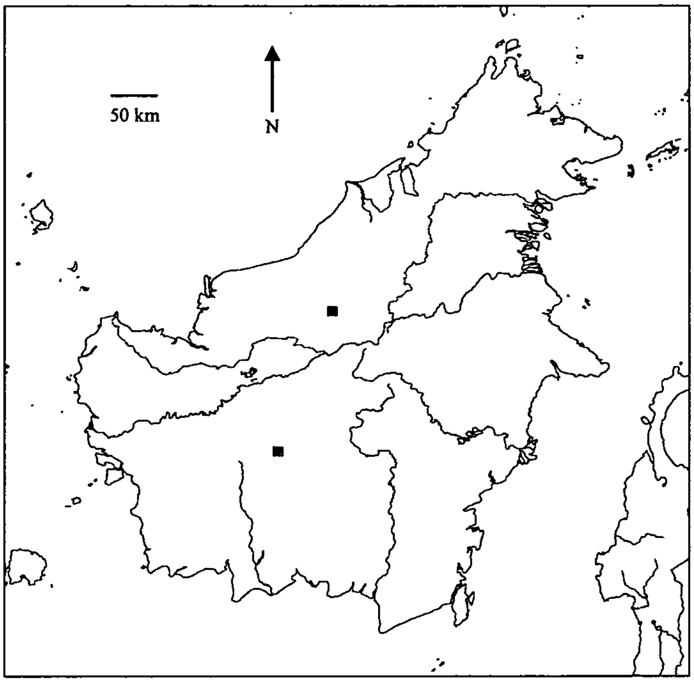

Figure 6.10: *Cyrtandra rubropicta* Kraenzl. distribution map.

SPECIMENS EXAMINED.

SARAWAK. S. Hose mtns, W of Bukit Sanpandai, camp 4, 2° 7' 30 N 113° 41' 30 E, 31 iii 1980, *Burtt* B12751 (E); S. Hose mtns, E of Bukit Sanpandai, 2° 8' N 113° 42' E, 1370 m [4500 ft], 2 iv 1980, *Burtt* B12770 (E); Bukit Sampadai, Ulu Sampurau, Melinau, Kapit, 2° 07 N 113° 41 E, 1119 m, 4 iv 1980, *Ilias Paie* S41186 (E, K, L). WEST KALIMANTAN. Serawai, east of Uut Labang, 0° 36' 6.1 S 112° 38' 56.2 E, 750 m, 9 x 1995, *Church et al.* 2354 (E).

NOTES. *Cyrtandra rubropicta* is distinctive, like *C. impar*, because of its tendency for roughened to flaky bark and serrate leaf margins. However, the bark of *C. rubropicta* is much less flaky, and often only roughened, unlike the tessellate bark of *C. impar*. It differs further from *C. impar* in its hairy rather than glabrous or sparsely hairy bracts and calyx, and in the shape of its calyx lobes, especially that of the upper. In addition it is reported to have an epiphytic habit rather than the shrubby habit of *C. impar*, and the corolla is pink marked with red and hairy in parts, unlike the yellow-marked white glabrous corolla of *C. impar*. Furthermore, as its name suggests, *C. rubropicta* has red colouring on the underside of the leaves and on the calyx.

10. Cyrtandra iliasii B.L.Burtt in Edinburgh J. Bot. 47: 219 (1990). Type: MALAYSIA, Sarawak, 7 th div., SE end Hose Mountains, c. 2° 6' N 113° 42' E, c. 1220 m [4000 ft], above Ulu Melinau Falls, 20 viii 1967, *Burtt & Martin* B5012 (holotype: E; isotype: SAR [*n.v.*]).

Small epiphyte or plant with a tendency to climb, stems woody, bark with a tendency to become flaky near the tops of the stems, when young with rough hairs, older growth glabrous. *Leaves* markedly anisophyllous: the major leaf with a hairy, often bryophyte covered 1 - 1.5 cm petiole, lamina 13 - 17 x 2 - 2.8 cm, lorate, apex acuminate c. 1 cm, base asymmetric, the shorter side acute, the longer side rounded, margins more or less entire, upper surface glabrous, often encrusted with bryophytes, lower surface with scattered rough hairs, these often breaking off leaving the base, the midrib and lateral nerve pairs covered with rough hairs, lateral nerve pairs 9 - 10, connected by a skirting vein c. 2 mm from the margins; the minor leaf sessile, 1 - 1.2 x 0.5 - 0.7 cm, the lower half adpressed to and sheathing the stem, the upper half deflexed, apex acuminate, margins entire, lower surface thickened at the base and along the midrib, with rough hairs especially along the midrib, upper surface glabrous. *Inflorescence* axillary, more or less sessile. *Bracts* c. 1 cm, ovate, outer and inner surfaces hairy. *Bracteoles* slightly smaller. *Pedicels* c. 2 mm. *Calyx* fused upper lobe c. 10 x 4.5 mm, narrow elliptic, the apex divided into three narrowed triangular thickened points, c. 2.5 - 3 mm; the lower two lobes c. 10 x 2 mm, lanceolate; outer surface of calyx with quite rough hairs, these shorter at the tips, inner surface glabrous and gland dotted. *Corolla* white with an orange mark on the mouth that becomes purple in the throat, c. 13 mm (lobes not seen intact); outer surface of corolla with hairs on the backs of the lobes, inner surface not seen. *Filaments* not seen (coll. notes 'with red glandular hairs'). *Anthers* not seen. *Gynoecium* immature, ovary glabrous, style with glandular hairs, stigma bilobed. *Disk* c. 1 mm, cupular, margin undulate. *Fruit* not seen.
ETYMOLOGY. Named after Ilias bin Paie, of the Sarawak Forest Department.

ECOLOGY. c. 1219 m [4000 ft], lower montane forest.

DISTRIBUTION. Hose Mountains, Sarawak (Figure 6.11).

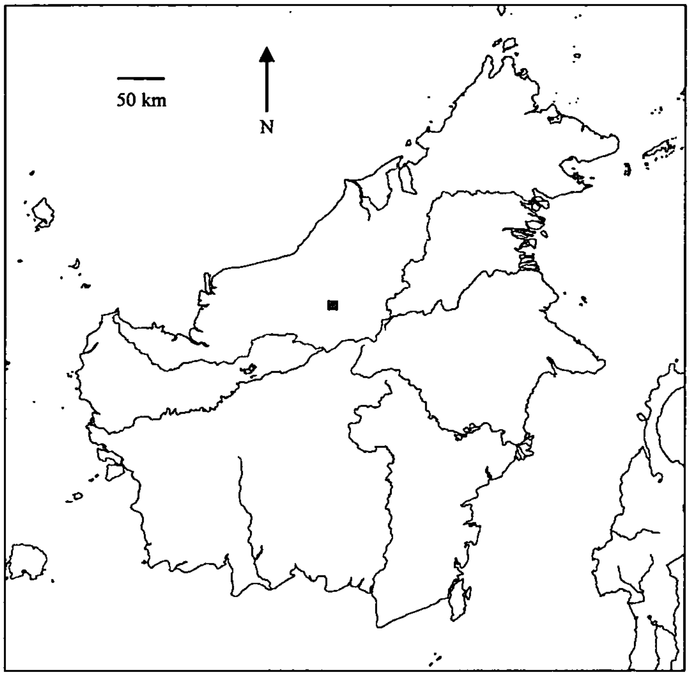

Figure 6.11: *Cyrtandra iliasii* B.L.Burtt distribution map.

NOTES. *Cyrtandra iliasii* is very closely related to *C. rubropicta*. Close examination of two specimens (*Paie* S41186, *Burtt* B12751), cited under the protologue of *C. iliasii*, has determined them to be *C. rubropicta*, so *C. iliasii* is now only known from the type specimen. This specimen differs in a few characters from *C. rubropicta*: the leaves are lorate rather than oblanceolate; the leaf margins appear to be entire rather than serrate; the lower leaf surface has scattered rough hairs especially on the venation, as opposed to the glabrous lower leaf surface of *C. rubropicta*, and the corolla is described as being white with an orange mark in the mouth, purple downwards, rather than pink with a red mark in the throat. It therefore was felt that there was not enough evidence to reduce *C. iliasii* to synonymy, despite the similarity in all other features of the inflorescence, especially the calyx. Neither the fruit nor the androecium were seen.

11. Cyrtandra bryophila B.L.Burtt in Edinburgh J. Bot. 47: 209 (1990). Type: MALAYSIA, Sarawak, 7th div., Kapit district, S. Hose mountains, Camp VI, c 2° 8' 20 N 113° 43' E, c. 1370 m [4500 ft], 13 iv 1980, *Burtt* B12880 (holotype: E).

Herb to 30 cm, stems woody, bark slightly wrinkled in places, when young with rough hairs, in older growth these remaining to an extent around the axils. *Leaves* markedly anisophyllous: the major leaf with a roughly hairy, often bryophyte covered, 1 - 1.5 cm petiole, the lamina 8 - 11 x 2.8 - 4 cm, oblanceolate, rarely narrow elliptic, the apex acuminate c. 1 cm, the base slightly asymmetric, the shorter side acute, the longer side more rounded, margins shallowly serrate in the upper half, otherwise more or less entire, upper surface glabrous with distinctive small raised bumps connected by wrinkles, often encrusted with bryophytes, lower surface bumpy, with short rough hair, this longer and more dense on the raised midrib, lateral nerve pairs 8 - 9, connected by a faint skirting vein c. 3 mm in from the margin; the minor leaf sessile, often caducous, c. 1 x 0.5 cm, the lower half sheathing the stem, the upper half deflexed, apex shortly acuminate, margins more or less entire, the lower surface with rough hairs on the thickened midrib, the upper surface glabrous. *Inflorescence* axillary, more or less sessile. *Bracts* 13 - 15 x 6 - 7 mm, narrow ovate, margins undulate, outer surface warty, with hairs especially concentrated along the midrib, inner surface glabrous, gland dotted, with a tuft of hair at the base. *Bracteoles* similar in size to bracts, surfaces as bracts. *Pedicels* c. 2 mm. *Calyx* fused upper lobe c. 12 x 5 mm, obovate, the apex divided into three rounded triangular tips, each one c. 3 mm, narrowing to a thickened point, c. 1 mm, margins more or less entire; the lower two lobes c. 12 x 2 mm, the tips rounded but slightly thickened at the very top, distinctively hooked over, margins undulate; outer surface of calyx with hair concentrated on the tips and centre of the lobes, inner surface with scattered gland dots. *Corolla* white with a yellow palate, c. 16 mm; tube c. 12 mm, the upper two lobes c. 3 x 3 mm with a c. 1.5 mm central sinus, the lower three lobes c. 4 x 4 mm; outer surface of corolla with hairs on the backs of the lobes, inner surface glabrous apart from a patch of glandular hairs concentrated on the area between the two upper lobes, becoming more scattered near the lobe edges. *Filaments* with sessile glands in the upper half. *Anthers* c. 1 - 1.5 mm. *Gynoecium*

c. 9 mm (immature), ovary glabrous, style with glandular hairs, stigma bilobed. *Disk* c. 1.5 mm, cupular, margin more or less entire. *Fruit* (immature) c. 6 x 4 mm, warty.

ETYMOLOGY. '*bryophila*' refers to this small plant's tendency to grow amongst, and become encrusted with, bryophytes.

ECOLOGY. c. 1370 - 1447 m [4500 - 4750 ft], lower to upper montane forest, often in moss patches at the base of trees.

DISTRIBUTION. Hose mountains, Sarawak (Figure 6.12).

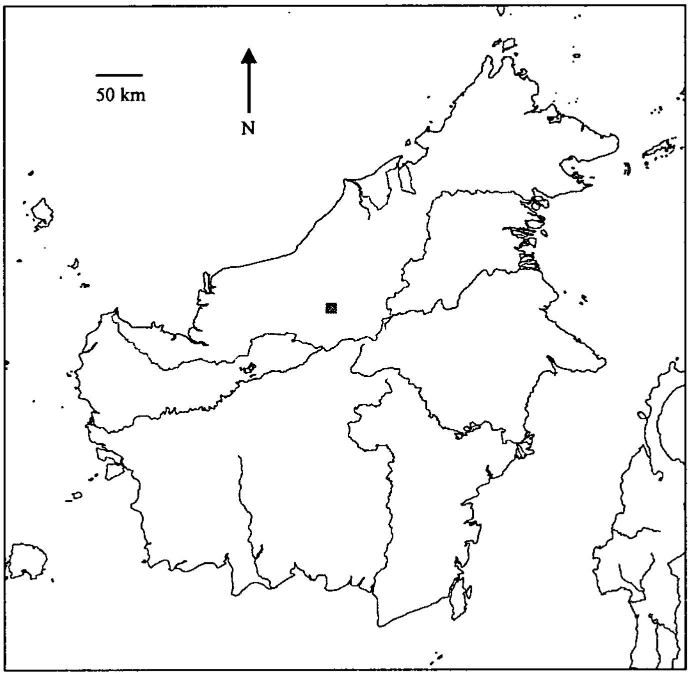

Figure 6.12: *Cyrtandra bryophila* B.L.Burtt distribution map.

NOTES. *Cyrtandra bryophila* is represented only by its type specimen. Its closest ally is probably *C. impar*, but it seems distinctive due to the wrinkled texture of its leaf surfaces, and in addition it differs from *C. impar* by its hairy bracts, calyx and outside of corolla lobe backs, and its bark, which is smooth with slight wrinkles in places. It is also close to *C. rubropicta* and *C. iliasii*, but can be distinguished by its different calyx shape and corolla coloration (white marked with yellow rather than pink marked with red or white marked with orange and purple).

6.3 THE ADVANTAGES AND DISADVANTAGES OF THIS MONOGRAPHIC REVISIONARY APPROACH

Monographic approaches tackling all species in a genus are advantageous because species delimitation is accurate: the variation between taxa can be interpreted more accurately than in a geographic approach, where it is possible that the closest relatives of the species being revised occur in different geographical areas. However, large genera such as *Cyrtandra* are not amenable to this approach and first require division such as a sectional classification. Ideally, sections should be monophyletic. Not only does this allow species complexes to be tackled more effectively than in a regional approach, but monophyletic groups are the best basis for evolutionary and comparative studies. Hence, they may be more useful than geographical revisions, where one cannot be certain that all species in an area represent a monophyletic group.

However, despite the benefits of a monographic approach that tackles individual monophyletic groups, taxonomists cannot treat the whole of *Cyrtandra* section by section because there is no satisfactory infrageneric classification. Ideally, a molecular phylogeny of *Cyrtandra* could be used to suggest the basis for an infrageneric classification based upon monophyly, but at present the molecular sampling of the genus is far from complete. Instead, sections are beginning to be defined as a result of focused regional taxonomy, such as that covering Bornean *Cyrtandra* (e.g. Hilliard *et al.*, 2003). These sections are hard to diagnose because they are defined by a specific suite of characters rather than unique individual characters. Only distinctive groups are recognised and most species are not assigned to sections. For example, Hilliard *et al.* (2003) have recently described a new section of 12 species, section *Pleuroschisma*, based on a unique combination of fruit characters: the fruit has a smooth wall and a median septicidal split with inrolled margins on each side (not reaching either the apex or the base of the fruit). In addition, section *Whitia* C.B.Clarke is distinct because of its reduced calyx, the lobes of which scarcely reach 4 mm long, generally anisophyllous leaf pairs and a sausage shaped fruit.

Cyrtandra highlights the problem of defining monophyletic groups within a large genus in the absence of a clear phylogeny. When a phylogeny is lacking, it is perhaps useful to examine infrageneric groups using the principles of numerical taxonomy, where groups are polythetic or monothetic (Sokal & Sneath, 1963). Polythetic groups are defined by the possession of a unique set of features: none of these features is necessary or sufficient to define the group and the lack of any feature by a taxon does not exclude it from the group. Monothetic groups are defined by the possession of a unique feature which is both necessary and sufficient to define the group. In a cladistic sense, if the characters defining a monothetic group were synapomorphies, it would be monophyletic.

In the examples for *Cyrtandra* given above, section *Pleuroschisma* is a monothetic group because all its members possess the unique fruit characters. In addition, section *Whitia* could be defined as a monothetic group because its species can be recognised by their reduced calyces. Further characters are distinctive to section *Whitia* but are not so easy to define, for example, the species all tend to have anisophyllous leaves, but this can vary even on the same specimen (e.g. *C. suffruticosa*, chapter four). In addition, the species all have a long, sausage shaped fruit, but this is a character based on shape and size, and is hence difficult to strictly define.

Similarly, section *Dissimiles* could be defined as monothetic because of its unique asymmetric calyx, with the upper three lobes fused to form one, and the lower two divided to the base. Section *Dissimiles* species also have anisophyllous leaf pairs, but occasionally this can vary within a species, (e.g. *C. fulvisericea*), and the corolla is generally less than 2 cm long, predominantly white, quite fleshy and almost translucent. Further characters detailed in the introduction such as the glandular hairy style and typical leaf venation pattern also collectively help to assign species to the section. However, if the section was defined using these characters in addition to the asymmetric calyx, it would be polythetic, as they are not present or consistent in every species.

The advantages of monothetic groups are that they enable keys and hierarchies to be easily made, because groups are easily defined and do not overlap. But in Nature divisions between groups are unlikely to be so clear cut: Sokal & Sneath (1963) stated that monothetic taxa do not yield 'natural' taxa except by a lucky choice of the feature used for division. Monothetic taxa are also seen as disadvantageous as they tend to accentuate single unique features at the expense of nearly unique ones (Stace, 1989). When a genus is large and morphologically variable, and is not completely understood throughout its distribution, as is the case for *Cyrtandra*, characters thought to be unique to a group may be found to be homoplasious during more extensive study of the genus. We may therefore be more inclined to define infrageneric groups such as sections polythetically, associating more characters with the group and not relying solely on one character or character set. However, polythetic groups are disadvantageous because of their lack of diagnosability, and they may not be monophyletic. This makes them difficult to interpret from an evolutionary sense. Perhaps an alternative is to define groups using putative synapomorphies (monothetically) but to also provide an additional set of characters that are common within the group but are not necessarily present in all members. This is essentially the approach taken for section *Dissimiles* by Burtt (1990), and is discussed at the species level by Sidwell (1999).

In summary, in the absence of a phylogeny of *Cyrtandra*, any infrageneric classification will have to be based only on morphological characters, but whether groups are defined monothetically or polythetically, they may well be non-monophyletic and therefore unsatisfactory.

In theory, the best way to complete a monograph of *Cyrtandra* that contained the most accurate species delimitation, would be using a monographic and phylogenetic approach. The first step would be to complete extensive fieldwork in order to collect material for DNA extraction and for the herbarium. The generation of a molecular phylogeny, including as many *Cyrtandra* species as possible, would allow monophyletic groups to be recognised. These groups would then be diagnosed using morphological synapomorphies, and an additional set of characters, as discussed above. Subsequently, an infrageneric classification based upon monophyly could be created, and a complete monograph would then be obtained by carrying out taxonomic revisions of each section. However, the resources required to complete a strategy such as this are not currently available: a more practical future strategy for *Cyrtandra* is discussed in the next chapter (chapter seven).

7 CHAPTER SEVEN: SUMMARY - EVALUATING THE DIFFERENT REVISIONARY APPROACHES

7.1 INTRODUCTION

Despite the importance of monographs, they are often not possible to produce in a reasonable period because of the sheer size of some genera. However, as discussed in chapter one, monographs of large genera are particularly important as an essential first step towards evolutionary and biogeographic research.

The main objective of this thesis was to evaluate different approaches to dividing large genera into groups of species suitable for taxonomic revision, to allow monographs of large genera to be completed. This was done using the exemplar taxon *Cyrtandra*. The relative merits of each revisionary approach to *Cyrtandra* were discussed at the end of each of the relevant chapters, and in conclusion, the most suitable approach is described here. In addition, the relevance of the approaches taken is discussed in reference to other large genera, and also in regard to the needs of specific users of taxonomic revisions.

7.2 FUTURE APPROACHES TO *CYRTANDRA*

From the point of view of the taxonomist, the most important criterion determining the suitability of the revisionary approaches is accurate species delimitation. In addition, there must be an efficient use of time.

The local approach (chapter two) is not entirely suitable for a species-rich genus with a large distribution such as *Cyrtandra*, even though it has a high propensity for producing local endemic species. A series of local revisions aiming to provide a full monograph of *Cyrtandra* would be repetitive and time consuming, since for each individual local revision, specimens from a much wider area have to be examined. In addition, there may be more of a tendency to examine a less representative sample of specimens for species not endemic to the local area being revised, leading to inaccurate species delimitation. From a logistic point of view, local approaches allow concentration of fieldwork, but not coverage of a large area, so important areas may be ignored. However, local approaches may be useful as preliminary indicators of the species richness of a larger area, and may also provide a starting point and introduction to the genus for those who are new to it.

The monographic approach (chapter six) does not seem suitable for *Cyrtandra*, since the genus lacks an infrageneric classification. Such an infrageneric classification would ideally be based upon monophyly. This would require a phylogeny based on both molecular and morphological data. This would allow us to identify well-supported monophyletic groups and identify morphological characters that diagnose them absolutely. However, the resources required to produce this phylogeny - fieldwork to collect accessions of virtually every species for DNA extraction - are unavailable.

In conclusion, I believe that the regional approach is the most suitable for *Cyrtandra*. The distribution of the genus is across South East Asia and the Pacific to the Hawaiian Islands, and the majority of species inhabit islands. This island distribution makes regions for study easy to define, and because species tend to be restricted to particular islands, an approach writing taxonomic accounts island by island is feasible and non-repetitive. The larger islands remain problematic, as they have high species numbers and are still under-collected. These islands need to be further divided, or worked on by a team of taxonomists, following the example of O.M. Hilliard & B.L. Burtt working on Bornean *Cyrtandra*. Large scale collaborative projects would take shorter periods of time to complete substantial amounts of work, and might also be more successful in attracting funding (Stuessy, 1993).

Regional approaches may be the most efficient way to achieve the much needed increase in collections of material of large genera such as *Cyrtandra*, vital for the completion of accurate revisionary work. As suggested in chapter one, molecular phylogenies can help to provide a phylogenetic framework to divide the genus, and using a regional approach may be the most efficient way of sampling for these. For example, chapter five shows how a molecular phylogeny demonstrates the Peninsular Malaysian *Cyrtandra* species fit into Sundaland species groups, providing a wider biogeographic picture.

Through both regional taxonomic revisions and molecular phylogenetics, we can increase our knowledge of *Cyrtandra* and perhaps identify further sections that can eventually be treated monographically. Essential to the success of this approach to the genus is the need to carry out more fieldwork to collect material for herbaria and DNA extraction, and also to gain more of an understanding of the ecology and pollination biology of the genus.

7.3 SUITABILITY OF APPROACHES TO OTHER LARGE GENERA

The relative merits of revisionary approaches to other large genera depend on the biology of their species (for example, whether they are herbs or trees) and where they are distributed.

Accurate species delimitation is crucial. A taxonomist needs to have a well balanced and seriously considered standard for specific delimitation, based on a complex of good structural characters (Van Steenis, 1957). A local botanist is likely to possess the most detailed knowledge of the characters of the local flora, but with a local interpretation or evaluation of this knowledge, may be inclined to have a narrow species concept. A monographer, "who is in a position to examine taxa from a wider distance, has a better evaluation of variability patterns between taxa, and will therefore place these in better proportion to those closest akin" (Van Steenis, 1957).

7.3.1 Local

In the local approach there is more of a tendency to examine a less representative sample of specimens, and the same may be true for the regional approach for species that are not endemic to the region. This leads to inaccurate species delimitation. For example (Gentry, 1979) found that different names had been applied to widespread species in the Bignoniaceae, for example *Tabebuia impetiginosa* (Mart. ex DC.) Standl., in almost every Neotropical country in which they occur. In addition, in the large genus *Garcinia* (Guttiferae), *G. hombroniana* Pierre, described from Malaysia, is likely to be synonymous with *G. celebica* L., described from Indonesia; and *G. maingayi* Hook.f. described from Peninsular Malaysia, is likely to be synonymous with *G. bailonii* Pierre, described from Sabah and Sarawak (M. Nazre-Saleh, pers. comm.). Monographic approaches are likely to make inaccurate species delimitation such as this apparent, and will consign many names to synonymy, because they examine a preferably monophyletic group of species, across entire distributions. The effectiveness of monographs in identifying names as synonyms has been shown by Scotland and Wortley, (2003; see chapter one).

From a practical standpoint, the disadvantages of the local approach are clear. Even in herbaceous or shrubby genera with a high level of endemism such as *Cyrtandra*, they will be repetitive. However, they are still useful for insight at a local level, whether for molecular or ecological studies.

7.3.2 Regional

The suitability of the regional approach depends on where a genus is distributed and the size of individual species distributions. For *Cyrtandra*, distributed across South East Asia, regions are most conveniently defined as islands, and because the genus has few examples of species with distributions spanning different islands, regional revisions are unlikely to be repetitive. This may also be true of other herbaceous and epiphytic genera in South East Asia (e.g. *Impatiens*, *Begonia*, *Dendrobium, Bulbophyllum*) as the region generally has high levels of endemic species because it is composed of islands: islands are geographically isolated and are often renowned for high levels of endemism (Gentry, 1986). Indeed, although there are no comprehensive revisions of any of the genera listed above, it is estimated that at least 40% of the orchids of Borneo are endemic (Lamb, 1991), and 93% of the *Impatiens* of Sumatra are endemic (Grey-Wilson, 1989). Endemism is also high in regions that are not islands, for example 96% of the *Begonia* species of Peninsular Malaysia are endemic (Kiew, 1991).

However, the regional approach may not be applicable to all South East Asian taxa: Johns (1995) stated that the lowland vegetation of Malesia shows greater floristic similarity than the higher altitude vegetation that has more endemic species. This can be seen using the example of the lowland family Dipterocarpaceae and the montane forest family Ericaceae (e.g. the large genera *Rhododendron* and *Vaccinium*). The Dipterocarpaceae has 400 species, of which 60% are island endemics whereas the Ericaceae has 757 species, of which 92% are island endemics (Johns, 1995). Therefore, a regional island approach may not be as suitable for genera confined to lowland forest.

In continental areas such as South America or Africa, regions have to be defined differently and the most usual method is by using political boundaries. But species do not respect political borders so revising a genus country by country would be repetitive. This would be exacerbated in genera containing many species with large distributions, such as *Trichilia* and *Guarea* (Meliaceae; Pennington, 1981), and *Pouteria* (Sapotaceae; Pennington, 1992). Instead, regions could be defined non-politically, for example, in his work on the *Impatiens* of Africa, Grey-Wilson (1980) discussed the following divisions: East Africa (44 species); West Africa (23 species); Central Africa (16 species). He noted that there were only two species that occurred in all three regions, four species in common between East and Central Africa, and five between Central and West Africa. He also suggested that since *Impatiens* are usually restricted to montane forest, montane regions could be studied without much overlap of species.

These divisions are more likely to be successful if made with a good understanding of the genus. This is shown by Croat (e.g. 1983, 1986) who divided the task of monographing the large genus *Anthurium* in Central America by first revising the 219 species of *Anthurium* in Middle America and Mexico (1983), and secondly the 152 *Anthurium* species of Panama (1986). Of the Panamanian species, 85 were endemic, and those species that had already been described in part one of the revision were only given abbreviated descriptions in part two. Prior knowledge allowed

Croat to make this division, hence minimising repetition. However, both *Impatiens* and *Anthurium* are examples of a number of herbaceous genera that have a high degree of local endemic species (Grey-Wilson, 1980; Gentry, 1989). Indeed, it is well known that herbs and shrubs are more prone to local endemism than trees and lianas (e.g. Gentry, 1986). Divisions made successfully for herbaceous and shrubby genera may not ease the problem of repetition to the same extent in tree and liana genera with larger species distributions and lower population densities, such as those in the Bignoniaceae tribe Tecomeae (Gentry, 1979). It may be more efficient to divide genera by phytogeographic regions, because these reflect patterns of endemism. For example, in South America, a study of the distributions of 127 tree species from the Brazilian coastal forests phytogeographic region showed that 53.5% tree species were endemic, and only 7.8% of species also occurred in Amazonia (Mori *et al.*, 1981). In Amazonia, it is estimated that 80% of canopy tree and liana species are endemic (Gentry, 1982).

7.3.3 Monographic

Where the regional approach is not suitable, a monographic approach may be a better alternative. However, this requires infrageneric groups to be defined, and for this to be possible, there must be a good understanding and overview of the genus. Delimiting infrageneric groups such as sections is problematic: infrageneric groups should ideally reflect monophyly. Using molecular phylogenies, sections can be defined as monophyletic groups. It is then possible to identify key morphological characters associated with groups defined by molecular synapomorphies. However, this is likely to cause problems of diagnosability, as in the worse case, some clades that are well-supported by molecular data lack any morphological support and are therefore 'cryptic' (Pennington & Gemeinholzer, 2000). In other cases, it may be likely that groups recognised by molecular data are not supported by unique synapomorphies (monothetic), but by homoplasies. In this case, the combination of homoplasies may be unique (polythetic), allowing a morphological definition, but not easy diagnosability.

In summary, it seems that regional or monographic revisions are the most advantageous taxonomic approaches to monography. Local, regional and monographic approaches all represent a compromise, but can be important as a source of biological information. In order to assess how useful the different approaches are, the questions scientists may want to address using the biological information provided by the revisions, and also the needs of some of the specific users of the revisions, need to be considered.

7.3.4 Conservation: what species, areas or habitats should be prioritised?

In order to make sound, informed decisions about conservation priorities, it is necessary to have detailed information on species distributions, their rarity and their habitat requirements (Mori, 1992). It is the job of the taxonomist to provide this information within revisionary studies. Plant species cannot be used or conserved unless we have both a basic inventory and an adequate prediction system of classification, and good, unambiguous taxonomy is essential to the working of conservation legislation (Prance, 1995). Taxonomists need to make revisions accurate, and include as much detail about distributions and ecology of species as is possible. In addition, molecular phylogenetic studies can provide information on the genetic diversity of species or genera (e.g. chapter three of this thesis).

The conservation of whole areas, not just individual species, is also reliant on taxonomic information. A frequently used strategy for establishing biological reserves has been to determine where the greatest number of species co-occur and then to delimit reserves to coincide with these centres of species richness (Thomas, 1999). It is also important to know the degree of species endemism for particular areas. These strategies are probably most applicable to larger scale revisionary approaches, for example, the regional approach. In this thesis, the revision of the *Cyrtandra* of Peninsular Malaysia (chapter four) showed that the Main range, running down the west coast, was particularly diverse with six of the nine Peninsular Malaysian species occurring there, and it also highlighted the two locally endemic species *C. lanceolata*, restricted to one mountain in the state of Johore, and *C. stonei*, restricted to the Genting Highlands.

For the conservation of individual species, the local approach may provide insight into how a particular species fits into a community, but may not give accurate information about non-endemic species over their whole distributions. For example, in chapter two, the revision of the *Cyrtandra* of Mount Kerinci only cited specimens from Mount Kerinci, and further selected specimens for species that were not endemic to the mountain (e.g. *C. anisophylla*, *C. rhyncanthera*) therefore only giving partial information about the non-endemic species throughout their distributions. Similarly, in terms of the conservation of particularly species rich areas, a local approach will give a detailed account of species richness of a small area, but will lack detailed information about the wider area, which might include areas of greater species richness. The regional approach is likely to provide more complete information about species distributions and endemism, especially in *Cyrtandra*, where regional revisions, mostly of islands, have shown that species tend to be endemic to those regions: for example, seven of the nine species of *Cyrtandra* in Peninsular Malaysia are endemic to the Thai-Malay Peninsula (chapter four of this thesis), and ten of the twelve species of *Cyrtandra* from Palawan are endemic to the island (Atkins & Cronk, 2001). Regional approaches also allow hotspots of species richness to be identified, as for each species reviewed, collections from the whole area are examined and cited.

7.3.5 Biodiversity: where are the global centres of species diversity?

The demand for accurate knowledge about the biodiversity of this planet, at national, regional and global scales, has been highlighted by the Convention on Biological Diversity (Heywood, 2001). In order to provide this accurate knowledge of the earth's biodiversity, Renner & Ricklefs (1994) argued that monographic treatments of taxonomic groups were more suitable than other sources such as species inventories, primarily because lists of species may not even be correct if no monographic treatments exist for particular groups, especially large genera, and any undescribed species would not be included. This emphasises the need for taxonomists to provide accurate revisions so that they might be used to help produce species inventories for particular areas, and also to predict the numbers of species in other areas.

When considering questions about species diversity, a number of issues are raised. The local approach is particularly useful in that it provides species numbers for small areas that can be scaled to estimate the total number of species, and also the number of endemic species, in other similar or even larger areas (see chapter two). A regional approach, especially of a country, may be more useful in the provision of information suitable to include in species inventories and reports on the status of the biodiversity in particular countries. The inclusion of species names in such reports that are in reality synonyms, can inflate numbers dramatically. Different approaches may have different power to accurately delimit species, and in these cases to condense under few names a high number of synonyms.

7.3.6 Local botanists and ecologists

Some of the key users of taxonomic revisions are botanists and ecologists working in the area covered in the revision. Their need is primarily to be able to identify species. In revisions it is therefore important to include keys that use easily observable characters and to ensure descriptions are accurate and detailed. This is especially important in the case of species that are morphologically variable.

Geographical revisions are the most relevant to those needing to identify collections or plants in the field. A monographic revision of an infrageneric group would usually only include some of the species encountered in any particular area. But even with a complete series of such accounts, covering the whole genus, a synoptical key would be necessary in order to easily identify a species to a group. In the case of *Cyrtandra*, since the latter suggestion is not possible, either of the two geographical approaches seems the most advantageous. To ease identification, the local and regional approaches of this thesis provide keys that can be used to identify sterile and flowering material. From a practical point of view, a regional revision is probably more useful than a local revision to local botanists and ecologists, simply because it covers a larger area, is likely to discuss all the morphological variation within a particular species more accurately than a local revision, and will contain more detailed information about species distributions.

7.3.7 Evolutionary biologists and biogeographers

Phylogenetic studies based on monographic work establish the basic data for identifying patterns of historical biogeography and for testing hypotheses about the processes that produce these patterns such as adaptation or coevolution (Renner & Ricklefs, 1994). Furthermore, Barraclough & Nee (2001) state that species-level phylogenies offer enormous potential for investigating the general causes and rates of speciation within clades.

In this thesis, the local and regional taxonomic revisions (chapters two and four) both provided the basis for molecular phylogenetic studies (chapters three and five). These studies addressed biogeographical and evolutionary questions concerning the evolution of local rain forest diversity and the geographical affinities of a region's flora. This highlights the advantage of the taxonomic revisions themselves, as the species included in the phylogeny were accurately identified, and also the advantages of molecular phylogenetic studies to evolutionary biologists and biogeographers. Another example is the neotropical tree genus *Inga*, where a monograph (Pennington, 1997) formed the basis of molecular phylogenetic work on the genus that posed hypotheses to explain the high species numbers in the tropics (Richardson *et al.*, 2001).

7.3.8 Community Ecologists

Community ecologists would find the local revisionary approach the most advantageous. Taxonomy on such a local scale is useful for providing insight into the community of a particular area. In addition, the revision can form the basis of molecular phylogenetic studies, and provide morphological evidence to give confidence in the molecular phylogenies produced. In a recent review, Webb *et al.* (2002) highlighted the potential for community ecologists to benefit from phylogenetic knowledge. They believe that in phylogenies, ecologists have an invaluable new dimension of information available with which to study the phylogenetic basis of niche differentiation, to add a community context to character evolution and biogeography, and to analyse community, population or phylogenetic structure.

7 CHAPTER SEVEN: SUMMARY - EVALUATING THE DIFFERENT REVISIONARY APPROACHES

7.1 INTRODUCTION

Despite the importance of monographs, they are often not possible to produce in a reasonable period because of the sheer size of some genera. However, as discussed in chapter one, monographs of large genera are particularly important as an essential first step towards evolutionary and biogeographic research.

The main objective of this thesis was to evaluate different approaches to dividing large genera into groups of species suitable for taxonomic revision, to allow monographs of large genera to be completed. This was done using the exemplar taxon *Cyrtandra*. The relative merits of each revisionary approach to *Cyrtandra* were discussed at the end of each of the relevant chapters, and in conclusion, the most suitable approach is described here. In addition, the relevance of the approaches taken is discussed in reference to other large genera, and also in regard to the needs of specific users of taxonomic revisions.

7.2 FUTURE APPROACHES TO *CYRTANDRA*

From the point of view of the taxonomist, the most important criterion determining the suitability of the revisionary approaches is accurate species delimitation. In addition, there must be an efficient use of time.

The local approach (chapter two) is not entirely suitable for a species-rich genus with a large distribution such as *Cyrtandra*, even though it has a high propensity for producing local endemic species. A series of local revisions aiming to provide a full monograph of *Cyrtandra* would be repetitive and time consuming, since for each individual local revision, specimens from a much wider area have to be examined. In addition, there may be more of a tendency to examine a less representative sample of specimens for species not endemic to the local area being revised, leading to inaccurate species delimitation. From a logistic point of view, local approaches allow concentration of fieldwork, but not coverage of a large area, so important areas may be ignored. However, local approaches may be useful as preliminary indicators of the species richness of a larger area, and may also provide a starting point and introduction to the genus for those who are new to it.

The monographic approach (chapter six) does not seem suitable for *Cyrtandra*, since the genus lacks an infrageneric classification. Such an infrageneric classification would ideally be based upon monophyly. This would require a phylogeny based on both molecular and morphological data. This would allow us to identify well-supported monophyletic groups and identify morphological characters that diagnose them absolutely. However, the resources required to produce this phylogeny - fieldwork to collect accessions of virtually every species for DNA extraction - are unavailable.

In conclusion, I believe that the regional approach is the most suitable for *Cyrtandra*. The distribution of the genus is across South East Asia and the Pacific to the Hawaiian Islands, and the majority of species inhabit islands. This island distribution makes regions for study easy to define, and because species tend to be restricted to particular islands, an approach writing taxonomic accounts island by island is feasible and non-repetitive. The larger islands remain problematic, as they have high species numbers and are still under-collected. These islands need to be further divided, or worked on by a team of taxonomists, following the example of O.M. Hilliard & B.L. Burtt working on Bornean *Cyrtandra*. Large scale collaborative projects would take shorter periods of time to complete substantial amounts of work, and might also be more successful in attracting funding (Stuessy, 1993).

Regional approaches may be the most efficient way to achieve the much needed increase in collections of material of large genera such as *Cyrtandra*, vital for the completion of accurate revisionary work. As suggested in chapter one, molecular phylogenies can help to provide a phylogenetic framework to divide the genus, and using a regional approach may be the most efficient way of sampling for these. For example, chapter five shows how a molecular phylogeny demonstrates the Peninsular Malaysian *Cyrtandra* species fit into Sundaland species groups, providing a wider biogeographic picture.

Through both regional taxonomic revisions and molecular phylogenetics, we can increase our knowledge of *Cyrtandra* and perhaps identify further sections that can eventually be treated monographically. Essential to the success of this approach to the genus is the need to carry out more fieldwork to collect material for herbaria and DNA extraction, and also to gain more of an understanding of the ecology and pollination biology of the genus.

7.3 SUITABILITY OF APPROACHES TO OTHER LARGE GENERA

The relative merits of revisionary approaches to other large genera depend on the biology of their species (for example, whether they are herbs or trees) and where they are distributed.

Accurate species delimitation is crucial. A taxonomist needs to have a well balanced and seriously considered standard for specific delimitation, based on a complex of good structural characters (Van Steenis, 1957). A local botanist is likely to possess the most detailed knowledge of the characters of the local flora, but with a local interpretation or evaluation of this knowledge, may be inclined to have a narrow species concept. A monographer, "who is in a position to examine taxa from a wider distance, has a better evaluation of variability patterns between taxa, and will therefore place these in better proportion to those closest akin" (Van Steenis, 1957).

7.3.1 Local

In the local approach there is more of a tendency to examine a less representative sample of specimens, and the same may be true for the regional approach for species that are not endemic to the region. This leads to inaccurate species delimitation. For example (Gentry, 1979) found that different names had been applied to widespread species in the Bignoniaceae, for example *Tabebuia impetiginosa* (Mart. ex DC.) Standl., in almost every Neotropical country in which they occur. In addition, in the large genus *Garcinia* (Guttiferae), *G. hombroniana* Pierre, described from Malaysia, is likely to be synonymous with *G. celebica* L., described from Indonesia; and *G. maingayi* Hook.f. described from Peninsular Malaysia, is likely to be synonymous with *G. bailonii* Pierre, described from Sabah and Sarawak (M. Nazre-Saleh, pers. comm.). Monographic approaches are likely to make inaccurate species delimitation such as this apparent, and will consign many names to synonymy, because they examine a preferably monophyletic group of species, across entire distributions. The effectiveness of monographs in identifying names as synonyms has been shown by Scotland and Wortley, (2003; see chapter one).

From a practical standpoint, the disadvantages of the local approach are clear. Even in herbaceous or shrubby genera with a high level of endemism such as *Cyrtandra*, they will be repetitive. However, they are still useful for insight at a local level, whether for molecular or ecological studies.

7.3.2 Regional

The suitability of the regional approach depends on where a genus is distributed and the size of individual species distributions. For *Cyrtandra*, distributed across South East Asia, regions are most conveniently defined as islands, and because the genus has few examples of species with distributions spanning different islands, regional revisions are unlikely to be repetitive. This may also be true of other herbaceous and epiphytic genera in South East Asia (e.g. *Impatiens*, *Begonia*, *Dendrobium*, *Bulbophyllum*) as the region generally has high levels of endemic species because it is composed of islands: islands are geographically isolated and are often renowned for high levels of endemism (Gentry, 1986). Indeed, although there are no comprehensive revisions of any of the genera listed above, it is estimated that at least 40% of the orchids of Borneo are endemic (Lamb, 1991), and 93% of the *Impatiens* of Sumatra are endemic (Grey-Wilson, 1989). Endemism is also high in regions that are not islands, for example 96% of the *Begonia* species of Peninsular Malaysia are endemic (Kiew, 1991).

However, the regional approach may not be applicable to all South East Asian taxa: Johns (1995) stated that the lowland vegetation of Malesia shows greater floristic similarity than the higher altitude vegetation that has more endemic species. This can be seen using the example of the lowland family Dipterocarpaceae and the montane forest family Ericaceae (e.g. the large genera *Rhododendron* and *Vaccinium*). The Dipterocarpaceae has 400 species, of which 60% are island endemics whereas the Ericaceae has 757 species, of which 92% are island endemics (Johns, 1995). Therefore, a regional island approach may not be as suitable for genera confined to lowland forest.

In continental areas such as South America or Africa, regions have to be defined differently and the most usual method is by using political boundaries. But species do not respect political borders so revising a genus country by country would be repetitive. This would be exacerbated in genera containing many species with large distributions, such as *Trichilia* and *Guarea* (Meliaceae; Pennington, 1981), and *Pouteria* (Sapotaceae; Pennington, 1992). Instead, regions could be defined non-politically, for example, in his work on the *Impatiens* of Africa, Grey-Wilson (1980) discussed the following divisions: East Africa (44 species); West Africa (23 species); Central Africa (16 species). He noted that there were only two species that occurred in all three regions, four species in common between East and Central Africa, and five between Central and West Africa. He also suggested that since *Impatiens* are usually restricted to montane forest, montane regions could be studied without much overlap of species.

These divisions are more likely to be successful if made with a good understanding of the genus. This is shown by Croat (e.g. 1983, 1986) who divided the task of monographing the large genus *Anthurium* in Central America by first revising the 219 species of *Anthurium* in Middle America and Mexico (1983), and secondly the 152 *Anthurium* species of Panama (1986). Of the Panamanian species, 85 were endemic, and those species that had already been described in part one of the revision were only given abbreviated descriptions in part two. Prior knowledge allowed

Croat to make this division, hence minimising repetition. However, both *Impatiens* and *Anthurium* are examples of a number of herbaceous genera that have a high degree of local endemic species (Grey-Wilson, 1980; Gentry, 1989). Indeed, it is well known that herbs and shrubs are more prone to local endemism than trees and lianas (e.g. Gentry, 1986). Divisions made successfully for herbaceous and shrubby genera may not ease the problem of repetition to the same extent in tree and liana genera with larger species distributions and lower population densities, such as those in the Bignoniaceae tribe Tecomeae (Gentry, 1979). It may be more efficient to divide genera by phytogeographic regions, because these reflect patterns of endemism. For example, in South America, a study of the distributions of 127 tree species from the Brazilian coastal forests phytogeographic region showed that 53.5% tree species were endemic, and only 7.8% of species also occurred in Amazonia (Mori *et al.*, 1981). In Amazonia, it is estimated that 80% of canopy tree and liana species are endemic (Gentry, 1982).

7.3.3 Monographic

Where the regional approach is not suitable, a monographic approach may be a better alternative. However, this requires infrageneric groups to be defined, and for this to be possible, there must be a good understanding and overview of the genus. Delimiting infrageneric groups such as sections is problematic: infrageneric groups should ideally reflect monophyly. Using molecular phylogenies, sections can be defined as monophyletic groups. It is then possible to identify key morphological characters associated with groups defined by molecular synapomorphies. However, this is likely to cause problems of diagnosability, as in the worse case, some clades that are well-supported by molecular data lack any morphological support and are therefore 'cryptic' (Pennington & Gemeinholzer, 2000). In other cases, it may be likely that groups recognised by molecular data are not supported by unique synapomorphies (monothetic), but by homoplasies. In this case, the combination of homoplasies may be unique (polythetic), allowing a morphological definition, but not easy diagnosability.

In summary, it seems that regional or monographic revisions are the most advantageous taxonomic approaches to monography. Local, regional and monographic approaches all represent a compromise, but can be important as a source of biological information. In order to assess how useful the different approaches are, the questions scientists may want to address using the biological information provided by the revisions, and also the needs of some of the specific users of the revisions, need to be considered.

7.3.4 Conservation: what species, areas or habitats should be prioritised?

In order to make sound, informed decisions about conservation priorities, it is necessary to have detailed information on species distributions, their rarity and their habitat requirements (Mori, 1992). It is the job of the taxonomist to provide this information within revisionary studies. Plant species cannot be used or conserved unless we have both a basic inventory and an adequate prediction system of classification, and good, unambiguous taxonomy is essential to the working of conservation legislation (Prance, 1995). Taxonomists need to make revisions accurate, and include as much detail about distributions and ecology of species as is possible. In addition, molecular phylogenetic studies can provide information on the genetic diversity of species or genera (e.g. chapter three of this thesis).

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For the conservation of individual species, the local approach may provide insight into how a particular species fits into a community, but may not give accurate information about non-endemic species over their whole distributions. For example, in chapter two, the revision of the *Cyrtandra* of Mount Kerinci only cited specimens from Mount Kerinci, and further selected specimens for species that were not endemic to the mountain (e.g. *C. anisophylla*, *C. rhyncanthera*) therefore only giving partial information about the non-endemic species throughout their distributions. Similarly, in terms of the conservation of particularly species rich areas, a local approach will give a detailed account of species richness of a small area, but will lack detailed information about the wider area, which might include areas of greater species richness. The regional approach is likely to provide more complete information about species distributions and endemism, especially in *Cyrtandra*, where regional revisions, mostly of islands, have shown that species tend to be endemic to those regions: for example, seven of the nine species of *Cyrtandra* in Peninsular Malaysia are endemic to the Thai-Malay Peninsula (chapter four of this thesis), and ten of the twelve species of *Cyrtandra* from Palawan are endemic to the island (Atkins & Cronk, 2001). Regional approaches also allow hotspots of species richness to be identified, as for each species reviewed, collections from the whole area are examined and cited.

7.3.5 Biodiversity: where are the global centres of species diversity?

The demand for accurate knowledge about the biodiversity of this planet, at national, regional and global scales, has been highlighted by the Convention on Biological Diversity (Heywood, 2001). In order to provide this accurate knowledge of the earth's biodiversity, Renner & Ricklefs (1994) argued that monographic treatments of taxonomic groups were more suitable than other sources such as species inventories, primarily because lists of species may not even be correct if no monographic treatments exist for particular groups, especially large genera, and any undescribed species would not be included. This emphasises the need for taxonomists to provide accurate revisions so that they might be used to help produce species inventories for particular areas, and also to predict the numbers of species in other areas.

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Some of the key users of taxonomic revisions are botanists and ecologists working in the area covered in the revision. Their need is primarily to be able to identify species. In revisions it is therefore important to include keys that use easily observable characters and to ensure descriptions are accurate and detailed. This is especially important in the case of species that are morphologically variable.

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Community ecologists would find the local revisionary approach the most advantageous. Taxonomy on such a local scale is useful for providing insight into the community of a particular area. In addition, the revision can form the basis of molecular phylogenetic studies, and provide morphological evidence to give confidence in the molecular phylogenies produced. In a recent review, Webb *et al.* (2002) highlighted the potential for community ecologists to benefit from phylogenetic knowledge. They believe that in phylogenies, ecologists have an invaluable new dimension of information available with which to study the phylogenetic basis of niche differentiation, to add a community context to character evolution and biogeography, and to analyse community, population or phylogenetic structure.

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APPENDIX 1: Large angiosperm genera, modified from Minelli (1993).

Family	Genus	No. species; Mabberley (1997)	No.species; other estimates
Acanthaceae	*Justicia*	600	
Alliaceae	*Allium*	690	
Aquifoliaceae	*Ilex*	400	
Araceae	*Anthurium*	700	713 (Govaerts & Frodin, 2002)
Araceae	*Philodendron*	350-400	398 (Govaerts & Frodin, 2002)
Asphodelaceae	*Aloe*	365	
Balsaminaceae	*Impatiens*	850	
Begoniaceae	*Begonia*	900	1400 (Doorenbos *et al.* 1998)
Berberidaceae	*Berberis*	500	
Bromeliaceae	*Tillandsia*	380	
Campanulaceae	*Campanula*	300	
Campanulaceae	*Lobelia*	300	
Caryophyllaceae	*Dianthus*	300	
Caryophyllaceae	*Silene*	700	
Compositae	*Artemisia*	350	
Compositae	*Aster*	250	
Compositae	*Centaurea*	500	
Compositae	*Cousinia*	500	
Compositae	*Helichrysum*	600	
Compositae	*Hieracium*	?90; c. 1000 microspecies	
Compositae	*Saussurea*	300	
Compositae	*Senecio*	1250	
Compositae	*Vernonia*	500	
Convolvulaceae	*Ipomoea*	650	
Cyperaceae	*Carex*	2000	
Cyperaceae	*Cyperus*	300	
Dioscoreaceae	*Dioscorea*	850	
Ebenaceae	*Diospyros*	475	
Ericaceae	*Erica*	735	
Ericaceae	*Rhododendron*	850	
Ericaceae	*Vaccinium*	450	
Eriocaulaceae	*Eriocaulon*	400	

Family	**Genus**	**No. species; Mabberley (1997)**	**No.species; other estimates**
Eriocaulaceae	*Paepalanthus*	485	
Euphorbiaceae	*Acalypha*	430	464 (Govaerts *et al.*, 2000a)
Euphorbiaceae	*Croton*	750	1223 (Govaerts *et al.*, 2000b)
Euphorbiaceae	*Euphorbia*	2000	1836 (Govaerts *et al.*, 2000b)
Euphorbiaceae	*Phyllanthus*	600	833(Govaerts *et al.*, 2000c)
Fagaceae	*Quercus*	400	
Gentianaceae	*Gentiana*	361	
Geraniaceae	*Geranium*	300	
Gesneriaceae	*Cyrtandra*	550	600+
Graminae	*Panicum*	500	
Graminae	*Stipa*	300	
Guttiferae	*Hypericum*	370	
Labiatae	*Hyptis*	300	
Labiatae	*Salvia*	900	
Labiatae	*Stachys*	300	
Lauraceae	*Litsea*	400	
Leguminosae	*Acacia*	1200	
Leguminosae	*Astragalus*	1750	2000 (Sanderson & Wojciechowski, 1996)
Leguminosae	*Senna*	350	
Leguminosae	*Crotalaria*	600	
Leguminosae	*Desmodium*	450	
Leguminosae	*Indigofera*	700	
Leguminosae	*Inga*	350	
Leguminosae	*Mimosa*	480	
Leguminosae	*Tephrosia*	400	
Marantaceae	*Calathea*	300	
Melastomataceae	*Medinilla*	400	
Melastomataceae	*Miconia*	1000	
Moraceae	*Ficus*	750	
Myrsinaceae	*Ardisia*	250	c.500 (Chen & Pipoly, 1996)
Myrtaceae	*Eucalyptus*	600	
Myrtaceae	*Eugenia*	550	
Myrtaceae	*Syzygium*	1000	

Family	Genus	No. species; Mabberley (1997)	No.species; other estimates
Orchidaceae	*Bulbophyllum*	1000	
Orchidaceae	*Dendrobium*	900	
Orchidaceae	*Epidendrum*	800	
Orchidaceae	*Habenaria*	600	
Orchidaceae	*Maxillaria*	420	
Orchidaceae	*Oncidium*	680	
Orchidaceae	*Pleurothallis*	1120	
Oxalidaceae	*Oxalis*	700	
Pandanaceae	*Pandanus*	700	
Passifloraceae	*Passiflora*	430	
Piperaceae	*Peperomia*	1000	
Piperaceae	*Piper*	2000	
Polygalaceae	*Polygala*	500	
Primulaceae	*Primula*	425	
Ranunculaceae	*Delphinium*	320	
Ranunculaceae	*Ranunculus*	600	
Rosaceae	*Potentilla*	500	
Rubiaceae	*Galium*	300	
Rubiaceae	*Ixora*	300	400 (De Block, 1998)
Rubiaceae	*Pavetta*	400	
Rubiaceae	*Psychotria*	800-1500	2000 (Sohmer, 1988)
Salicaceae	*Salix*	400	
Saxifragaceae	*Saxifraga*	440	
Scrophulariaceae	*Pedicularis*	350	
Selaginellaceae	*Selaginella*	700	
Smilaceae	*Smilax*	300	
Solanaceae	*Solanum*	1700	
Urticaceae	*Pilea*	200+	
Verbenaceae	*Clerodendron*	400	
Violaceae	*Viola*	400	

APPENDIX 2: VOUCHER DETAILS FOR ITS AND *TRNL*-F ANALYSES

Taxon	**Origin (distribution)**	**Collector(s)**	**Collector number**
Aeschynanthus pulcher (Blume) G.Don	Gunung Salak, Java (Malay Peninsula)	Argent	19882557 (RBGE accession no.)
Cyrtandra sp. (Lantuyang)	Oriental Province, Mindoro	Mendum, Argent, Pennington, Wilkie, Romero, Fuentes	29035
C. sp. (Naga)	Camarine Sur, Naga Province, Luzon	Mendum, Argent, Pennington, Wilkie, Romero, Fuentes	29130
C. sp. (Isabella)	Isabella Province, Barangay San Jose, Luzon	Mendum, Argent, Pennington, Wilkie, Romero, Fuentes	29009
C. cumingii C.B.Clarke	Oriental Province, Mindoro (Philippines)	Mendum, Argent, Pennington, Wilkie, Reynoso, Gaerlan	29034
C. ferruginea Merrill	Camarine Sur, Naga Province, Luzon	Mendum, Argent, Pennington, Wilkie, Romero, Fuentes	29182
C. sp. (Halcon 1)	Oriental Province, Mindoro	Mendum, Argent, Pennington, Wilkie, Romero, Fuentes	29053
C. sp. (Halcon 2)	Oriental Province, Mindoro	Mendum, Argent, Pennington, Wilkie, Romero, Fuentes	29054
C. baileyi F.Muell.	Queensland, Australia	Cronk & Percy	T118
C. monticola K.Schum.	Lae, Morobe Province, New Guinea	Takeuchi	6002
C. umbellifera Merrill	Taiwan	Wen-Pen Leu	1388
C. tohiveaensis G.W.Gillett	Society Islands	Cronk & Percy	T28
C. sandei de Vriese	Limau Manis Research Forest, West Sumatra [LMRF] (Java)	Radhiah & Cronk	53
C. picta Blume	LMRF, West Sumatra (Java)	Radhiah & Cronk	54
C. sandei de Vriese	LMRF, West Sumatra (Java)	Radhiah & Cronk	55

Taxon	Origin (distribution)	Collector(s)	Collector number
C. sp. (LMRF1)	LMRF, West Sumatra	Radhiah & Cronk	57
C. sp. (LMRF2)	LMRF, West Sumatra	Radhiah & Cronk	58
C. peltata Jack	Lembah Anai, West Sumatra	Radhiah & Cronk	71
C. pendula Blume	Lembah Anai, West Sumatra (Java, Malay peninsula)	Radhiah & Cronk	74
C. longepetiolata de Vriese	Mount Kerinci, (Sumatra, ?Java)	Radhiah & Cronk	108
C. anisophylla C.B.Clarke	Mount Kerinci (Sumatra)	Radhiah & Cronk	109
C. stenoptera Bramley & Cronk (a)	Mount Kerinci (and surrounding area)	Radhiah & Cronk	110
C. rhyncanthera C.B.Clarke (b)	Mount Kerinci (West Sumatra)	Radhiah & Cronk	111
C. rhyncanthera C.B.Clarke (a)	Mount Kerinci (West Sumatra)	Radhiah & Cronk	112
C. stenoptera Bramley &Cronk (b)	Mount Kerinci (and surrounding area)	Radhiah & Cronk	113
C. rosea Ridl	Mount Kerinci	Radhiah & Cronk	115
C. impressivenia C.B.Clarke	Mount Kerinci (West Sumatra)	Radhiah & Cronk	116
C. aureotincta Bramley & Cronk	Mount Kerinci	Radhiah & Cronk	122
C. trichodon Ridl.	Mount Kerinci	Radhiah & Cronk	124
C. mesilauensis B.L.Burtt	Mesilau Park, Sabah (Borneo)	Cronk, Burtt, Hilliard, Mendum, Gunsalam	CBHM7
C. kermesina B.L.Burtt	Mesilau Park, Sabah (Borneo)	Cronk, Burtt, Hilliard, Mendum, Gunsalam	CBHM8
C. corniculata B.L. Burtt	Mesilau Park, Sabah (Borneo)	Cronk, Burtt, Hilliard, Mendum, Gunsalam	CBHM9
C. gibbsiae S.Moore	Mesilau Park, Sabah (Sarawak)	Cronk, Burtt, Hilliard, Mendum, Gunsalam	CBHM11
C. fulvisericea Bramley ined.	Mount Kinabalu, Sabah (Sarawak)	Cronk, Burtt, Hilliard, Mendum, Gunsalam	CBHM16

Taxon	**Origin (distribution)**	**Collector(s)**	**Collector number**
C. clarkei Stapf	Mount Kinabalu, Sabah (Borneo)	Cronk, Burtt, Hilliard, Mendum, Gunsalam	CBHM19
C. chrysea C.B.Clarke	Mount Kinabalu, Sabah (Brunei)	Cronk, Burtt, Hilliard, Mendum, Gunsalam	CBHM20
C. burbidgei C.B.Clarke	Crocker Range, Sabah (Borneo)	Cronk, Burtt, Hilliard, Mendum, Gunsalam	CBHM22
C. aurantiaca B.L.Burtt	Mount Kinabalu, Sabah	Cronk, Burtt, Hilliard, Mendum, de Wilde	CBHM23
C. smithiana B.L.Burtt	Mount Kinabalu, Sabah	Cronk, Burtt, Hilliard, Mendum, Gunsalam	CBHM25
ADDITIONAL ACCESSIONS IN CHAPTER FIVE			
C. wallichii (C.B.Clarke) B.L.Burtt	VJR Semangkok, Selangor (Peninsular Malaysia, southern Thailand)	G. Bramley with S.Neale & Markandan Moorthy	GB25
C. cupulata Ridl.	Kanching FR, Selangor (Peninsular Malaysia, southern Thailand)	G. Bramley with S. Neale, Y-Y. Sam & Ramli Punyuh	GB28
C. aff. *wallichii* (C.B.Clarke) B.L.Burtt	Rd down Gunung Brinchang, Pahang	G. Bramley & S. Neale	GB32
C. wallichii (C.B.Clarke) B.L.Burtt	Robinsons Falls, Pahang (Peninsular Malaysia, southern Thailand)	G. Bramley & S. Neale	GB33
C. stonei B.L.Burtt	Genting Highlands, Selangor	G. Bramley with S. Neale, Markandan Moorthy & Angan Atan	GB34
C. wallichii (C.B.Clarke) B.L.Burtt	Awana eco park, Selangor (Peninsular Malaysia, southern Thailand)	G. Bramley with S. Neale, Markandan Moorthy & Angan Atan	GB35

Taxon	Origin (distribution)	Collector(s)	Collector number
C. patula Ridl.	Awana eco park, Selangor (western range Peninsular Malaysia, southern Thailand)	G. Bramley with S. Neale, Markandan Moorthy & Angan Atan	GB36
C. pendula Blume	Awana eco park, Selangor (Peninsular Malaysia, southern Thailand, Sumatra, Java)	G. Bramley with S. Neale, Markandan Moorthy & Angan Atan	GB37
C. wallichii (C.B.Clarke) B.L.Burtt	(Peninsular Malaysia, southern Thailand)	Y-Y. Sam	FRI47032
C. inconspicua B.L.Burtt ined.	West Kalimantan, Bukit Baka National Park	A.C. Church, U.W. Mahyar, A. Ruskandi & Nurdin	Church, A.C. 171
C. sp GB49	West Kalimantan, Bukit Baka National Park	A.C. Church, U.W. Mahyar, A. Ruskandi & Nurdin	Church, A.C. 489
C. aff. *cuprea* B.L.Burtt	West Kalimantan, Gunung Palung National Park	T.G. Laman, I.A. Rachman & E. Mirmanto	TL78
C. trisepala C.B.Clarke	West Kalimantan, Ulu Juwoi Deras	C.O. Webb	CW 3644
C. dispar DC.	Gunung Keledang, Peninsular Malaysia	A. Weber	840806-2/3
C. inconspicua B.L.Burtt ined.	West Kalimantan, Bukit Baka National Park	A.C. Church, U.W. Mahyar, A. Ruskandi & Nurdin	Church, A.C. 292
C. aff. *wallichii* (C.B.Clarke) B.L.Burtt	Gua Musang, Kelantan	Y-Y. Sam	FRI44491
A. longiflorus (Blume) DC.	Peninsular Malaysia, Perak, Maxwell's Hill to Gunung Hijau	A. Weber	Weber 950905

Taxon	**Origin (distribution)**	**Collector(s)**	**Collector number**
A. bracteatus var. *orientalis* W.T.Wang	China, Yunnan, Xichou	Wang	Wang 991113
A. sp.	China, Yunna, Nanxi, Hekou county	M. Möller	G=67, MMO-01-79,

APPENDIX 3: DNA Extraction Protocol (modified from Doyle & Doyle, 1990)

1 ml CTAB + 2µl 2-mercaptoethanol per sample were preheated at 65°C in a waterbath. A small amount of silica dried leaf material or herbarium leaf material was placed in a 1.5ml eppendorf, and a pinch of sand added to act as an abrasive. The eppendorf was immersed in liquid nitrogen for a few seconds and the leaf tissue carefully macerated with a plastic pestle until reduced to small fragments. Samples were re-chilled in liquid nitrogen if maceration proved difficult.

After adding 200µl of pre-heated CTAB buffer each sample was ground until green with small tissue fragments. A further 800µl of CTAB buffer and a pinch of PVPP were then added, and the contents mixed by flicking the tubes.

The tubes were incubated for 30 minutes at 65°C in a heated block. After 30 minutes the tubes were removed from the heated block and allowed to cool to ambient temperature.

500µl of chloroform isoamyl alcohol (24:1) was added to each sample, and ensuring the lid was secure, the contents of the tube were mixed gently by shaking 4 or 5 times to obtain a momentary single phase. The tubes were then transferred to the orbital shaker and shaken on minimum speed for 10 - 20 minutes.

The tubes were centrifuged for 10 minutes at 13,000 rpm, and the supernatant (upper layer) removed to a clean 1.5ml eppendorf tube. The chloroform extraction was then repeated, and the tubes centrifuged for 10 minutes at 13, 000 rpm. The supernatant was removed to a clean 1.5ml eppendorf tube, and the DNA precipitated by adding 2/3 volume freezer cold isopropanol and rocking gently. For silica dried material, the DNA was left overnight in the freezer at this stage, but in order to give better yields, for herbarium material the DNA was left in the freezer for up to two weeks.

The DNA precipitate by centrifuged for 10 minutes at 13,000 rpm to form a pellet. The supernatant was removed and 1ml of wash buffer added. The tube was vigorously agitated to release the pellet and left for at least 30 minutes.

After centrifuging for 5 mins at 13,000 rpm, the supernatant was removed and the tubes were inverted to allow the remaining wash buffer to drain away. The pellets were dried in a vacuum centrifuge for 5 minutes or until dry, and then dissolved in 75µl of TE.

REAGENTS

CTAB BUFFER

2% CTAB
20mM EDTA
100mM Tris-HCl pH8.0
1.4M NaCl

WASH BUFFER

76% Ethanol
10mM NH4

APPENDIX 4: Polymerase chain reaction (PCR) protocol for ITS

The following quantity of reagents were added to each 25μl reaction:

1.25μl of *50mM $MgCl_2$

2.5μl of a 2mM master mix of *dNTPs

2.5μl 10X *Reaction Buffer (10X: 160mM $(NH_4)_2SO_4$, 670Mm Tris-HCl (pH 8.8 at 25°C) 0.1% Tween-20)

0.75μl forward primer (10mM)

0.75μl reverse primer (10mM)

1 μl DNA

16.25μl sterile distilled H_2O

[0.125μl *DNA Polymerase]

(*all products of BIOLINE, London, UK; primers were from MWG)

The samples were run on a PCR machine using the following conditions:

94°C for 3 minutes (1 cycle)

$$\left.\begin{array}{l}\text{94°C for 1 minute}\\ \text{55°C for 1 minute}\\ \text{72°C for 1 min 30 secs}\end{array}\right\}\text{ 30 cycles}$$

72°C for 5 minutes (1 cycle)

4°C hold

The samples were viewed on a 1% agarose gel to check the reactions had been successful, and then purified using the QIAquick PCR purification kit (Qiagen Ltd., Crawley, W.Sussex, UK).

APPENDIX 5: Polymerase chain reaction (PCR) protocol for *trn*L-F

The following quantity of reagents were added to each 25µl reaction:

1.25µl of *50mM $MgCl_2$

2.5µl of a 2mM master mix of *dNTPs

2.5µl 10X *Reaction Buffer (10X: 160mM $(NH_4)_2SO_4$, 670Mm Tris-HCl (pH 8.8 at 25°C) 0.1% Tween-20)

0.75µl forward primer (10mM)

0.75µl reverse primer (10mM)

1 µl DNA

16.25µl sterile distilled H_2O

[0.125µl *DNA Polymerase]

(*all products of BIOLINE, London, UK; primers were from MWG)

The samples were run on a PCR machine using the following conditions:

94°C for 4 minutes (1 cycle)

$$\left.\begin{array}{l}94^{\circ}\text{C for 45 seconds}\\ 55^{\circ}\text{C for 45 seconds}\\ 72^{\circ}\text{C for 3 minutes}\end{array}\right\}\ \text{35 cycles}$$

72°C for 10 minutes (1 cycle)

4°C hold

The samples were viewed on a 1% agarose gel to check the reactions had been successful, and then purified using the QIAquick PCR purification kit (Qiagen Ltd., Crawley, W.Sussex, UK).

APPENDIX 6: Sequencing protocol

Preparation of sequencing reaction

For each 20 µl sequencing reaction, the following reagents were combined:

*Thermo Sequenase II reagent premix	4µl
Primer (10µM)	0.5µl
DNA template	2-6µl
H_2O	X
Total	20µl

*Amersham Biosciences, UK.

The samples were run on a PCR machine using the following conditions:

$$\left.\begin{array}{ll} 96^\circ\text{C} & 10\ \text{sec} \\ 50^\circ\text{C} & 5\ \text{sec} \\ 60^\circ\text{C} & 4\ \text{mins} \end{array}\right\} \text{25 cycles}$$

Sequencing purification

The sequencing reactions were purified as follows. Each 20µl PCR product was transferred to a fresh 0.5ml tube containing 2µl of sodium acetate/EDTA buffer. 2.5 volumes (i.e. 55µl) of 100% cold (-20°C) ethanol was added to each reaction. The tubes were mixed briefly with a vortex mixer and placed on ice for 15-20 mins to precipitate the DNA.

The tubes were centrifuged (~13,000rpm) for 15 mins, and as much of the supernatant removed as possible.

250-500μl of cold 70% ethanol was added to each tube to wash the pellet. The tubes were then centrifuged (~13,000rpm) for 5 mins.

The supernatant was drawn off and the pellets vacuum dried in a vacuum centrifuge for 2-5 minutes.

The samples were run on an ABI 377 Prism Automatic DNA Sequencer according to the manufacturer's protocols (Perkin Elmer, Applied Biosystems Division, Foster City, CA, USA).

APPENDIX 7: ITS Matrix analysed in Chapter 3

```
[                             10        20        30        40        50        60        70        80        90       100]
[                              .         .         .         .         .         .         .         .         .         .]
Cyrtandrasp.Naga       CGAAACCCGCAAAGCAGACCCGCGAACATGTTT--AAAAA-CGC-------CGCGACGTCG---GATGTG--TG-CGT--CCAAC----GTCACGGCTT-    [77]
C.sp.Lantuyang         CGAAACCTACAAAGTAGACCCGTGAACATGTTT--GAATA-TGCTTGCGGTCGTGGTAGCG---GACGTGTTTG-CGT--CCAAC----ATCACGACCT-    [86]
C.sp.Isabella          CGAAACCTGCAAAGCAGACCCGCGAACATGTTT--AAATA-CGCTTGCGGCCGAGGTGTCG---GATG-------CGT--CCAAC----ATCAAGGCCT-    [80]
C.cumingii             CGAAACCTGCAAAGCAGACCCGCGAACATGTTT--AAATA-CGCTTGCGGCCGCGATGTCG---GATG-------CGT--CCAAC----ATCAAGGCTT-    [80]
C.ferruginea           CGAAACCCGCAAAGCAGACCCGCGAACATGTTT--AAATA-CGC-------CGCGACGTGG---GATG-------CGT--CCGAC----GTCACGGCCT-    [73]
C.sp.Halcon1           CGAAACCTGCAAAGCAGACCCGCGAACATGTTT--AAATA-CGCTTGCGGCCGCGATGTTG---GATG-------CGT--CCAAC----ATCACGGCCT-    [80]
C.sp.Halcon2           CGAAACCTGTAAAGCAGACCCGCGAACACGTTT--AAACA-CGCTTGCGGTCGCGATGTGG---GATG-------CGT--CCAAC----ATCACGGCCTC    [81]
C.baileyi              CGAAACCTGCAAAGCAGACCCGTGAACTTGTTA-AAAATA-TGCTTGCGGCCGCGATGTCG---GATGCATTTG-CGT--CCAACCAACATCACGACCC-    [91]
C.monticola            CGAAACTTGCAAAGCAGACCCGTGAACTTGTTT--AAATA-CGCTTGCGGCCGCGATGTCGTCGGATGCATTTG-CGT--CCAACCGACATCACGGCCC-    [93]
C.umbellifera          CGAAACCTGCAAAGCAGACCCGTGAACATG-TT--AAATA-CG-TTGCGGCCGCGGTGTCG---GATGC-GTT-------CC-AC----ATCACGGCCT-    [78]
C.tohiveaensis         CGAAACCTGCAAAGCAGACCCGTGAACATGATT--AAATA-CGCTTGCGGCCGCGATGTCG---GATGC-TTTGGCGT--CCCAC----ATCACGACCT-    [86]
C.stenoptera.a         CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGCG---GATGTGTTTG-CGT--CCAAC----ATCACGACCT-    [86]
C.stenoptera.b         CGAAACCTGCAAAACAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGCG---GATGTGTTTG-CGT--CCAAC----ATCACRACAT-    [86]
C.trichodon            CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGCG---GATGTGTTTG-CGT--CCAAC----ATCACGACCT-    [86]
C.rhyncanthera.a       CGAAACCTGCAAAGCAGACCCGTGAACATGATT--AAATA-TGCTTCCGGCCGCGGTGGTG---GACGCGTTTG-CGT--TCAAC----ATCACGACCT-    [86]
C.rosea                CGAAACCTGCAAAGCAGACCCGCGAACATGTTT--AAATA-CGCTTGCGGCCGCGACGTCG---GGTGCCTTTG-CGT--CCGGC----TTCACGGCCT-    [86]
C.impressivenia        CGAAACCTGCAAAGCAGACCCGCGAACATGTTT--AAACA-CGCTTGCGGCCGCGATGTCG---GATGCGTTTG-CGT--CCGGC----TCCACGGCCT-    [86]
C.sandei               CGAAACCTGCAAAGCAGACCCGCGAACATGTTT--AAATA-CGCTTGCGGCCGCGACGTCG---GGTGCCTTTG-CGT--CCGGC----TTCACGGCCT-    [86]
C.sandei55             CGAAACCTGCAAAGCAGACCCGCGAACATGTTT--AAATA-CGCTTGCGGCCGCGACGTCG---GGTGCCTTTG-CGT--CCGGC----TTCACGGCCT-    [86]
C.picta                CAAAACCTGCAAAGCAGACCCGTGAACACGTTT--AAATA-TGCTTGCGGCCGCGGTGGAG---GATGCGTTTG-CGT--CCAAC----ATCACGACCT-    [86]
C.aureotincta          CGAAACCCGCAAAGCAGACCCGTGAACATGTTT--AAACA-CGCTTGCGGCCGCGATGCCG---GGCGCGTTTG-CGTGTCCGGC----CTCACGGCCT-    [88]
C.sp.LMRF1             CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGCG---GACGCGTTTG-CGT--CCAAC----ATCACGACCT-    [86]
C.sp.LMRF2             CGTAACCTGCAAAGCAGACCTGTGAACATGTTT--AAACA-CGCTTGCGGCCGCGACGTCG---GATGCGTTTG-TGT--CCAAC----TTCACGACCT-    [86]
C.peltata              CGAAACCTGCAAAGCAGACCCGTGAACACGTTT--AAATA-TGATTGCGGCCGCGGTGGCG---GATGTGTTTG-CGT--CCAAC----ATCACGGCCT-    [86]
C.pendula              CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGCG---GACGCGTTTG-CGT--CCAAC----ATCACGACCT-    [86]
C.rhyncanthera.b       CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGTG---GACGCGTTTG-CGT--TCAAC----ATCACGACCT-    [86]
C.anisophylla          CGAAACCTGCAAAGCAGACCCGTGAACATGTTTAAAAATA-CGCTTGCGGCCGTGATGTCG---GATGCGTTTG-CGT--CCCAC----ATCACGACCT-    [88]
C.longepetiolata       CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGCG---GACGCGTTTG-CGT--CCAAC----ATCACGACCT-    [86]
C.mesilauensis         CGAAACCTGCAAAGCAGACCCGTGAAMATGTTT--AAATA-CGATTGCGGCCGCGAWGTYG---GAWGCGTTTG-CGT--CCAAT----ATYACGACCT-    [86]
C.corniculata          CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-CGCTTGTGGCCGCGATGTCG---GATGCGTTTG-CGT--CCAAT----ATCACGACTT-    [86]
C.fulvisericea         CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--ACATA-CGCTTGTGGCCGCGATGTCG---GATGCGTTTG-CGC--CCCAC----ATCACGACTT-    [86]
C.burbidgei            CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGATTGCGGCCGCGGTGGCG---GATGTGTTTG-CAT--CCAAC----ATCACGACTT-    [86]
C.smithiana            CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-CGCTGGCGGCCGCGATGTCG---GATGCGTTTTGCGT--CCAAC----ATCACGACCT-    [87]
C.aurantiaca           ??????????????CAGACCCGTGAACATGTTT--AAATA-CTCTTGCGGCCGCGACGTCG---GATGCGTTTG-CGT--CCAAC----ATCACGACCT-    [86]
C.gibbsiae             CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-CGCTTGCGGACGCGATGTCG---GATGCGCTTG-CGC--CCGAT----ATCACGACTT-    [86]
C.clarkei              CGAAACATGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGCG---GATGCGTTTG-CAT--CCAAC----ATCACGACCC-    [86]
C.chrysea              CGTAACCTGCAAAGCAGACCCGTGAACATGTTTAAAAACA-CGCTTGCGGCCACGGTGTCG---GATGCGTCTG-CGT--CCCAC----ATCGCGACTT-    [88]
C.kermesina            CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGCG---GATGCGTTTG-CAT--CCAAC----ATCACGACCC-    [86]
Aeschynanthuspulch.    CGAAACCTGCAAAGCAGACTCGTGAACATGTGT--AAATAACATCGGGGGTCGTGAGGTTG---GATGCATTTG-TGT--CCAGC----ATCACGACCT-    [87]
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[                              110       120       130       140       150       160       170       180       190       200]
[                                .         .         .         .         .         .         .         .         .         .]
Cyrtandrasp.Naga       -----CGGCCCC-AAGTGGCGCAAGTCG---CTCGGGGCATCCTAACAA--CCTCCCGGCGCGGCAAGCGCCAAGGAAAACCATACGGACCACCTCTCCG   [166]
C.sp.Lantuyang         -----TGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAAGCGCCAAGGAAAAATGTATCGAACGCCTCTCCG   [171]
C.sp.Isabella          -----CGACCCC-AAGTGGCGCAAGTCG---CTGGGGGCAAACTAACAA--CCTTTCGGCGCGGCAAGCGCCAAGGAAAACCATACGGAACGCCTCTCCG   [169]
C.cumingii             -----CGACCCC-AAGTGGCGCAAGTCG---CTCGGGGCATACTAACAA--CCTCTCGGCGCGGCAAGCGCCAAGGAAAACCATACGGAACACCTCTCCG   [169]
C.ferruginea           -----CGACCCC-AAGTGGCGCAAGTCG---CTCGGGGCATACCAACAA--CCTCTCGGCGCGGCAAGCGCCAAGGAAAACCATACGGACCACCTCTCCG   [162]
C.sp.Halcon1           -----CGACCCC-AAGTGGCGCAAGTCG---CTCGGGGCATACTAACAA--CCTCTCGGCGCGGCAAGCGCCAAGGAAAACCATACGGACCACCTCTCCA   [169]
C.sp.Halcon2           GGCCTCGACCCC-AAGTGGCGCGAGTCG---CTCGGGGCATACTAACAA--CCTCTCGGCGCGGCAAGCGCCAAGGAAAACCATATCGAACGCCTCTCCT   [175]
C.baileyi              -----TGACCCC-AAGTGGCGCAAGTCGTTGCTC-GGGCGTGCTAACAA--CCTCTCGGCGCGGCAAGCGCCAAGGAAAATCATATCGAACGCCTCTCCG   [182]
C.monticola            -----TGACCCC-GAGTGGCGCAAGTCGTTGCTT-GGGCGTGCTAACAA--CCTCTCGGCGCGGCAAGCGCCAAGGAAAACCATATCGAACGCCTCTCCG   [184]
C.umbellifera          -----CGACCCC-AAGTGGCGCAAGTCA--GCTGGGGGCATACTAACAA--CCTCTCGGCGTGGCAAGCGC-AAGGAAAACCATA?CGAACACCTGTCCG   [167]
C.tohiveaensis         -----CGACCCC-AGGTGGCGCAAGTCG---CTCGGGGCACACTAACAA--CCTCTCGGCGCGGCAAGCGCCAAGGAAAACGATGTCGAATGCCTCTCCG   [175]
C.stenoptera.a         -----CGATCCC-AAGTGGCGCAAGTCG---CTC-GGGTGTACTAA-----CCTCTCGGCGCGGCAAGCGCCAAGGAAAAACGTATCGAACGCCTCTCCG   [171]
C.stenoptera.b         -----CGATCCC-AAGTGGCGCAAGTCG---CTC-GGGTGTACTAA-----CCTCTCGGCGCGGCAAGCGCCAAGGAAAAACGTATCGAACGCCTCTCCG   [171]
C.trichodon            -----CGATCCC-AAGTGGCGCAAGTCG---CTC-GGGTGTACTAA-----CCTCTCGGCGCGGCAAGCGCCAAGGAAAAACGTATCGAACGCCTCTCCG   [171]
C.rhyncanthera.a       -----CGACCCC-AAGCGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAAGCGCCAAGGAAAAACGTATCGAACGCCTCTCCG   [171]
C.rosea                -----CGACCCC-GAGTGGCGCGAGTCG---CTC-GGGCGTACTAACAAA--CTCTCGGCGCGGCAAGCGCCAAGGAAAACCATACCGAACACCTCTCCG   [174]
C.impressivenia        -----CGACCCC-GAGTGGCGCAAGTCG---CTC-GGGCGTACTAACAA--CCTCTCGGCGCGGCAAGCGCCAAGGAAAACCATACCGAACACCTCTCCG   [174]
C.sandei               -----CGACCCC-GAGTGGCGCGAGTCG---CTC-GGGCGTACTAACAAA--CTCTCGGCGCGGCAAGCGCCAAGGAAAACCATACCGAACACCTCTCCG   [174]
C.sandei55             -----CGACCCC-GAGTGGCGCGAGTCG---CTC-GGGCGTACTAACAAA--CTCTCGGCGCGGCAAGCGCCAAGGAAAACCATACCGAACACCTCTCCG   [174]
C.picta                -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAAGCGCCAAGGAAAAACGTATCGAACGCCTCTCCG   [171]
C.aureotincta          -----CGACCCC-GAGTGGCGCAAGCCG---CTC-GGGCGTACTAACAAAA-CTCTGGGCGCGGCAAGCGCCAAGGAAAACCATACCGAACACCTCTCCG   [177]
C.sp.LMRF1             -----CGACCCC-AAGTGGCGCAAGTCG---CTT-GGGCGTACTAA-----CCTCTCGGCGCGGCAAGCGCCAAGGAAAAACGTATTGAACGCCTCTCCG   [171]
C.sp.LMRF2             -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAACAA--CCTCTCGGCGCGGCAAGCGCCAAGGAAAACAATACCGAAAACCTCTCCG   [174]
C.peltata              -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAAGCGCCAAGGAAAAACGTATCGAACGCCTCTCCG   [171]
C.pendula              -----CGACCCC-AAGTGGCGCAAGTCG---CTT-GGGCGTACTAA-----CCTCTCGGCGCGGCAAGCGCCAAGGAAAAACGTATTGAACGCCTCTCCG   [171]
C.rhyncanthera.b       -----CGACCCC-AAGCGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAAGCGCCAAGGAAAAACGTATCGAACGCCTCTCCG   [171]
C.anisophylla          -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAACAA--CCTCTCGGCGCGGCAAGCGCCAAGGAAAACCATACCGAACACCTCTCCG   [176]
C.longepetiolata       -----CGACCCC-AAGTGGYGCAAGTCG---CTT-GGGCGTACTAA-----CCTCTCGGCGCGGCAAGCGCCAAGGAAAAACGTATTGAACGCCTCTCCG   [171]
C.mesilauensis         -----TGACCCC-AAGTGGSGCAAGTYG---CTY-GGGSGTACCAA-----CCTTTTGGCGCGGCAAGCGCCAAGGRAAAAMGTACCGAACACCTTTCCG   [171]
C.corniculata          -----CGACCCC-AAGTGGCACAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGTGGCAAGCGCCAAGGAAAAACATATCGAACACCTCTCTG   [171]
C.fulvisericea         -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAACAA--CTTCTCGGCGCGGCAAGCGCCAAGGAAAACCATATCGAACGCCTCCCCG   [174]
C.burbidgei            -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAAGCGCCAAGGAAAAACGTATCGAACGTCTCTCCG   [171]
C.smithiana            -----CGACCCCCAAGTGGCGCAAGTCA---CTC-GGGCGTACTAACAA--CCTCTCGGCGCGGCAAGCGCCAAGGAAAACCATACCGAACACCTCTCCG   [176]
C.aurantiaca           -----CGACCTC-GAGTGGCGCAAGTCG---CTC-GGGTGAACTAA-----CCTCTCGGCGCGGCAAGCGCCAAGGAAAACCATACAGAACACCTCTCCG   [171]
C.gibbsiae             -----CGACCCC-AAGTGGCGCAAGTCG---CTG-GGGCGTACTAA-----CCTCTCGGCGCGGCAAGCGCCAAGGAAAAACATACCGAACGCCTCTCCG   [171]
C.clarkei              -----TGACCCC-AAGTGGCGCAAGTCK---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAAGCGCCAAGGAAAAACGTATCGAACGCCTCTCCG   [171]
C.chrysea              -----CGGCCCC-GAGTGGCGCAAGTCG---CTC-GGGCGTACCAA-----CCTCTCGGCGCGGGAAGCGCCAAGGAAAAACATACCGAACGCCTCTCCG   [173]
C.kermesina            -----AGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAAGCGCCAAGGAAAAACGTATCGAACGCCTCTCCG   [171]
Aeschynanthuspulch.    -----CGACCCC-AAGTGGCGCAAGTCG---CTT-GGG?GTACTAAA-----CTCTCGGCGCGGCAAGCGCCAAGGAAAACCGTATCGAACACCTCTCCG   [172]
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[                                210       220       230       240       250       260       270       280       290       300]
[                                  .         .         .         .         .         .         .         .         .         .]

Cyrtandrasp.Naga         TCTCGGTGCCGTGCGCGGTA--CCC--AGGACGTG-ACGAGGA-GGA-CTATCGAAAG--AGCACCTTGTT-CCC-CACTCACT-CAGAG----TGCCGG   [250]
C.sp.Lantuyang           TCTCGGTGCCGTGCGCGGTA--CCC--AGGACGCG-ACGAGGA-GCGTCTATTGAATA--AGCATCGTCTT-CCC-CACT-----CAAAG----TGCCGG   [252]
C.sp.Isabella            TCTCGGTGCCGTGCGCGGTA--CCC--AGGACGTG-ACGAGGA-GCA-CCATTGAATA--AACATCCTCTT-CCC-CACT-----CAGAG----TGCCGG   [249]
C.cumingii               TCTCGGCGCCGTGCGCGGTATACCC--AGGACGTG-ACGAGGA-GCA-CCATTGAATA-AAACATCTTCTT-CCC-CACT-----CAGAG----TGCCGG   [252]
C.ferruginea             TCTCGGTGCCGTGCGCGGTA--CCC--AGGGGGTG-GYGAGGA-GGA-CTATCGAAAA-AGGC?TCG-CTG-CCC-CGCT-----CACAG----TGCCGG   [242]
C.sp.Halcon1             TCTCGGTGCCGTGCGCGGTA--CCA--GGGATGTG-ATGAGGA-GAA-CGATTGAATA--AGCATCCTCTT-CCA-CACT-----CAGAG----TGCCGA   [249]
C.sp.Halcon2             TCCCGGCGCCGTGCGCGGCA--CCA--GGGACGTG-AGGAGGA-GCA-CGATTTAATA--AACATCCTCTT-CCC-CACT-----CAGAG----TGTCGG   [255]
C.baileyi                TCACGGTGCCGTGCGCGGTG--CGC--AGGACTTG-ACGAGGA-GCGTCCATTGAATA--AACATCCTCTT-CCA-CACT-----AAGAG----TGCCGG   [263]
C.monticola              TCTCGGTGCCGTGCGCGGTA--CGC--AGGACGTG-ACGATGA-GCGTCCATTGAATT--AACATCCTCTT-CCA-AACT-----AAGAG----TGCCGG   [265]
C.umbellifera            TCTCGGTGCCGTGCGCAGTA--CCC--AGGCCGTGTACGAGGA-GCA-CTTT?GAATA--A-GTC-TCTT---CC-CACT-----CAGAG----TGGCCG   [244]
C.tohiveaensis           TCCCGGTGTCGTGCGCGGTA--CCC--AGGACGTG-ACGAGGA-ACA-CTATCGAATA---ACGTCCTCTTTGCC-CACT-----CAGAG----TG-C--   [252]
C.stenoptera.a           TCTCGGTGCCGTGCGCGGTA--CCC--AGGACGCG-ATGAGGA-GTGTCTATTGAATA--AGCATCGTCTT-CCC-CACT-----CAGAG----TGTCGG   [252]
C.stenoptera.b           TCTCGGTGCCGTGCGCGGTA--CCC--AGGACGCG-ATGAGGA-GTGTCTATTGAATA--AGTATCGTCTT-CCC-CACT-----CAGAG----TGTCGG   [252]
C.trichodon              TCTCGGTGCCGTGCGCGGTA--CCC--AGGACGCG-ATGAGGA-GTGTCTATTGAATA--AGCATCGTCTT-CCC-CACT-----CAGAG----TGTCGG   [252]
C.rhyncanthera.a         TCTTGGCGCCGTGCGCGGTA--CCC--AGGACGCG-ACGAGGA-GTATCTATTGAATA--AGCATCGTCTT-CCC-CACT-----CAGAG----TGCCGG   [252]
C.rosea                  TCCCGGTGCCGTGCGCGGTA--CCG--AGGACGTG-ACGAGGA-GCGTCTATTGAATA--ATCATCTTCTT-CCC-CACT----CCAGAG----TGCCGG   [256]
C.impressivenia          TCCCGGTGCCGTGCGCGGTA--CCG--GGGACGTG-ACGAGGA-GCGTCTATTGAATA--GTCATCTTCTT-CCC-CACT----CTCGAG----TGCCGG   [256]
C.sandei                 TCCCGGTGCCGTGCGCGGTA--CCG--AGGACGTG-ACGAGGA-GCGTCTATTGAATA--ATCATCTTCTT-CCC-CACT----CCAGAG----TGTCGG   [256]
C.sandei55               TCCCGGTGCCGTGCGCGGTA--CCG--AGGACGTG-ACGAGGA-GCGTCTATTGAATA--ATCATCTTCTT-CCC-CACT----CCAGAG----TGTCGG   [256]
C.picta                  TCTCGGTGCCGTGCGCGGTA--CAA--AGGACGCG-ATGAGGA-GCGTCTATTGAATA--AKCATCGTCTT-CCC-CACT-----CAGAG----TGCCGG   [252]
C.aureotincta            TCCCGGTGCCGTGCGCGGTA--CCG--AGGACGTG-ACGAGGA-GCGTCTATTGAATA--ATCATCTTCTT-CCCCCACTCCCTCCAGAGGAGC-GCCGG   [267]
C.sp.LMRF1               TCTCGGCGCCGTGCGCGGTA--CCC--AGGACGCG-ATGAGGA-GCTTCTATTGAATA--AACATCGTCTT-CCC-CACT-----CAGAG----TGTCGG   [252]
C.sp.LMRF2               TCCCGGTGCCGTGCGCGGTG--CCG--AGGACGTG-ACGAGGA-TTGTCTATTGAATA--ATCGTGTTCTT-CCC-CACT----CCAGAG----TGTCGG   [256]
C.peltata                TCTCGGTGCCGTGCGCGGTA--CCC--AGGACGCG-ATGAGGA-GCGTCTATTGAATA--AGCATCGTCTT-CCC-CACT-----CAGAG----TGTCGG   [252]
C.pendula                TCTCGGCGCCGTGCGCGGTA--CCC--AGGACGCG-ATGAGGA-GCTTCTATTGAGTAA-AACATCGTCTT-CCC-CACT-----CAGAG----TGTCGG   [253]
C.rhyncanthera.b         TCTTGGCGCCGTGCGCGGTA--CCC--AGGACGCG-ATGAGGA-GTATCTATTGAATA--AGCATCGTCTT-CCC-CACT-----CAGAG----TGCCGG   [252]
C.anisophylla            TCCYGGTGCCGTGCGCGGCA--CCT--AGGACGTG-ACGAGGG-GCGTCAATAGAGTA-CAGCATCCTCTT-CCC-CACT-----CAGAG----TGCCGG   [258]
C.longepetiolata         TCTCGGCGCCGTGCGCGGTA--??C--A?GACGCG-A?GAGGA-GCTTCTATTGAATA--AACATCGTCTT-CCC-CACT-----CAGAG----TGTCGG   [252]
C.mesilauensis           TTTGGGTGCCGTGCGCGGTA-ACCC--AGGATGTG-ACGAGGA-GCGTCTATCGAATA--AACATCCTCTT-CCC-CACT-----CAGAG----TGTCGG   [253]
C.corniculata            TCTCGGTGCCGTGCGCGGTA--CCC--AGAACGTG-ATGAGGA-GCGTCTATCGAATA--AACATCCTCTT-CCC-CACT-----CAGAG----TGCCGG   [252]
C.fulvisericea           TCCCGGTGCCGCGCGCGGCA-ACCC--TGGACGTG-GCGAGGA-GCGTCTATCGAGTA--GACATCCTCTC-CCC-CACT-----CAGAG----TGCCGG   [256]
C.burbidgei              TCTCGGCGCCGTGCGCGGTA--CCC--AGGACGTG-ACGAGGA-GCGTMTAYTGAATA--AGCATCGTCTT-CCC-CACT-----CAGAG----TGCCGG   [252]
C.smithiana              TCTCGGTGCCGTGCGCGGTG--CCT--AGGACGTG-ACGAGGA-GCGTCTACTGAATA-CAACATCCTCTT-CCC-CACT-----CAGAG-TGGTGCCGG   [261]
C.aurantiaca             TATCGGTGCCGTGCGCGGTA--CCC--AAGACGTG-ACGAGGA-GCGTCTATTGAATA-CAACATCGTCTT-CCC-CACTCACT-CAGAG----TGTCGG   [257]
C.gibbsiae               TCTCGGCGCCGTGCGCGGTA--CCC--AGGACGTG-ACGAGGA-GCGTCTATTGAATA--AACATCCTCTT-CCC-CACT-----CCGAG----TGCCGG   [252]
C.clarkei                TCTCGGCGCCGTTCGCGGTA--CCC--AGGACGTG-ACGAGGA-GCGTCTATTGAATA--AGCATCGTCTT-CCC-CACT-----CAGAG----TGCCGG   [252]
C.chrysea                TCTCGGCGCCGTCCGCGGCA--CCCCCGGGACGTG-ACGAGGAAGCGTCTATTGAATA--AGCATCCTCTC-CCC-CTCT-----CAGAA----TGCCGG   [257]
C.kermesina              TCTCGGCACCGTGCGCGGTA--CCC--AGGACGTG-ACGAGGA-GCGTCTATTGAATA--AGCATCGTCTT-CCC-CACT-----CAGAG----TGCGGG   [252]
Aeschynanthuspulch.      TCTCGGTGC--TATGCGGTA--CCC--AGGACGTG-ATGAGGA-GTGTCTATCGAATAA-AATGTCTTGTT-CCCTGATTCAGT-CAAAG----TGTTGG   [257]
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[                             310       320       330       340       350       360       370       380       390       400]
[                              .         .         .         .         .         .         .         .         .         .]

Cyrtandrasp.Naga      GGAGACGATGCATAC---GAAGGAG---GGGCG---GATATTGGCCTCCCGTTATCA-CTGCGTAGCGGCCGGCCCAAACAACATACCGTGCC--GATGG   [338]
C.sp.Lantuyang        G-AGACGATACATAC---GAAAGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TCGTGTAGCGGCCGGCCCAAATAACATACCGTGTC--GACGG   [339]
C.sp.Isabella         G-AGACGATGCATAC---GAAGGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TTGTGTAGCGGCCGGCCCAAACAACATGCCGTGTC--GATGG   [336]
C.cumingii            G-AGACGATGCGTAC---GAAGGAG---GGGCG---GATATTGGCCTCCCGTTATCT-TGGCGTAGCGGCCGGCCCAAACAAGATACCGTGTC--GATGG   [339]
C.ferruginea          GGAGACAAT?CATTC---GAAGGAG---GGGCG---GATATTGGCCTCCCGTTATCATCACCATATCGGCCGGCCCTAA?AAC?T?CC?TGCC--GACAG   [331]
C.sp.Halcon1          GGAGAAGATGCACAC---CGAGGAG---GGGCG---GATATTGGCCTCCCGTTACCC-TTGTGTAGCGGCCGGCCCAAACAACATGCCGTGTC--GATGG   [337]
C.sp.Halcon2          GGAGACGATGCATAC---GACGGAG---GGGCG---GATGTTGGCCTCCCGTTATCC-TTGTGTAGCGGCCGGCCCAAACAACATACCGTGTC--GATGG   [343]
C.baileyi             G-AGACGATACATAC---GAAGGAG---GGGCG-CGGATATTGGCCTCCCGTTATCC-TTGCATAGCGGCCGGCCCAAATAACATGCCGTGGC--GATGG   [352]
C.monticola           G-AGACGATAGATAC---GGAGGAG---GGGCG-CGGATATTGGCCTCCCGTAATGC-TAGCATAGCGGCCGGCCCAAATAACATGCTGTGGC--KATGC   [354]
C.umbellifera         GGAGACGGTGCATAC---GA-GGAG---GGGCG---GATATTGGCCTCC-GTTATCC-TTGTGTAGCGGCCGGCC-AAATAACATACCGTGTC--GATG-   [328]
C.tohiveaensis        ----ATGA----------GAAGGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TTGTGTAGCGGCCGGCCCAAATAACATACCGTGTC--GATGG   [329]
C.stenoptera.a        G-AGAAGATGCATAC---GAAGGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TCGTGTAGCGGCCGGCCCAAATAACATACCGTGCC--GACGG   [339]
C.stenoptera.b        G-AGAAGATGCATAC---GAAGGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TCGTGTATCGGCCGGCCCAAATAACATACCGTGCC--GACGG   [339]
C.trichodon           G-AGAAGATGCATAC---GAAGGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TCGTGTAGCGGCCGGCCCAAATAACATACCGTGCC--GACGG   [339]
C.rhyncanthera.a      G-AGACGATGCACAC---GAAAGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TCGTGTAGCGGCCGGCCCAAATAACATACCGTGCC--GACGG   [339]
C.rosea               G-AGACGATGCGTACTACGAAGGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TTGTGTAGCGGCCGGCCCAAATAACATACCGTGTC--GATGA   [346]
C.impressivenia       G-AGACGATGCGTAC---GAAGGAG---GGGCG---GATATTGGCCTCCCGTTACCC-TTGTGTAGCGGCCGGCCCAAATAACATACCGTGTC--GATGA   [343]
C.sandei              G-AGACGATGCGTACTACGAAGGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TTGTGTAGCGGCCGGCCCAAATAACATACCGTGTC--GATGA   [346]
C.sandei55            G-AGACGATGCGTACTACGAAGGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TTGTGTAGCGGCCGGCCCAAATAACATACCGTGTC--GATGA   [346]
C.picta               G-AGATGATGCATAC---GAAGGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TCGTGTAGCGGCCGGCCCAAATAACATACCGTGCC--GACGG   [339]
C.aureotincta         G-AGACGATGCGTAC---GAAGGAG---GGGCGGCGGATATTGGCCTCCCGTTATCC-TTGTGTAGCGGCCGGCCCAAATAACATACCGTGTC--GATAA   [357]
C.sp.LMRF1            G-AGGCGATGCATAC---GAGAGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TCGTGTAGCGGCCGGCCCAAATAACATACCGTGTC--GATGG   [339]
C.sp.LMRF2            G-AGATGGTGCGTAC---GGAGGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TCGTGTAGCGGCCGGCCCAAATAACATACCGTGCC--GATGA   [343]
C.peltata             G-AGAAGATGCATGC---GAAGGAG-AGGGGCG---GATATTGGCCTCCCGTTATCC-TCGTGTAGCGGCCGGCCCAAATAACATACCGTGCC--GACGG   [341]
C.pendula             G-AGGCGATGCATAC---GAGAGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TCGTGTAGCGGCCGGCCCAAATAACATACCGTGTC--GATGG   [340]
C.rhyncanthera.b      G-AGACGATGCATAC---GAAAGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TCGTGTAGCGGCCGGCCCAAATAACATACCGTGCC--GACGG   [339]
C.anisophylla         G-AGACGATGCACAG---GAAGGAG---GGTCG---GATATTGGCCTCCCGTTATCC-TCGAGTAGCGGCCGGCCCAAATAACAGACCGTGTC--GATGG   [345]
C.longepetiolata      G-AGGCGATGCATAC---AGAGAAG---GGGCG---GATATTGGCCTCCCGTTATCC-TCGTGTAGCGGCCGGCCCAAATAACATACCGTGTC--GATGG   [339]
C.mesilauensis        G-AGACGATGCATAC---GAAAGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TCGTGTAGCGGCCGGCCCAAATAACATACCGTGTG--GACGG   [340]
C.corniculata         G-AGACGATGCATAC---GAAAGAG--GGGGCG---GATATTGGCCTCCCGTTATCT-TCGTGCAGCGGCCGGCCCAAATAACATACCGTGTC--GATGG   [340]
C.fulvisericea        G-AGACGATGCACAC---GACGGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TCGTGTAGCGGCCGGCCCAAATGACATACCGTGTCTCGATGG   [345]
C.burbidgei           G-AGACGACGCATAC---GGAAGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TCGTGTAGCGGCCGGCCCAAATAACATACCGTGCC--GACGG   [339]
C.smithiana           G-AGACGATGCGTAC---GAAGGAG---GGGCG---GATATTGGCCTCCCGTTATCC-TTGTGTAGCGGCCGGCCCAAATAACATACCGTGCC--GATGT   [348]
C.aurantiaca          G-AGACGATTCATTC---GAAGCAG--GGGGCG---GATATTGGCCTCCCGTTATCC-------------------------CATACCGTGTC--GATGG   [321]
C.gibbsiae            G-AGACGATGCATAC---GAAAGAG---GGGCG---GATATTGGCCTCCCGTTATCT-TCGTGTAGCGGCCGGCCCAAATAACATACCGTGTC--GACGG   [339]
C.clarkei             T-AGGCGACGCATAC---GAAAAGA--GGGGCG---GATATTGGCCTCCCGTTATCC-TCGTGTAGCGGCCGGCCCAAATAACATTCCGTGCC--GACGG   [340]
C.chrysea             G-AGACGACGCATAC---GAAAGAA---GGGCG---GATATTGGCCTCCCGTTATCC-TCATGTAGCGGCCGGCCCAAATAACATGCCGTGTC--TGCGC   [344]
C.kermesina           T-AGGCGACGCATAC---GAAAAGA--GGGGCG---GATATTGGCCTCCCGTTATCC-TCGTGTAGCGGCCGGCCCAAATAACATGCCGTGCC--GACGG   [340]
Aeschynanthuspulch.   G-GGACAATGCGTAC---CAAGGAGGAGGGACG---GATATTGGCCTCCCGTTATCC-AAGTATAGCGGCCGGCACAAATAGTATACCGTGTC--GATTG   [347]
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[                             410       420       430       440       450       460       470       480       490       500]
[                              .         .         .         .         .         .         .         .         .         .]

Cyrtandrasp.Naga      ATGTCACACGATACGTGGTGG---TCGGATTCGTGAA-----------CTAATCGTGTGGGAACGC-GTCGAGCCACGGGCACGACCCAA---CGGCAGC  [420]
C.sp.Lantuyang        ATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGGTACGACCCAA---CGGCACC  [429]
C.sp.Isabella         ATGTCACACGATACGTGGTGG---TTGGATTCGTGAACT-TTACGAA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGGAACGACCCAA---CGGCAGC  [427]
C.cumingii            ATGTCACACGATACGTGGTGG---TTGGATTCGTGAA-----------CTAATCGTGTGGGAATGC-GTCGAGCCACGGGCACGACCCAA---CGGCAGC  [421]
C.ferruginea          ATGTCACAC?ACACGTGGTGG---TCAGAT?CGTGAA-----------STAATCGTGTGGGAATGC-?TC?A-CCACGGGGGAAAAAACCCCCCGGCAGC  [415]
C.sp.Halcon1          ATGTCACACGATACGTGGTGG---TTGGATTCGCGAA-----------CTAATCGTGTGGGAATGC-GCCGAGCCACGGTCACGACCCAA---CGGCAGC  [419]
C.sp.Halcon2          ATGTCGCACGATACGTGGTGG---TTGGATTTGTGAA-----------CTAATCGTGTGGGAATGC-GTCGAGCCACGGCCACGACCCAA---CGGCAGC  [425]
C.baileyi             ATGTCACACGATACGTGGTGGCGGTTAGATCCTTCGAC--TTGCAAAACTAATCGTGTGGGAATGC-GTCTAGCCACGGGCACGACCCTG---TGGCAGC  [446]
C.monticola           ATGTCACACGATACGTGGTGGCGGTTAGATTCCTCGAC--TTGCAAAACTAATCGTGTGGGAATGC-GTCGAGCCACGGGCACGACCCGGTGGCGGCAGC  [451]
C.umbellifera         ATGTCACACGATGCGTGGTGG---TTGGAT-CGCGAAC--TTACGAA-CTAATCGTGTGG--ATGCG--CG?----CGGGCACGACCCAAA--CGGCAGC  [411]
C.tohiveaensis        ATGTCGCACGATGCGTGGTGG---TTGAATTCGTCAAC--TTGCAAA-CTAATCGTGTGGGAATGC-GTCCAGTGACGGGCATGACCCAA---CGGCAGC  [419]
C.stenoptera.a        ATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGGCACGACCCAA---CGGCACC  [429]
C.stenoptera.b        ATGTCACACGATAAGTGGTGG---TTGGATTCGTCAAC--TCGCGGA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGGCATGACCCAA---CGGCACC  [429]
C.trichodon           ATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-CTGATCGTGTGGGAATGC-GTCGAGCCACGGGCACGACCCAA---CGGCACC  [429]
C.rhyncanthera.a      ATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TTGCGGA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGGCACGACCCAA---CGGCACC  [429]
C.rosea               ATGTCACACGATACGTGGTGG---TTGGATTTCTCATC--TTGCGAA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGGCACGACCCAA---GGGCGCC  [436]
C.impressivenia       ATGTCACACGATACGTGGTGG---TTGGATTTCTCATC--TTGCGAA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGGCAAGACCCAA---TGGCACA  [433]
C.sandei              ATGTCACACGATACGTGGTGG---TTGGATTTCTCATC--TTGCGAA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGGCACGACCCAA---CGGCGCC  [436]
C.sandei55            ATGTCACACGATACGTGGTGG---TTGGATTTCTCATC--TTGCGAA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGGCACGACCCAA---CGGCGCC  [436]
C.picta               ATGTCACACGATAAGTGGTGG---TTGGATTCCTCAACTCTCGCGGA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGGCACGACCCAA---CGGCACC  [431]
C.aureotincta         ATGTCACACGATACGTGGTGG---TCGGATTTCTCATC--TTGCGAA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGGCATGACCCAA---CGGCGCC  [447]
C.sp.LMRF1            ATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGACACGACCCAA---CGGCACC  [429]
C.sp.LMRF2            ATGTCACACGATACGTGGTGG---TCGGATTTCTCATC--TCGCAAA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGGCACGACCCAA---TGGCACC  [433]
C.peltata             ATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGGCACGACCCAG---CGGCACC  [431]
C.pendula             ATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGACACGACCCAA---CGGCACC  [430]
C.rhyncanthera.b      ATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TTGCGGA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGGCACGACCCAA---CGGCACC  [429]
C.anisophylla         ATGTCACACGATACGTGGTGG---TCGGATTCCTCGAG--TTGCGAA-CTGATCGTGTGGGAATGC-GTCGAGCCACGGGCACGACCCAA---CGGCACC  [435]
C.longepetiolata      ATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGACACGACCCAA---CGGCACC  [429]
C.mesilauensis        ATGTCACACGATAAGTGGTGG---TCGTATTCCTCAAC--TTGCGGA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGCCAAGACCCAA---TGGCACC  [430]
C.corniculata         ATGTCACACGATAAGTGGTGG---TCGGATTCCTCAAC--TTGCGGA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGCCACGACCCAA---TGGCATC  [430]
C.fulvisericea        ATGTCACACGATACGTGGTGG---TTGGATTCCTCGAC--TTGCGAA-CTGATCGTGTGGGAATGC-TTCGAGCCACGGGCACGACCCAA---CGGCACC  [435]
C.burbidgei           ATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGGCACGACCCAA---CGGCACC  [429]
C.smithiana           ATGTCACACGATACTTGGTGGTGGTTGGATTCCTCAAC--TGGCGAA-CTAATCGTGTGGGAATGT-GTCGAGCCACGGGCACGACCCAA---TGGCACC  [441]
C.aurantiaca          ATGTCACACGATACGTGGTGG---TTGGATTCCCCAAC--TTGTGAA-CTAATCGTGTGGGAATGC-ATCGAGCCACGGGCAAGACCCAA---TGGCACA  [411]
C.gibbsiae            ATGTCACACGATAAGTGGTGG---TCGGATTCCTCAAC--TTGCGTA-CTAATCG?GTGGGAATGT-GTCGAGCCACGGCCAAGACCCAA---TGGCACG  [429]
C.clarkei             ATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-CTAATCGTGTGGGAATGC-GTCGAGCCACGGGCACGACCCAA---CGGCACC  [430]
C.chrysea             ATGTCACACGATGAGTGGTGG---TTGGATTCCTCAAC--TTGCGGA-CTACTCGTGTGGGAATGC-GTCTCGCCACGGGCACGACCCAA---CGGCACC  [434]
C.kermesina           ATGTCACACGATAAGTGGTGG---TTGGATTCTTCAAC--TCGCGGA-CTAATCGTGTGGGAATGC-ATCGAGCCAMGGGCACGACCCAA---CGGCACC  [430]
Aeschynanthuspulch.   ATGTCACACGATACGTGGTGG---TTGGATTCCTCAAC--TTGCGAA-CTAATCGTGTGGGACTCC-ATCAATCCACGGGCCTGACCCAA---TGGCACA  [437]
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[                             510       520]
[                              .        . ]

Cyrtandrasp.Naga      --AGATCG------CCCTCGA   [433]
C.sp.Lantuyang        --AGATCG------CCCTCGA   [442]
C.sp.Isabella         --AGATTG------CCCTCGA   [440]
C.cumingii            --AGATTG------CCTTCGA   [434]
C.ferruginea          --AGA----------------   [418]
C.sp.Halcon1          --AGATTG------CCCTCGA   [432]
C.sp.Halcon2          GCAGATTG------CCCTCGA   [440]
C.baileyi             --AGATTGGTGCTGCCTTCCA   [465]
C.monticola           --AGATCGGTGCTGCCCTCCA   [470]
C.umbellifera         A-AGATTG------CCCTCGA   [425]
C.tohiveaensis        --AGATTG------CCCTCGA   [432]
C.stenoptera.a        --AGATCG------CCCTCGA   [442]
C.stenoptera.b        --AGATCG------CCCTCGA   [442]
C.trichodon           --AGATCG------CCCTCGA   [442]
C.rhyncanthera.a      --AGATCG------CCCTCGA   [442]
C.rosea               --AGATCG------CCCTCGA   [449]
C.impressivenia       --AGATCG------CCCTCGA   [446]
C.sandei              --AGATCG------CCCTCGA   [449]
C.sandei55            --AGATCG------CCCTCGA   [449]
C.picta               --AGATCG------CCCTCGA   [444]
C.aureotincta         --AGATCG------CCCTCGA   [460]
C.sp.LMRF1            --AGATCG------CCCTCGA   [442]
C.sp.LMRF2            --AGATCG------CCCTCGA   [446]
C.peltata             --AGATCG------CCCTCGA   [444]
C.pendula             --AGATCG------CCCTCGA   [443]
C.rhyncanthera.b      --AGATCG------CCCTCGA   [442]
C.anisophylla         --AGATTG------CCCTCGA   [448]
C.longepetiolata      --AGATCG------CCCTCGA   [442]
C.mesilauensis        --AGATTG------CCCTCGA   [443]
C.corniculata         --TGTTTG------CCCTCGA   [443]
C.fulvisericea        --AGATCG------CCCTCGA   [448]
C.burbidgei           --AGATCG------CCCTCGA   [442]
C.smithiana           --AGATTG------CCCTCGA   [454]
C.aurantiaca          --AGATTG------CCCTCGA   [424]
C.gibbsiae            --AGGT-G------CCCTCGA   [441]
C.clarkei             --AGATCG------CCCTCGA   [443]
C.chrysea             --AGATTG------CCCTCGA   [447]
C.kermesina           --AGATCG------CCCTCGA   [443]
Aeschynanthuspulch.   --AGATTG------CCCTCGA   [450]
```

APPENDIX 8: ITS Gap Matrix analysed in Chapter 3

Species	1	6	11	16	21
C. sp. *Naga*	11001	11010	01??1	10011	?111?11
C. sp. *Lantuyang*	10001	111?1	00??1	?1111	?110111
C. sp. *Isabella*	101??	11010	01??1	?1111	?110111
C. cumingii	101??	11010	01011	?1111	?111?11
C. ferruginea	111??	11010	01011	?1011	?111?0?
C. sp. *Halcon 1*	101??	11010	01??1	?1011	?111?11
C. sp. *Halcon 2*	101??	11010	01??1	?1011	?111?11
C. baileyi	00001	00110	00??1	?1111	?000010
C. monticola	10001	00110	00??1	?1111	?000000
C. umbellifera	10011	11010	01??1	?1011	?1101?1
C. tohiveaensis	10010	11010	01??1	?1111	?110111
C. stenoptera a	10001	111?1	00??1	?1111	?110111
C. stenoptera b	10001	111?1	00??1	?1111	?110111
C. trichodon	10001	111?1	00??1	?1111	?110111
C. rhyncanthera a	10001	111?1	00??1	?1111	?110111
C. rosea	10001	11100	10??1	0?101	?110111
C. impressivenia	10001	11110	00??1	0?111	?110111
C. sandei	10001	11100	10??1	0?101	?110111
C. sandei 55	10001	11100	10??1	0?101	?110111
C. picta	10001	111?1	00??1	?1111	?110111
C. aureotincta	10001	11100	10??0	00111	??10111
C. sp. LMRF1	10001	111?1	00??1	?1111	?110111
C. sp. LMRF2	10001	11110	00??1	0?111	?110111
C. peltata	10001	111?1	00??1	?1110	0110111
C. pendula	10001	111?1	00011	?1111	?110111
C. rhyncanthera b	10001	111?1	00??1	?1111	?110111
C. anisophylla	00001	11110	00101	?1111	?110111
C. longepetiolata	10001	111?1	00??1	?1111	?110111
C. mesilauensis	10001	111?1	00??1	?1111	?110111
C. corniculata	10001	111?1	00??1	?1110	1110111
C. fulvisericea	10001	11110	00??1	?1111	?110111
C. burbidgei	10001	111?1	00??1	?1111	?110111
C. smithiana	10000	11110	00101	?1111	?100111
C. aurantiaca	10001	111?1	00101	10110	1110111

Species	1	6	11	16	21
C. gibbsiae	10001	111?1	00??1	?1111	?110111
C. clarkei	10001	111?1	00??1	?1110	1110111
C. chrysea	00001	111?1	00??1	?1111	?110111
C. kermesina	10001	111?1	00??1	?1110	1110111
Aeschynanthus pulcher	10001	111?0	00010	10110	0110111

Gap position

1= 34-35

2= 45-51

3= 69-74

4= 70

5= 75

6= 86-89

7= 129-131

8= 135

9= 147-149

10= 150-151

11= 152

12= 248

13= 259

14= 260

15= 275

16= 285

17= 281-284

18= 302

19= 316-318.

20= 328

21= 327

22= 335-336

23= 422-424

24= 438-447

25= 448

26= 491-493

27= 509-514

APPENDIX 9: Aligned ITS Matrix analysed in Chapter 5

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[                              10        20        30        40        50        60        70        80        90        100]
[                               .         .         .         .         .         .         .         .         .         .]
Cyrtandrasp.Naga       CGAAACCCGCAAAGCAGACCCGCGAACATGTTT--AAAAA-CGC-------CGCGACGTCG---GATGTG--TG-CGT--CCAAC----GTCACGGCTT-   [77]
C.sp.Lantuyang         CGAAACCTACAAAGTAGACCCGTGAACATGTTT--GAATA-TGCTTGCGGTCGTGGTAGCG---GACGTGTTTG-CGT--CCAAC----ATCACGACCT-   [86]
C.sp.Isabella          CGAAACCTGCAAAGCAGACCCGCGAACATGTTT--AAATA-CGCTTGCGGCCGAGGTGTCG---GATG-------CGT--CCAAC----ATCAAGGCCT-   [80]
C.cumingii             CGAAACCTGCAAAGCAGACCCGCGAACATGTTT--AAATA-CGCTTGCGGCCGCGATGTCG---GATG-------CGT--CCAAC----ATCAAGGCTT-   [80]
C.ferruginea           CGAAACCCGCAAAGCAGACCCGCGAACATGTTT--AAATA-CGC-------CGCGACGTGG---GATG-------CGT--CCGAC----GTCACGGCCT-   [73]
C.sp.Halcon1           CGAAACCTGCAAAGCAGACCCGCGAACATGTTT--AAATA-CGCTTGCGGCCGCGATGTTG---GATG-------CGT--CCAAC----ATCACGGCCT-   [80]
C.sp.Halcon2           CGAAACCTGTAAAGCAGACCCGCGAACACGTTT--AAACA-CGCTTGCGGTCGCGATGTGG---GATG-------CGT--CCAAC----ATCACGGCCTC   [81]
C.baileyi              CGAAACCTGCAAAGCAGACCCGTGAACTTGTTA-AAAATA-TGCTTGCGGCCGCGATGTCG---GATGCATTTG-CGT--CCAACCAACATCACGACCC-   [91]
C.monticola            CGAAACTTGCAAAGCAGACCCGTGAACTTGTTT--AAATA-CGCTTGCGGCCGCGATGTCGTCGGATGCATTTG-CGT--CCAACCGACATCACGGCCC-   [93]
C.umbellifera          CGAAACCTGCAAAGCAGACCCGTGAACATG-TT--AAATA-CG-TTGCGGCCGCGGTGTCG---GATGC-GTT-------CC-AC----ATCACGGCCT-   [78]
C.tohiveaensis         CGAAACCTGCAAAGCAGACCCGTGAACATGATT--AAATA-CGCTTGCGGCCGCGATGTCG---GATGC-TTTGGCGT--CCCAC----ATCACGACCT-   [86]
C.stenoptera.a         CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGCG---GATGTGTTTG-CGT--CCAAC----ATCACGACCT-   [86]
C.stenoptera.b         CGAAACCTGCAAAACAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGCG---GATGTGTTTG-CGT--CCAAC----ATCACRACAT-   [86]
C.trichodon            CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGCG---GATGTGTTTG-CGT--CCAAC----ATCACGACCT-   [86]
C.rhyncanthera.a       CGAAACCTGCAAAGCAGACCCGTGAACATGATT--AAATA-TGCTTCCGGCCGCGGTGGTG---GACGCGTTTG-CGT--TCAAC----ATCACGACCT-   [86]
C.rosea                CGAAACCTGCAAAGCAGACCCGCGAACATGTTT--AAATA-CGCTTGCGGCCGCGACGTCG---GGTGCCTTTG-CGT--CCGGC----TTCACGGCCT-   [86]
C.impressivenia        CGAAACCTGCAAAGCAGACCCGCGAACATGTTT--AAACA-CGCTTGCGGCCGCGATGTCG---GATGCGTTTG-CGT--CCGGC----TCCACGGCCT-   [86]
C.sandei               CGAAACCTGCAAAGCAGACCCGCGAACATGTTT--AAATA-CGCTTGCGGCCGCGACGTCG---GGTGCCTTTG-CGT--CCGGC----TTCACGGCCT-   [86]
C.sandei55             CGAAACCTGCAAAGCAGACCCGCGAACATGTTT--AAATA-CGCTTGCGGCCGCGACGTCG---GGTGCCTTTG-CGT--CCGGC----TTCACGGCCT-   [86]
C.picta                CAAAACCTGCAAAGCAGACCCGTGAACACGTTT--AAATA-TGCTTGCGGCCGCGGTGGAG---GATGCGTTTG-CGT--CCAAC----ATCACGACCT-   [86]
C.aureotincta          CGAAACCCGCAAAGCAGACCCGTGAACATGTTT--AAACA-CGCTTGCGGCCGCGATGCCG---GGCGCGTTTG-CGTGTCCGGC----CTCACGGCCT-   [88]
C.sp.LMRF1             CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGCG---GACGCGTTTG-CGT--CCAAC----ATCACGACCT-   [86]
C.sp.LMRF2             CGTAACCTGCAAAGCAGACCTGTGAACATGTTT--AAACA-CGCTTGCGGCCGCGACGTCG---GATGCGTTTG-TGT--CCAAC----TTCACGACCT-   [86]
C.peltata              CGAAACCTGCAAAGCAGACCCGTGAACACGTTT--AAATA-TGATTGCGGCCGCGGTGGCG---GATGTGTTTG-CGT--CCAAC----ATCACGGCCT-   [86]
C.pendula              CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGCG---GACGCGTTTG-CGT--CCAAC----ATCACGACCT-   [86]
C.rhyncanthera.b       CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGTG---GACGCGTTTG-CGT--TCAAC----ATCACGACCT-   [86]
C.anisophylla          CGAAACCTGCAAAGCAGACCCGTGAACATGTTTAAAAATA-CGCTTGCGGCCGTGATGTCG---GATGCGTTTG-CGT--CCCAC----ATCACGACCT-   [88]
C.longepetiolata       CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGCG---GACGCGTTTG-CGT--CCAAC----ATCACGACCT-   [86]
C.trisepalaGB51        CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--ACATA-CGCTCGTGGGCCGTGATGCA--GGATGCGTTTG-CGT--CCCAA----GTCACGACCT-   [87]
C.pendulaGB37          CGAAACCTGCAAAGCAGACCCGTGAACACGTTT--AAATA-TGCTTGCGGCCGCGGTGGCG---GATGTGTTTG-CGT--CCAAC----ATCACGACCT-   [86]
C.wallichiiGB25        CGAAACCTACAGAGCAGACCCGCGAACATGTTT--AAATA-TGCTTGCGGCCGCGATGTCG---GATGTGTTTA-CGT--CCAAC----ATCACGACCT-   [86]
C.cupulata             CGAAACCTACAAAGCAGACCCGTGAACATGTTT--GAATA-CGCTCGCGGCCGCGATGTCG---GATGCTCTTG-CGT--CCGGA----ATCACGACCT-   [86]
C.affwallichiiGB32     CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGTGGTGGTG---GATGCGTTTG-CGT--CCAAC----ATCACGACCT-   [86]
C.wallichiiGB33        CGAAACCTACAAAGAAGACCCGCGAACATGTTT--AAATA-TGCTTGCGGCCGCGATGTCG---GATGTGTTTG-CGT--CCAAC----ATCACGACCT-   [86]
C.wallichiiFRI44491    CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TAATTGCGGCCGTGGTGGTG---GATGCGTTTG-CGT--CCAAC----ATCACGACCT-   [86]
C.stonei               CGAAACTTGCAAAGCCGACCCGTGAACATGTTTAAAAATA-CGCTGGCGGCCGTGCTGCCG---GATGCGTTTG-CGT--CCCAC----ATCACGACCT-   [88]
C.wallichiiGB35        CGAAACCTGCAAAGCAGACCCGCGAACATGTTT--AAATA-TGCTTGCGGCCGTGATGTCG---GATGTGTTTG-CGT--CCAAC----ATCACGACCT-   [86]
C.patula               CGAAACCTGCAAAGCAGACCCGTGAACATGTTG--AAATG-CGCTTGCGGCCGCCATGTCG---GATGCGTTCG-CGTGTCCGGC----TTCACGGCCT-   [88]
C.wallichiiFRI47032    CGAAACCTGCAAAGCAGACCCGCGAACATGTTT--AAATA-TGCTTGCGGCCGCGATGTCG---GATGTGTTTG-CGT--CCAAC----ATCACGACCT-   [86]
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[                              10        20        30        40        50        60        70        80        90       100]
[                               .         .         .         .         .         .         .         .         .         .]

C.inconspicuaChurch292 CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-CGCTTGCGGCCGTGATGTCG---GATGCGTCCG-CGT--CCAAC----GTCACGACCT-    [86]
C.inconspicuaChurch171 CGAAACCTGCGAAGCAGACCCGTGAACATGTTT--AAATA-CGCTTGCGGCCGTGATGTCG---GATGCGTCCG-CGT--CCAAC----GTCACGACCT-    [86]
C.aff.chrysea          CGAAACCTGCAAAGTAGACCCGCGAACATGTTT--AAATA-TGCTTGCGGCCGTGATGTCG---GATGCGTTTG-CGT--CCAAC----ATCACGACCT-    [86]
C.spGB49               CGAAACCTGCGAAGCAGACCCGTGAACATGTTT--AAATA-CGCTTGCGGCCGCGATGTCG---GATGCGTTTG-CAT--CCAAT----ATCACGACCT-    [86]
C.mesilauensis         CGAAACCTGCAAAGCAGACCCGTGAAMATGTTT--AAATA-CGATTGCGGCCGCGAWGTYG---GAWGCGTTTG-CGT--CCAAT----ATYACGACCT-    [86]
C.corniculata          CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-CGCTTGTGGCCGCGATGTCG---GATGCGTTTG-CGT--CCAAT----ATCACGACTT-    [86]
C.fulvisericea         CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--ACATA-CGCTTGTGGCCGCGATGTCG---GATGCGTTTG-CGC--CCCAC----ATCACGACTT-    [86]
C.burbidgei            CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGATTGCGGCCGCGGTGGCG---GATGTGTTTG-CAT--CCAAC----ATCACGACTT-    [86]
C.smithiana            CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-CGCTGGCGGCCGCGATGTCG---GATGCGTTTTGCGT--CCAAC----ATCACGACCT-    [87]
C.aurantiaca           ??????????????CAGACCCGTGAACATGTTT--AAATA-CTCTTGCGGCCGCGACGTCG---GATGCGTTTG-CGT--CCAAC----ATCACGACCT-    [86]
C.gibbsiae             CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-CGCTTGCGGACGCGATGTCG---GATGCGCTTG-CGC--CCGAT----ATCACGACTT-    [86]
C.clarkei              CGAAACATGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGCG---GATGCGTTTG-CAT--CCAAC----ATCACGACCC-    [86]
C.chrysea              CGTAACCTGCAAAGCAGACCCGTGAACATGTTTAAAAACA-CGCTTGCGGCCACGGTGTCG---GATGCGTCTG-CGT--CCCAC----ATCGCGACTT-    [88]
C.kermesina            CGAAACCTGCAAAGCAGACCCGTGAACATGTTT--AAATA-TGCTTGCGGCCGCGGTGGCG---GATGCGTTTG-CAT--CCAAC----ATCACGACCC-    [86]
C.dispar               CGTAACCTGCAAAGCAGACCTGTGAACATGTTT--AAACA-CGCTTGCGGCCGTGATGTCG---GATGCGTTTG-CGT--CCAAC----TTCACGACCT-    [86]
Aeschynanthuspulch.    CGAAACCTGCAAAGCAGACTCGTGAACATGTGT--AAATAACATCGGGGGTCGTGAGGTTG---GATGCATTTG-TGT--CCAGC----ATCACGACCT-    [87]

[                             110       120       130       140       150       160       170       180       190       200]
[                               .         .         .         .         .         .         .         .         .         .]

Cyrtandrasp.Naga       -----CGGCCCC-AAGTGGCGCAAGTCG---CTCGGGGCATCCTAACAA--CCTCCCGGCGCGGCAA-GCGCCAAGGAAAACC--ATACG--GACCACCT    [161]
C.sp.Lantuyang         -----TGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAAAT--GTATC--GAACGCCT    [166]
C.sp.Isabella          -----CGACCCC-AAGTGGCGCAAGTCG---CTGGGGGCAAACTAACAA--CCTTTCGGCGCGGCAA-GCGCCAAGGAAAACC--ATACG--GAACGCCT    [164]
C.cumingii             -----CGACCCC-AAGTGGCGCAAGTCG---CTCGGGGCATACTAACAA--CCTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--ATACG--GAACACCT    [164]
C.ferruginea           -----CGACCCC-AAGTGGCGCAAGTCG---CTCGGGGCATACCAACAA--CCTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--ATACG--GACCACCT    [157]
C.sp.Halcon1           -----CGACCCC-AAGTGGCGCAAGTCG---CTCGGGGCATACTAACAA--CCTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--ATACG--GACCACCT    [164]
C.sp.Halcon2           GGCCTCGACCCC-AAGTGGCGCGAGTCG---CTCGGGGCATACTAACAA--CCTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--ATATC--GAACGCCT    [170]
C.baileyi              -----TGACCCC-AAGTGGCGCAAGTCGTTGCTC-GGGCGTGCTAACAA--CCTCTCGGCGCGGCAA-GCGCCAAGGAAAATC--ATATC--GAACGCCT    [177]
C.monticola            -----TGACCCC-GAGTGGCGCAAGTCGTTGCTT-GGGCGTGCTAACAA--CCTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--ATATC--GAACGCCT    [179]
C.umbellifera          -----CGACCCC-AAGTGGCGCAAGTCA--GCTGGGGGCATACTAACAA--CCTCTCGGCGTGGCAA-GCGC-AAGGAAAACC--ATA?C--GAACACCT    [162]
C.tohiveaensis         -----CGACCCC-AGGTGGCGCAAGTCG---CTCGGGGCACACTAACAA--CCTCTCGGCGCGGCAA-GCGCCAAGGAAAACG--ATGTC--GAATGCCT    [170]
C.stenoptera.a         -----CGATCCC-AAGTGGCGCAAGTCG---CTC-GGGTGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAAAC--GTATC--GAACGCCT    [166]
C.stenoptera.b         -----CGATCCC-AAGTGGCGCAAGTCG---CTC-GGGTGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAAAC--GTATC--GAACGCCT    [166]
C.trichodon            -----CGATCCC-AAGTGGCGCAAGTCG---CTC-GGGTGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAAAC--GTATC--GAACGCCT    [166]
C.rhyncanthera.a       -----CGACCCC-AAGCGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAAAC--GTATC--GAACGCCT    [166]
C.rosea                -----CGACCCC-GAGTGGCGCGAGTCG---CTC-GGGCGTACTAACAAA--CTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--ATACC--GAACACCT    [169]
C.impressivenia        -----CGACCCC-GAGTGGCGCAAGTCG---CTC-GGGCGTACTAACAA--CCTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--ATACC--GAACACCT    [169]
C.sandei               -----CGACCCC-GAGTGGCGCGAGTCG---CTC-GGGCGTACTAACAAA--CTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--ATACC--GAACACCT    [169]
C.sandei55             -----CGACCCC-GAGTGGCGCGAGTCG---CTC-GGGCGTACTAACAAA--CTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--ATACC--GAACACCT    [169]
C.picta                -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAAAC--GTATC--GAACGCCT    [166]
C.aureotincta          -----CGACCCC-GAGTGGCGCAAGCCG---CTC-GGGCGTACTAACAAAA-CTCTGGGCGCGGCAA-GCGCCAAGGAAAACC--ATACC--GAACACCT    [172]
C.sp.LMRF1             -----CGACCCC-AAGTGGCGCAAGTCG---CTT-GGGCGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAAAC--GTATT--GAACGCCT    [166]
C.sp.LMRF2             -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAACAA--CCTCTCGGCGCGGCAA-GCGCCAAGGAAAACA--ATACC--GAAACCT    [169]
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[                               110       120       130       140       150       160       170       180       190       200]
[                               .         .         .         .         .         .         .         .         .         .]

C.peltata              -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAAAC--GTATC--GAACGCCT   [166]
C.pendula              -----CGACCCC-AAGTGGCGCAAGTCG---CTT-GGGCGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAAAC--GTATT--GAACGCCT   [166]
C.rhyncanthera.b       -----CGACCCC-AAGCGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAAAC--GTATC--GAACGCCT   [166]
C.anisophylla          -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAACAA--CCTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--ATACC--GAACACCT   [171]
C.longepetiolata       -----CGACCCC-AAGTGGYGCAAGTCG---CTT-GGGCGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAAAC--GTATT--GAACGCCT   [166]
C.trisepalaGB51        -----CGACCCC-GAGCGGCGCAAGTCG---CTC-GGGCGTGCTAACAA--CCTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--ACATC--GAACACCT   [170]
C.pendulaGB37          -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAAAC--GTATC--GAACGCCT   [166]
C.wallichiiGB25        -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAAAGCGCCAAGGAAAAAC--ATATT--GAACGCCT   [167]
C.cupulata             -----CGACCCC-GAGTGGCGCAAGTCG---CTT-GGGCGTACCACTAA--CCTCTCGGCGCGGCAA-GCGCCAAGGAAAACCACATACC--GGACGCCT   [171]
C.affwallichiiGB32     -----CAACCCC-AAGTGGCGCAAGTCG---CTT-GGGCGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAATAAC--GTATC--GAACGTCT   [166]
C.wallichiiGB33        -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAAAGCGCCAAGGAAAAAC--ATATT--GAACGCCT   [167]
C.wallichiiFRI44491    -----CAACCCC-AAGTGKCGCAAGTCG---CTT-GGGCGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAATAAT--GTATC--GAACGTCT   [166]
C.stonei               -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAACAA--CCTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--ATACC--GAACACCT   [171]
C.wallichiiGB35        -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAAAGCGCCAAGGAAAAAC--ATATT--GAACGCCT   [167]
C.patula               -----CGACCCC-GAGTGGCGCAAGTCG---CTC-GGGCGTACTAACAAA--CTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--ATACC--GAACACCT   [171]
C.wallichiiGB41        -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAAAGCGCCAAGGAAAAAC--ATATT--GAACGCCT   [167]
C.inconspicuaChurch292 -----CGACCCC-GAACGGCGCAAGTCG---ATC-GGGCGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAGACC--ATACC--GAACACCT   [166]
C.inconspicuaChurch171 -----CGACCCC-GAACGGCGCAAGTCG---ATC-GGGCGTACTAA-----ACTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--ATACC--GAACACCT   [166]
C.aff.chrysea          -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGAACTAA-----CCTCTCGGCGTGGCAAAGCGCCAAGGAAAAAC--ATACC--GAACGCCT   [167]
C.spGB49               -----CGACCCC-AAGTGGCACAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAAAC--ATATC--GAACACCT   [166]
C.mesilauensis         -----TGACCCC-AAGTGGSGCAAGTYG---CTY-GGGSGTACCAA-----CCTTTGGCGCGGCAA-GCGCCAAGGRAAAAM--GTACC--GAACACCT   [166]
C.corniculata          -----CGACCCC-AAGTGGCACAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGTGGCAA-GCGCCAAGGAAAAAC--ATATC--GAACACCT   [166]
C.fulvisericea         -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAACAA--CTTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--ATATC--GAACGCCT   [169]
C.burbidgei            -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAAAC--GTATC--GAACGTCT   [166]
C.smithiana            -----CGACCCCCAAGTGGCGCAAGTCA---CTC-GGGCGTACTAACAA--CCTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--ATACC--GAACACCT   [171]
C.aurantiaca           -----CGACCTC-GAGTGGCGCAAGTCG---CTC-GGGTGAACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--ATACA--GAACACCT   [166]
C.gibbsiae             -----CGACCCC-AAGTGGCGCAAGTCG---CTG-GGGCGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAAAC--ATACC--GAACGCCT   [166]
C.clarkei              -----TGACCCC-AAGTGGCGCAAGTCK---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAAAC--GTATC--GAACGCCT   [166]
C.chrysea              -----CGGCCCC-GAGTGGCGCAAGTCG---CTC-GGGCGTACCAA-----CCTCTCGGCGCGGGAA-GCGCCAAGGAAAAAC--ATACC--GAACGCCT   [168]
C.kermesina            -----AGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAA-----CCTCTCGGCGCGGCAA-GCGCCAAGGAAAAAC--GTATC--GAACGCCT   [166]
C.dispar               -----CGACCCC-AAGTGGCGCAAGTCG---CTC-GGGCGTACTAACAA--CCTCTCGGCGCGGCAA-GCGCCAAGGAAAACA--ATACC--GAACACCT   [169]
Aeschynanthuspulch.    -----CGACCCC-AAGTGGCGCAAGTCG---CTT-GGG?GTACTAAA-----CTCTCGGCGCGGCAA-GCGCCAAGGAAAACC--GTATC--GAACACCT   [167]

[                               210       220       230       240       250       260       270       280       290       300]
[                               .         .         .         .         .         .         .         .         .         .]

Cyrtandrasp.Naga       CTCCG---TCTCGGTGCCGTGCGCGGTA--CCC--AGGACGTG----ACGAGGA-----GGA-CTATCGAAAG----GATATT-ATTTGTCGCCCCTCC   [239]
C.sp.Lantuyang         CTCCG---TCTCGGTGCCGTGCGCGGTA--CCC--AGGACGCG----ACGAGGA-----GCGTCTATTGAATA----GATTCT-ATCTCGTCGCCCCCTC   [245]
C.sp.Isabella          CTCCG---TCTCGGTGCCGTGCGCGGTA--CCC--AGGACGTG----ACGAGGA-----GCA-CCATTGAATA----GATATT-ATCTCGTCGCCCCCCC   [242]
C.cumingii             CTCCG---TCTCGGCGCCGTGCGCGGTATACCC--AGGACGTG----ACGAGGA-----GCA-CCATTGAATA----GATATA-ATCTCGTCGCCCCCCC   [244]
C.ferruginea           CTCCG---TCTCGGTGCCGTGCGCGGTA--CCC--AGGGGGTG----GYGAGGA-----GGA-CTATCGAAAA----GATATT-ATCYC?TCGCCCCTCC   [235]
C.sp.Halcon1           CTCCA---TCTCGGTGCCGTGCGCGGTA--CCA--GGGATGTG----ATGAGGA-----GAA-CGATTGAATA----GATATT-ATCTCGTCGCCCCTCC   [242]
C.sp.Halcon2           CTCCT---TCCCGGCGCCGTGCGCGGCA--CCA--GGGACGTG----AGGAGGA-----GCA-CGATTTAATA----GATACT-GTCTCGTCGCCCCCCC   [248]
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[                              210       220       230       240       250       260       270       280       290       300]
[                               .         .         .         .         .         .         .         .         .         .]

C.baileyi              CTCCG---TCACGGTGCCGTGCGCGGTG--CGC--AGGACTTG----ACGAGGA-----GCGTCCATTGAATA----GATATT-ATCTCGTCGCCCCTTC   [256]
C.monticola            CTCCG---TCTCGGTGCCGTGCGCGGTA--CGC--AGGACGTG----ACGATGA-----GCGTCCATTGAATT----GATATC-ATCTCGTCGCCCCCCC   [258]
C.umbellifera          GTCCG---TCTCGGTGCCGTGCGCAGTA--CCC--AGGCCGTGT---ACGAGGA-----GCA-CTTT?GAATA----GATATT-ATC--GTCGCCCCCTC   [239]
C.tohiveaensis         CTCCG---TCCCGGTGTCGTGCGCGGTA--CCC--AGGACGTG----ACGAGGA-----ACA-CTATCGAATA----GATACT-ATCTCGTCGCCCCCTC   [248]
C.stenoptera.a         CTCCG---TCTCGGTGCCGTGCGCGGTA--CCC--AGGACGCG----ATGAGGA-----GTGTCTATTGAATA----GAWTCT-ATCTCGTCGCCCCT--   [243]
C.stenoptera.b         CTCCG---TCTCGGTGCCGTGCGCGGTA--CCC--AGGACGCG----ATGAGGA-----GTGTCTATTGAATA----GAATCT-ATCTCGTCGCCCCTTT   [245]
C.trichodon            CTCCG---TCTCGGTGCCGTGCGCGGTA--CCC--AGGACGCG----ATGAGGA-----GTGTCTATTGAATA----GAATCT-ATCTCGTCGCCCTTCC   [245]
C.rhyncanthera.a       CTCCG---TCTTGGCGCCGTGCGCGGTA--CCC--AGGACGCG----ACGAGGA-----GTATCTATTGAATA----GATTCT-ATCTCGTCGCCCCCTC   [245]
C.rosea                CTCCG---TCCCGGTGCCGTGCGCGGTA--CCG--AGGACGTG----ACGAGGA-----GCGTCTATTGAATA----GATATC-ATCTCGTCGCCCCCCT   [248]
C.impressivenia        CTCCG---TCCCGGTGCCGTGCGCGGTA--CCG--GGGACGTG----ACGAGGA-----GCGTCTATTGAATA----GATATC-ATCTCGTCGCCCCCCT   [248]
C.sandei               CTCCG---TCCCGGTGCCGTGCGCGGTA--CCG--AGGACGTG----ACGAGGA-----GCGTCTATTGAATA----GATATC-ATCTCGTCGCCCCCCT   [248]
C.sandei55             CTCCG---TCCCGGTGCCGTGCGCGGTA--CCG--AGGACGTG----ACGAGGA-----GCGTCTATTGAATA----GATATC-ATCTCGTCGCCCCCCT   [248]
C.picta                CTCCG---TCTCGGTGCCGTGCGCGGTA--CAA--AGGACGCG----ATGAGGA-----GCGTCTATTGAATA----GATTCT-ATCTCGTCGCCCTCTC   [245]
C.aureotincta          CTCCG---TCCCGGTGCCGTGCGCGGTA--CCG--AGGACGTG----ACGAGGA-----GCGTCTATTGAATA----GATATC-ATCTCGTCGCCCCCCT   [251]
C.sp.LMRF1             CTCCG---TCTCGGCGCCGTGCGCGGTA--CCC--AGGACGCG----ATGAGGA-----GCTTCTATTGAATA----GATTCT-ATCTCGTCGCCCCCTC   [245]
C.sp.LMRF2             CTCCG---TCCCGGTGCCGTGCGCGGTG--CCG--AGGACGTG----ACGAGGA-----TTGTCTATTGAATA----GATATT-ATCTCGTCGCCCCCCT   [248]
C.peltata              CTCCG---TCTCGGTGCCGTGCGCGGTA--CCC--AGGACGCG----ATGAGGA-----GCGTCTATTGAATA----GATTCTTATCTCGTCGCCCCCTC   [246]
C.pendula              CTCCG---TCTCGGCGCCGTGCGCGGTA--CCC--AGGACGCG----ATGAGGA-----GCTTCTATTGAGTA---AGATTCT-ATCTCGTCGCCCCCTC   [246]
C.rhyncanthera.b       CTCCG---TCTTGGCGCCGTGCGCGGTA--CCC--AGGACGCG----ATGAGGA-----GTATCTATTGAATA----GATTCT-ATCTCGTCGCCCCCTC   [245]
C.anisophylla          CTCCG---TCCYGGTGCCGTGCGCGGCA--CCT--AGGACGTG----ACGAGGG-----GCGTCAATAGAGTA----GATATC-ATCTCGTCGCCCCTCC   [250]
C.longepetiolata       CTCCG---TCTCGGCGCCGTGCGCGGTA--??C--A?GACGCG----A?GAGGA-----GCTTCTATTGAATA----GATTCT-ATCTCGTCGCCCCCTC   [245]
C.trisepalaGB51        CTCCG---TCCCGTTGCCGTGCGCGGTAA-CCC--AGGACGTG----ACGAGGA-----GCGTCTATCGAGTA----GATTAACATCTCGTCGCCCCTCC   [251]
C.pendulaGB37          CTCCG---TCTCGGTGCCGTGCGCGGTA--CTC-CAGGACGCG----ATGAGGA-----GCGTCTATTGAATA----GATTCT-ATCTCGTCGCCTCCTC   [246]
C.wallichiiGB25        CTTCG---TCTCGGTGCCGTGCGCGGTA--CCC--AAGACGTG----ACGAGGA-----CCGTCTATTGAATA----GATTTT-ATCTCGTAGCCCCCC-   [245]
C.cupulata             CTCCG---TCTCGGTGCCGTGCGCGGTG--ACC--AGGACGTG----ACGAGGA-----GCGTCAATGGAACA----TATATC-ATCTCGTCGCCCCTCC   [250]
C.affwallichiiGB32     CCCAG---TCTTGGCGCCGTGCGCGGTA--CCC--AGGACGCG----ATGAGGA-----GCGTCTATTGAATA----GATTAT-ATCTTGTCGCCCCCTC   [245]
C.wallichiiGB33        CTTCG---TCTCGGTTCCGTGCGCGGTA--CCY--GGGACGTG----ACGAGGA-----CCGTCTATGGAATA----GATTTT-ATCTCGTAGCCCCCC-   [245]
C.wallichiiFRI44491    CTCAG---TCTTGGCGCCGTTCGCGGTA--CCC--AGGACACA----ATGAGGA-----TCGTCTATTGAATA----GATTCT-ATCTCGTCGCCCCCTC   [245]
C.stonei               CTCCG---TCACGGTGCCGTGCGCGGCA--CCT--AGGACGTG----ACGAGGA-----GCGTCAATTGAGTA----GATATC-ATCTCGTCGCCCCTCC   [250]
C.wallichiiGB35        CTTCG---TCTCGGTGCCGTGCGCGGTA--CCC--AGGACGTG----ACGAGGA-----CCGTCTATTGAATA----GATTTT-ATCTCGTAGCCCCCC-   [245]
C.patula               CTCCG---TCCCGGTGCCGTGCGCGGCA--CGG--AGGACGTG----ACGAGGAGAGGAGCGTCTATTGAATA----GATATC-ATCTCGTCGCCCCCCT   [255]
C.wallichiiFRI47032    CTTCG---TCTCGGTGCCGTGCGCGGTA--CCC--AGGACGTG----ACGAGGA-----CCGTCTATTGAATA----GATTTT-ATCTCGTAGCCCCCC-   [245]
C.inconspicuaCHURCH292 CTCCG---TCTCGGTGCCGTGCGCGGTA--CCC--AGGACGTG----ACGAGGA-----GCGTCTATTGAATAGATAGATACA-ATCTCGTCGCCCCCTC   [249]
C.inconspicuaCHURCH171 CTCCG---TCTCAAGGCCGTGCGCGGTA--CCC--AGGACGTG----ACGAGGA-----GCGTCTATTGAATAGATAGATATA-ATCTCGTCGCCCCCTC   [249]
C.aff.chrysea          CTCTG---TCTCGGTGCCGTGCGCGGTA--CCC--ATGACGTG----ACGAGGA-----GCGTCCATTGAATA----GATTAT-ATCTCGTAGCCCCCC-   [245]
C.spGB49               CTCCG---TCTCGGTGCCGTGCGCGGTA--CCC--AGAACGTG----ACGAGGA-----GCGTCTATCGAATA----GATACT-ATCTCGTCCCCCCCC-   [244]
C.mesilauensis         TTCCG---TTTGGGTGCCGTGCGCGGTAA-CCC--AGGATGTG----ACGAGGA-----GCGTCTATCGAATA----GATACT-ATCTCGTCGCCCCCC-   [245]
C.corniculata          CTCTG---TCTCGGTGCCGTGCGCGGTA--CCC--AGAACGTG----ATGAGGA-----GCGTCTATCGAATA----GATACT-ATCTCGTCGCCCCCC-   [244]
C.fulvisericea         CCCCG---TCCCGGTGCCGCGCGCGGCAA-CCC--TGGACGTG----GCGAGGA-----GCGTCTATCGAGTA----GATAAC-ATCTCGTCGCCCCTCC   [249]
C.burbidgei            CTCCG---TCTCGGCGCCGTGCGCGGTA--CCC--AGGACGTG----ACGAGGA-----GCGTMTAYTGAATA----GATTCT-ATCTCGTCGCCCCCCC   [245]
C.smithiana            CTCCG---TCTCGGTGCCGTGCGCGGTG--CCT--AGGACGTG----ACGAGGA-----GCGTCTACTGAATA----GATATC-ATCTCGTCGCCCCCCG   [250]
C.aurantiaca           CTCCG---TATCGGTGCCGTGCGCGGTA--CCC--AAGACGTG----ACGAGGA-----GCGTCTATTGAATA----GATATT-ATCTCGTCGCCCC---   [242]
C.gibbsiae             CTCCG---TCTCGGCGCCGTGCGCGGTA--CCC--AGGACGTG----ACGAGGA-----GCGTCTATTGAATATATAGAACT--ATCTCGTCGCCCCC--   [246]
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[                            210       220       230       240       250       260       270       280       290       300]
[                              .         .         .         .         .         .         .         .         .         .]

C.clarkei             CTCCG---TCTCGGCGCCGTTCGCGGTA--CCC--AGGACGTG----ACGAGGA-----GCGTCTATTGAATA---GATTATATATCTCGTCGCCCCCCC  [247]
C.chrysea             CTCCG---TCTCGGCGCCGTCCGCGGCA--CCCCCGGGACGTG----ACGAGGAA----GCGTCTATTGAATA----TATATC-ATCTCGTCGCCCCCC-  [249]
C.kermesina           CTCCG---TCTCGGCACCGTGCGCGGTA--CCC--AGGACGTG----ACGAGGA-----GCGTCTATTGAATA----GATTAT-ATCTCGTCGCCCCCCC  [245]
C.dispar              CTCCG---TCCCGGTGCCGTGCGCGGTG--CCG--AAGACGTG----ACGAGGG-----TTGTCTATTGAATA----GATTATAATCTCGTCGCCCCCCC  [249]
Aeschynanthuspulch.   CTCCG---TCTCGGTGC--TATGCGGTA--CCC--AGGACGTG----ATGAGGA-----GTGTCTATCGAATA---AGATA-T-ATCTCGTCGCCCCACT  [244]

[                            310       320       330       340       350       360       370       380       390       400]
[                              .         .         .         .         .         .         .         .         .         .]

Cyrtandrasp.Naga      CC-------AGCACCTTGTT-CCC-CACTCACT-CAGAG----TGCCGGGGAGACGATGCATAC---GAAGGAG---GGGCG---GATATTGGCCTCCCG  [316]
C.sp.Lantuyang        CCCC-----AGCATCGTCTT-CCC-CACT-----CAAAG----TGCCGGG-AGACGATACATAC---GAAAGAG---GGGCG---GATATTGGCCTCCCG  [319]
C.sp.Isabella         ---------AACATCCTCTT-CCC-CACT-----CAGAG----TGCCGGG-AGACGATGCATAC---GAAGGAG---GGGCG---GATATTGGCCTCCCG  [312]
C.cumingii            CCCCCC-AAAACATCTTCTT-CCC-CACT-----CAGAG----TGCCGGG-AGACGATGCGTAC---GAAGGAG---GGGCG---GATATTGGCCTCCCG  [322]
C.ferruginea          CC------AGGC?TCG-CTG-CCC-CGCT-----CACAG----TGCCGGGGAGACAAT?CATTC---GAAGGAG---GGGCG---GATATTGGCCTCCCG  [308]
C.sp.Halcon1          CCCCC----AGCATCCTCTT-CCA-CACT-----CAGAG----TGCCGAGGAGAAGATGCACAC---CGAGGAG---GGGCG---GATATTGGCCTCCCG  [318]
C.sp.Halcon2          ---------AACATCCTCTT-CCC-CACT-----CAGAG----TGTCGGGGAGACGATGCATAC---GACGGAG---GGGCG---GATGTTGGCCTCCCG  [319]
C.baileyi             CCCC-----AACATCCTCTT-CCA-CACT-----AAGAG----TGCCGGG-AGACGATACATAC---GAAGGAG---GGGCG-CGGATATTGGCCTCCCG  [332]
C.monticola           CTCATCCC-AACATCCTCTT-CCA-AACT-----AAGAG----TGCCGGG-AGACGATAGATAC---GGAGGAG---GGGCG-CGGATATTGGCCTCCCG  [338]
C.umbellifera         AAC------A-GTC-TCTT---CC-CACT-----CAGAG----TGGCCGGGAGACGGTGCATAC---GA-GGAG---GGGCG---GATATTGGCCTCC-G  [307]
C.tohiveaensis        CCC-------ACGTCCTCTTTGCC-CACT-----CAGAG----TG-C------ATGA----------GAAGGAG---GGGCG---GATATTGGCCTCCCG  [308]
C.stenoptera.a        CCCCCCC--AGCATCGTCTT-CCC-CACT-----CAGAG----TGTCGGG-AGAAGATGCATAC---GAAGGAG---GGGCG---GATATTGGCCTCCCG  [320]
C.stenoptera.b        CCCCC----AGTATCGTCTT-CCC-CACT-----CAGAG----TGTCGGG-AGAAGATGCATAC---GAAGGAG---GGGCG---GATATTGGCCTCCCG  [320]
C.trichodon           CCCC-----AGCATCGTCTT-CCC-CACT-----CAGAG----TGTCGGG-AGAAGATGCATAC---GAAGGAG---GGGCG---GATATTGGCCTCCCG  [319]
C.rhyncanthera.a      CCCC-----AGCATCGTCTT-CCC-CACT-----CAGAG----TGCCGGG-AGACGATGCACAC---GAAAGAG---GGGCG---GATATTGGCCTCCCG  [319]
C.rosea               CCCCCC---ATCATCTTCTT-CCC-CACT----CCAGAG----TGCCGGG-AGACGATGCGTACTACGAAGGAG---GGGCG---GATATTGGCCTCCCG  [328]
C.impressivenia       CCCCCC---GTCATCTTCTT-CCC-CACT----CTCGAG----TGCCGGG-AGACGATGCGTAC---GAAGGAG---GGGCG---GATATTGGCCTCCCG  [325]
C.sandei              CTCCCC---ATCATCTTCTT-CCC-CACT----CCAGAG----TGTCGGG-AGACGATGCGTACTACGAAGGAG---GGGCG---GATATTGGCCTCCCG  [328]
C.sandei55            CTCCCC---ATCATCTTCTT-CCC-CACT----CCAGAG----TGTCGGG-AGACGATGCGTACTACGAAGGAG---GGGCG---GATATTGGCCTCCCG  [328]
C.picta               CCCCC----AKCATCGTCTT-CCC-CACT-----CAGAG----TGCCGGG-AGATGATGCATAC---GAAGGAG---GGGCG---GATATTGGCCTCCCG  [320]
C.aureotincta         CCCCCC---ATCATCTTCTT-CCCCCACTCCCTCCAGAGGAGC-GCCGGG-AGACGATGCGTAC---GAAGGAG---GGGCGGCGGATATTGGCCTCCCG  [339]
C.sp.LMRF1            CCCCC----AACATCGTCTT-CCC-CACT-----CAGAG----TGTCGGG-AGGCGATGCATAC---GAGAGAG---GGGCG---GATATTGGCCTCCCG  [320]
C.sp.LMRF2            CCCCCC---ATCGTGTTCTT-CCC-CACT----CCAGAG----TGTCGGG-AGATGGTGCGTAC---GGAGGAG---GGGCG---GATATTGGCCTCCCG  [325]
C.peltata             CCCCC----AGCATCGTCTT-CCC-CACT-----CAGAG----TGTCGGG-AGAAGATGCATGC---GAAGGAG-AGGGGCG---GATATTGGCCTCCCG  [323]
C.pendula             CCCCCC---AACATCGTCTT-CCC-CACT-----CAGAG----TGTCGGG-AGGCGATGCATAC---GAGAGAG---GGGCG---GATATTGGCCTCCCG  [322]
C.rhyncanthera.b      CCCC-----AGCATCGTCTT-CCC-CACT-----CAGAG----TGCCGGG-AGACGATGCATAC---GAAAGAG---GGGCG---GATATTGGCCTCCCG  [319]
C.anisophylla         CCCCGCAACAGCATCCTCTT-CCC-CACT-----CAGAG----TGCCGGG-AGACGATGCACAG---GAAGGAG---GGTCG---GATATTGGCCTCCCG  [329]
C.longepetiolata      CCCCC----AACATCGTCTT-CCC-CACT-----CAGAG----TGTCGGG-AGGCGATGCATAC---AGAGAAG---GGGCG---GATATTGGCCTCCCG  [320]
C.trisepalaGB51       CCCCC--GCGACATCCTCTT-CCC-CACC-----CAGAG----TGGCGGG-AGACGATGCACAC---GAAGGAG---GGGCG---GACATTGGCCTCCCG  [328]
C.pendulaGB37         CCCCG----AGCATCGTCTT-CCC-CACT-----CAGAG----TGTCGGG-AGACGATGCATAC---GAAGGAG---GGGCG---GATATTGGCCTCCCG  [321]
C.wallichiiGB25       -------AGCGCATCGTCTT-CCC-CACT-----CAGAG----TGCCGGG-AGATGATGCATAT-ACGAAAGAG---GGGCG---GATATTGGCCTCCCG  [319]
C.cupulata            CCC------GACATCCTCTT-CCC-CACT-----CAGAG----TGCCGGG-AGACGATGCCGCA--CGAGAGAG---GGGCG---GATATTGGCCTCCCG  [324]
C.affwallichiiGB32    CCCCC----AGCATCGTCTT-CCC-CACT-----CAGAG----TGCCGGG-AGACGATGCATAC---GAAAGAG---GGGCG---GATATTGGCCTCCCG  [320]
C.wallichiiGB33       ------AGCGGCATCGTCTT-CCC-CACT-----CAGAG----TGCCGGG-AGATGATGCATAT-ACGAAAGAG---GGGYG---GATATTGGCCTCCCG  [320]
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[                                      310       320       330       340       350       360       370       380       390       400]
[                                        .         .         .         .         .         .         .         .         .         .]

C.wallichiiFRI44491     C----ACCCAGCTTCGCCTT-CCC-CACT-----CAGAG----TGCCGGG-AGACGATGCATAC---GAAAGAG--GGGGCG---GATATTGGCCTCCCG   [321]
C.stonei                CCCC---GCAACATCCTCTT-CCC-CACT-----CAGAG----TGCCGGG-AGACGATGCACAC---GAAGGAG--GGGGCG---GATATTGGCCTCCCG   [327]
C.wallichiiGB37         -------AGCGCATCGTCTT-CCC-CACT-----CAGAG----TGCCGGG-AGATGATGCATAT-ACGAAAGAG---GGGYG---GATATTGGCCTCCCG   [319]
C.patula                CCCCCC---ACCATCTTCTT-CCC-CACT----CCAGAG----TGCCGGG-AGACGATGCGGAC---GAAGGAG---GGGCG---GATATTGGCCTCCCG   [332]
C.wallichiiFRI47032     -------AGCGCATCGTCTT-CCC-CACT-----CAGAG----TGCCGGG-AGATGATGCATAT-ATGAAAGAG---GGGCG---GATATTGGCCTCCCG   [319]
C.inconspicuaCHURCH292  CCCCC---AAACATCCTCTT-CCC-CACT-----CGGAG----TGTCGGG-AGACGATGAATAC---GAAGGAG---GGGCG---GATATTGGCCTCCCG   [325]
C.inconspicuaCHURCH171  CCCCC---AAACATCCTCTT-CCC-CACT-----CGGAG----TGTCGGG-AGACGATGAATAC---GAAGGAG---GGGCG---GATATTGGCCTCCCG   [325]
C.aff.chrysea           ---------AGCATCCTCTT-CCC-CACT-----CAGAG----TGTCGGG-AGATGATGCAATATACGAAAGAT--GGGGCG---GATATTGGCCTCCCG   [319]
C.spGB49                ---------AACATCCTCTT-CCC-CACT-----CAGAG----TGCCGGG-AGACGATGCGTAC---GAAAGAG---GGGTG---GATATTGGCCTCCCG   [314]
C.mesilauensis          ---------AACATCCTCTT-CCC-CACT-----CAGAG----TGTCGGG-AGACGATGCATAC---GAAAGAG---GGGCG---GATATTGGCCTCCCG   [315]
C.corniculata           ---------AACATCCTCTT-CCC-CACT-----CAGAG----TGCCGGG-AGACGATGCATAC---GAAAGAG--GGGGCG---GATATTGGCCTCCCG   [315]
C.fulvisericea          CCCCGC---GACATCCTCTC-CCC-CACT-----CAGAG----TGCCGGG-AGACGATGCACAC---GACGGAG---GGGCG---GATATTGGCCTCCCG   [325]
C.burbidgei             ---------AGCATCGTCTT-CCC-CACT-----CAGAG----TGCCGGG-AGACGACGCATAC---GGAAGAG---GGGCG---GATATTGGCCTCCCG   [315]
C.smithiana             --------CAACATCCTCTT-CCC-CACT-----CAGAG-TGGTGCCGGG-AGACGATGCGTAC---GAAGGAG---GGGCG---GATATTGGCCTCCCG   [324]
C.aurantiaca            ----AATCCAACATCGTCTT-CCC-CACTCACT-CAGAG----TGTCGGG-AGACGATTCATTC---GAAGCAG--GGGGCG---GATATTGGCCTCCCG   [322]
C.gibbsiae              ---------AACATCCTCTT-CCC-CACT-----CCGAG----TGCCGGG-AGACGATGCATAC---GAAAGAG---GGGCG---GATATTGGCCTCCCG   [316]
C.clarkei               ---------AGCATCGTCTT-CCC-CACT-----CAGAG----TGCCGGT-AGGCGACGCATAC---GAAAAGA--GGGGCG---GATATTGGCCTCCCG   [318]
C.chrysea               ---------AGCATCCTCTC-CCC-CTCT-----CAGAA----TGCCGGG-AGACGACGCATAC---GAAAGAA---GGGCG---GATATTGGCCTCCCG   [319]
C.kermesina             ---------AGCATCGTCTT-CCC-CACT-----CAGAG----TGCGGGT-AGGCGACGCATAC---GAAAAGA--GGGGCG---GATATTGGCCTCCCG   [316]
C.dispar                TCCCCCC--ATCGTCCTCTT-CCC-AACT----CAAGAG----TGTCGGG-AGACGATGCGTAC---GAGAAGG-AGGGGCG---GATATTGGCCTCCCG   [329]
Aeschynanthuspulch.     CCGCC----AATGTCTTGTT-CCCTGATTCAGT-CAAAG----TGTTGGG-GGACAATGCGTAC---CAAGGAGGAGGGACG---GATATTGGCCTCCCG   [327]

[                                      410       420       430       440       450       460       470       480       490       500]
[                                        .         .         .         .         .         .         .         .         .         .]
Cyrtandrasp.Naga        TTATCA-CTGCGTAGCGGCCGGCCCAAACAA---CATACCGTGCC--GATGGATGTCACACGATACGTGGTGG---TCGGATTCGTGAA-----------   [396]
C.sp.Lantuyang          TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGTC--GACGGATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-   [407]
C.sp.Isabella           TTATCC-TTGTGTAGCGGCCGGCCCAAACAA---CATGCCGTGTC--GATGGATGTCACACGATACGTGGTGG---TTGGATTCGTGAACT-TTACGAA-   [401]
C.cumingii              TTATCT-TGGCGTAGCGGCCGGCCCAAACAA---GATACCGTGTC--GATGGATGTCACACGATACGTGGTGG---TTGGATTCGTGAA-----------   [402]
C.ferruginea            TTATCATCACCATATCGGCCGGCCCTAA?AA---C?T?CC?TGCC--GACAGATGTCACAC?ACACGTGGTGG---TCAGAT?CGTGAA-----------   [389]
C.sp.Halcon1            TTACCC-TTGTGTAGCGGCCGGCCCAAACAA---CATGCCGTGTC--GATGGATGTCACACGATACGTGGTGG---TTGGATTCGCGAA-----------   [398]
C.sp.Halcon2            TTATCC-TTGTGTAGCGGCCGGCCCAAACAA---CATACCGTGTC--GATGGATGTCGCACGATACGTGGTGG---TTGGATTTGTGAA-----------   [399]
C.baileyi               TTATCC-TTGCATAGCGGCCGGCCCAAATAA---CATGCCGTGGC--GATGGATGTCACACGATACGTGGTGGCGGTTAGATCCTTCGAC--TTGCAAAA   [424]
C.monticola             TAATGC-TAGCATAGCGGCCGGCCCAAATAA---CATGCTGTGGC--KATGCATGTCACACGATACGTGGTGGCGGTTAGATTCCTCGAC--TTGCAAAA   [430]
C.umbellifera           TTATCC-TTGTGTAGCGGCCGGCC-AAATAA---CATACCGTGTC--GATG-ATGTCACACGATGCGTGGTGG---TTGGAT-CGCGAAC--TTACGAA-   [392]
C.tohiveaensis          TTATCC-TTGTGTAGCGGCCGGCCCAAATAA---CATACCGTGTC--GATGGATGTCGCACGATGCGTGGTGG---TTGAATTCGTCAAC--TTGCAAA-   [396]
C.stenoptera.a          TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGCC--GACGGATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-   [408]
C.stenoptera.b          TTATCC-TCGTGTATCGGCCGGCCCAAATAA---CATACCGTGCC--GACGGATGTCACACGATAAGTGGTGG---TTGGATTCGTCAAC--TCGCGGA-   [408]
C.trichodon             TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGCC--GACGGATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-   [407]
C.rhyncanthera.a        TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGCC--GACGGATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TTGCGGA-   [407]
C.rosea                 TTATCC-TTGTGTAGCGGCCGGCCCAAATAA---CATACCGTGTC--GATGAATGTCACACGATACGTGGTGG---TTGGATTTCTCATC--TTGCGAA-   [416]
C.impressivenia         TTACCC-TTGTGTAGCGGCCGGCCCAAATAA---CATACCGTGTC--GATGAATGTCACACGATACGTGGTGG---TTGGATTTCTCATC--TTGCGAA-   [413]
C.sandei                TTATCC-TTGTGTAGCGGCCGGCCCAAATAA---CATACCGTGTC--GATGAATGTCACACGATACGTGGTGG---TTGGATTTCTCATC--TTGCGAA-   [416]
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[                               410       420       430       440       450       460       470       480       490       500]
[                               .         .         .         .         .         .         .         .         .         .]
C.sandei55             TTATCC-TTGTGTAGCGGCCGGCCCAAATAA---CATACCGTGTC--GATGAATGTCACACGATACGTGGTGG---TTGGATTTCTCATC--TTGCGAA-   [416]
C.picta                TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGCC--GACGGATGTCACACGATAAGTGGTGG---TTGGATTCCTCAACTCTCGCGGA-   [410]
C.aureotincta          TTATCC-TTGTGTAGCGGCCGGCCCAAATAA---CATACCGTGTC--GATAAATGTCACACGATACGTGGTGG---TCGGATTTCTCATC--TTGCGAA-   [427]
C.sp.LMRF1             TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGTC--GATGGATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-   [408]
C.sp.LMRF2             TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGCC--GATGAATGTCACACGATACGTGGTGG---TCGGATTTCTCATC--TCGCAAA-   [413]
C.peltata              TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGCC--GACGGATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-   [411]
C.pendula              TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGTC--GATGGATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-   [410]
C.rhyncanthera.b       TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGCC--GACGGATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TTGCGGA-   [407]
C.anisophylla          TTATCC-TCGAGTAGCGGCCGGCCCAAATAA---CAGACCGTGTC--GATGGATGTCACACGATACGTGGTGG---TCGGATTCCTCGAG--TTGCGAA-   [417]
C.longepetiolata       TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGTC--GATGGATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-   [408]
C.trisepalaGB51        TTATCC-TCGTGTAGCGGCCGGCCCAAACAACAACATACCGTGTCTCGATGGATGTCACACGATACGTGGTGG---TCGGATTCCTCGAC--TTGCGAA-   [421]
C.pendulaGB37          TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGCC--GAYGGATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-   [409]
C.wallichiiGB25        TTATCC-TAGTGTAGCGGCCGGCCCAAATAA---CATACCGTGTC--GACGGATGTCACACGATAAGCGGTGG---TTGGATTCCTCAAC--TTGCGTA-   [407]
C.cupulata             TTATCC-TCGTGTAGCGGCCGGCCCAAATAG---TATGCCGTGTC--GACGGATGTCACGCGATACGTGGTGG---TTGGATTCCTCAAA--TTGCGAA-   [412]
C.affwallichiiGB32     TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---AATACCGTGCC--GACGGATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-   [408]
C.wallichiiGB33        TTATCC-TAGTGTAGCGGCCGGCCCAAATAA---CATACCGTGTC--GACGGATGTCACACGATAAGCGGTGG---TTGGATTCCTCAAC--TTGCGTA-   [408]
C.wallichiiFRI44491    TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGCC--GACGGATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-   [409]
C.stonei               TTATCC-TCGAGTAGCGGCCGGCCCAAATAA---CAAACCGTGTC--GATGGATGTCACGCGATACGTGGTGG---TCGGATTCCTCGAC--TTGCGAA-   [415]
C.wallichiiGB35        TTATCC-TAGTGTAGCGGCCGGCCCAAATAA---CATACCGTGTC--GACGGATGTCACACGATAAGCGGTGG---TTGGATTCCTCAAC--TTGCGTA-   [407]
C.patula               TTATCC-TTGTGTAGCGGCCTGCCCAAATAA---CATACCGTGTC--GATGAATGTCACACGATACGTGGTGG---TCGGATTTCTCATC--TTGCGAA-   [420]
C.wallichiiFRI47032    TTATCC-TAGTGTAGCGGCCGGCCCAAATAA---CATACCGTGTC--GACGGATGTCACACGATAAGCGGTGG---TTGGATTCCTCAAC--TTGCGTA-   [407]
C.inconspicuaCHURCH292 TTATCC-TTGTGTCACGGCCGGCCCAAATAA---CATACCGTGCC--GATGGATGTCACACGATACGTGGTGG---TTGGATTCCTCGAC--TTGCGAA-   [413]
C.inconspicuaCHURCH171 TTATCC-TTGTGTAGCGGCCGGCCCAAATAA---CATACCGTGCC--GATGGATGTCACACGATACGTGGTGG---TTGGATTCCTCGAC--TTGCGAA-   [413]
C.aff.chrysea          TTATCC-CAGTGTAGCGGCCGGCCCAAATTA---CATACCGTGTC--GACGGATGTCACACGATAAGCGGTGG---TTGGATTCCTCAAC--TTGCGTA-   [407]
C.spGB49               TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGTC--GACGGATGTCACACGATAAGTGGTGG---TCGGATTCCTCAAC--TTGCGGA-   [402]
C.mesilauensis         TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGTG--GACGGATGTCACACGATAAGTGGTGG---TCGTATTCCTCAAC--TTGCGGA-   [403]
C.corniculata          TTATCT-TCGTGCAGCGGCCGGCCCAAATAA---CATACCGTGTC--GATGGATGTCACACGATAAGTGGTGG---TCGGATTCCTCAAC--TTGCGGA-   [403]
C.fulvisericea         TTATCC-TCGTGTAGCGGCCGGCCCAAATGA---CATACCGTGTCTCGATGGATGTCACACGATACGTGGTGG---TTGGATTCCTCGAC--TTGCGAA-   [415]
C.burbidgei            TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGCC--GACGGATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-   [403]
C.smithiana            TTATCC-TTGTGTAGCGGCCGGCCCAAATAA---CATACCGTGCC--GATGTATGTCACACGATACTTGGTGGTGGTTGGATTCCTCAAC--TGGCGAA-   [415]
C.aurantiaca           TTATCC---------------------------CATACCGTGTC--GATGGATGTCACACGATACGTGGTGG---TTGGATTCCCCAAC--TTGTGAA-   [386]
C.gibbsiae             TTATCT-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGTC--GACGGATGTCACACGATAAGTGGTGG---TCGGATTCCTCAAC--TTGCGTA-   [404]
C.clarkei              TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATTCCGTGCC--GACGGATGTCACACGATAAGTGGTGG---TTGGATTCCTCAAC--TCGCGGA-   [406]
C.chrysea              TTATCC-TCATGTAGCGGCCGGCCCAAATAA---CATGCCGTGTC--TGCGCATGTCACACGATGAGTGGTGG---TTGGATTCCTCAAC--TTGCGGA-   [407]
C.kermesina            TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATGCCGTGCC--GACGGATGTCACACGATAAGTGGTGG---TTGGATTCTTCAAC--TCGCGGA-   [404]
C.dispar               TTATCC-TCGTGTAGCGGCCGGCCCAAATAA---CATACCGTGCC--GATGAATGTCACACGATACGTGGTGG---TCGGATTTCTCATC--TCGCAAG-   [417]
Aeschynanthuspulch.    TTATCC-AAGTATAGCGGCCGGCACAAATAG---TATACCGTGTC--GATTGATGTCACACGATACGTGGTGG---TTGGATTCCTCAAC--TTGCGAA-   [415]
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[                               510       520       530       540       550       560       570       580 ]
[                                .         .         .         .         .         .         .         .  ]
Cyrtandrasp.Naga       CTATCT---TATATCGTGTGGGAACGC-GTCGAGCCACGGGCAC-GACCCAA---CGGCAGC--AGATCG------CCCTCGA   [463]
C.sp.Lantuyang         CTATAT------ATCGTGTGGGAATGC-GTCGAGCCACGGGTAC-GACCCAA---CGGCACC--AGATCG------CCCTCGA   [471]
C.sp.Isabella          CTATCT---TATATCGTGTGGGAATGC-GTCGAGCCACGGGAAC-GACCCAA---CGGCAGC--AGATTG------CCCTCGA   [468]
C.cumingii             CTATCT---TATATCGTGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCAA---CGGCAGC--AGATTG------CCTTCGA   [469]
C.ferruginea           STATCT--GCATATCGTGTGGGAATGC-?TC?A-CCACGGGGGA-AAAAACCCCCCGGCAGC--AGA----------------   [449]
C.sp.Halcon1           CTATCT---TATATCGTGTGGGAATGC-GCCGAGCCACGGTCAC-GACCCAA---CGGCAGC--AGATTG------CCCTCGA   [465]
C.sp.Halcon2           CTATCT---TATATCGTGTGGGAATGC-GTCGAGCCACGGCCAC-GACCCAA---CGGCAGCGCAGATTG------CCCTCGA   [468]
C.baileyi              CTATCT---GATATCGTGTGGGAATGC-GTCTAGCCACGGGCAC-GACCCTG---TGGCAGC--AGATTGGTGCTGCCTTCCA   [497]
C.monticola            CTATCT---AATATCGTGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCGGTGGCGGCAGC--AGATCGGTGCTGCCCTCCA   [506]
C.umbellifera          CTATCT----ATATCGTGTGG--ATGC-G--CG?---CGGGCAC-GACCCAAA--CGGCAGCA-AGATTG------CCCTCGA   [453]
C.tohiveaensis         CTATCT----GCATCGTGTGGGAATGC-GTCCAGTGACGGGCAT-GACCCAA---CGGCAGC--AGATTG------CCCTCGA   [462]
C.stenoptera.a         CTATAT------ATCGTGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCAA---CGGCACC--AGATCG------CCCTCGA   [472]
C.stenoptera.b         CTATAT------ATCGTGTGGGAATGC-GTCGAGCCACGGGCAT-GACCCAA---CGGCACC--AGATCG------CCCTCGA   [472]
C.trichodon            CTGTAT------ATCGTGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCAA---CGGCACC--AGATCG------CCCTCGA   [471]
C.rhyncanthera.a       CTATAT------ATCGTGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCAA---CGGCACC--AGATCG------CCCTCGA   [471]
C.rosea                CTATGT--ATATATCGTGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCAA---GGGCGCC--AGATCG------CCCTCGA   [484]
C.impressivenia        CTATCG--ATATATCGTGTGGGAATGC-GTCGAGCCACGGGCAA-GACCCAA---TGGCACA--AGATCG------CCCTCGA   [481]
C.sandei               CTATGT--ATATATCGTGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCAA---CGGCGCC--AGATCG------CCCTCGA   [484]
C.sandei55             CTATGT--ATATATCGTGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCAA---CGGCGCC--AGATCG------CCCTCGA   [484]
C.picta                CTATAT------ATCGTGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCAA---CGGCACC--AGATCG------CCCTCGA   [474]
C.aureotincta          CTATGT--GTATATCGTGTGGGAATGC-GTCGAGCCACGGGCAT-GACCCAA---CGGCGCC--AGATCG------CCCTCGA   [495]
C.sp.LMRF1             CTATAT------ATCGTGTGGGAATGC-GTCGAGCCACGGACAC-GACCCAA---CGGCACC--AGATCG------CCCTCGA   [472]
C.sp.LMRF2             CTATCG--ATATATCGTGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCAA---TGGCACC--AGATCG------CCCTCGA   [481]
C.peltata              CTATAT------ATCGTGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCAG---CGGCACC--AGATCG------CCCTCGA   [475]
C.pendula              CTATAT------ATCGTGTGGGAATGC-GTCGAGCCACGGACAC-GACCCAA---CGGCACC--AGATCG------CCCTCGA   [474]
C.rhyncanthera.b       CTATAT------ATCGTGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCAA---CGGCACC--AGATCG------CCCTCGA   [471]
C.anisophylla          CTGTCT---TATATCGTGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCAA---CGGCACC--AGATTG------CCCTCGA   [484]
C.longepetiolata       CTATAT------ATCGTGTGGGAATGC-GTCGAGCCACGGACAC-GACCCAA---CGGCACC--AGATCG------CCCTCGA   [472]
C.trisepalaGB51        CTATCT---TATATCGTGTGGGAGTGC-GTCGAGCCACGGGCAC-GGCCCAA---CGGCGCC--AGAGCG------CCCTCGA   [488]
C.pendulaGB37          CTATAT------ATCGTGTGGGAATGC-GTCGAGCCACGGACAC-GACCCAA---CGGCACC--AGATCG------CCCTCGA   [473]
C.wallichiiGB25        GTATCT------ATCGTGTGGGAATGC-GTCGAGCCACGAGCAC-GGCCCAA---TGGCACA--AGATTG------CCTTCGA   [471]
C.cupulata             CTATGT------GTCGCGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCAA---TGGCACG--AGATTG------CCCTCGA   [476]
C.affwallichiiGB32     CTATAT------ATCGTGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCAA---CGGCACC--AGATCG------CCCTCGA   [472]
C.wallichiiGB33        GTATCT------ATCGTGTGGGAATGC-GTCGAGCCACGAGCAC-GGCCCAA---TGGCACA--AGATTG------CCTTCGA   [472]
C.wallichiiFRI44491    CTATAT------ATCGTGTGGGAATGC-GTCTAGCCACGGGCAC-GACCCAA---CGGCACC--AGATCG------CCCTCGA   [473]
C.stonei               CTATCT---TATATCGTGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCAA---CGGCACC--AGATTG------CCCTCGA   [482]
C.wallichiiGB35        GTATCT------ATCGTGTGGGAATGC-GTCGAGCCACGAGCAC-GGCCCAA---TGGCACA--AGATTG------CCTTCGA   [471]
C.patula               CTATGT--ATATATCGTGTGGGAATGC-GTCGAGCCACGGGCATTGACCCAA---CGGCGCC--AGATCG------CCCTCGA   [489]
C.wallichiiFRI47032    GTATCT------ATCGTGTGGGAATGC-GTCGAGCCACGAGCAC-GGCCCAA---TGGCACA--AGATTG-----CCTTTCGA   [472]
C.inconspicuaCHURCH292 CTATAT------ATCGTGTGGGAATGC-GTCGAGCCACGGACAC-GGCCCAA---TGGCACC--GGATTG------CCCTCGA   [477]
C.inconspicuaCHURCH171 CTATAT------ATCGTGTGGGAATGC-GTCGAGCCACGGACAC-GGCCCAA---TGGCATC--GGATTG------CCCTCGA   [477]
C.aff.chrysea          GTATCT------ATCGTGTGGGAATGC-GTCGAGCCACGGCCAC-GACCCAA---TGGCAAC--AGATTG------CCTTCGA   [471]
C.spGB49               CTATCT-----TATCGTGCGGGAATGC-GTCGAGCCACGGCCAC-GACCCAA---TGGCACC--AGATTG------CCATCGA   [467]
C.mesilauensis         CTATCT-----TATCGTGTGGGAATGC-GTCGAGCCACGGCCAA-GACCCAA---TGGCACC--AGATTG------CCCTCGA   [468]
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```
[                              510       520       530       540       550       560       570       580 ]
[                              .         .         .         .         .         .         .         .   ]
C.corniculata          CTATCT-----TATCGTGTGGGAATGC-GTCGAGCCACGGCCAC-GACCCAA---TGGCATC--TGTTTG------CCCTCGA   [468]
C.fulvisericea         CTGTCT---TATATCGTGTGGGAATGC-TTCGAGCCACGGGCAC-GACCCAA---CGGCACC--AGATCG------CCCTCGA   [482]
C.burbidgei            CTATAT------ATCGTGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCAA---CGGCACC--AGATCG------CCCTCGA   [467]
C.smithiana            CTATCT----ATATCGTGTGGGAATGT-GTCGAGCCACGGGCAC-GACCCAA---TGGCACC--AGATTG------CCCTCGA   [481]
C.aurantiaca           CTATCT----ATATCGTGTGGGAATGC-ATCGAGCCACGGGCAA-GACCCAA---TGGCACA--AGATTG------CCCTCGA   [452]
C.gibbsiae             CTATCT-----TATCG?GTGGGAATGT-GTCGAGCCACGGCCAA-GACCCAA---TGGCACG--AGGT-G------CCCTCGA   [468]
C.clarkei              CTATAT------ATCGTGTGGGAATGC-GTCGAGCCACGGGCAC-GACCCAA---CGGCACC--AGATCG------CCCTCGA   [470]
C.chrysea              CTATTC-----CCTCGTGTGGGAATGC-GTCTCGCCACGGGCAC-GACCCAA---CGGCACC--AGATTG------CCCTCGA   [472]
C.kermesina            CTATAT------ATCGTGTGGGAATGC-ATCGAGCCAMGGGCAC-GACCCAA---CGGCACC--AGATCG------CCCTCGA   [468]
C.dispar               CTATCGATATATATCGTGTGGGAATGC-GTCGAGCCACGGGCATTGACCCAA---TGGCACC--AGATCG------CCCTCGA   [488]
Aeschynanthuspulch.    CTAT--------ATCGTGTGGGACTCC-ATCAATCCACGGGCCT-GACCCAA---TGGCACA--AGATTG------CCCTCGA   [477]
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APPENDIX 10: ITS Gap Matrix analysed in chapter 5

Species	1	6	11	16	21
C. sp. *Naga*	11001	11101	11110	111?1	1
C. sp. *Lantuyang*	10001	11111	10111	11011	1
C. sp. *Isabella*	101?1	11101	11111	11011	1
C. cumingii	101?1	11101	?1111	111?1	1
C. ferruginea	111?1	11101	11110	111?1	?
C. sp. *Halcon 1*	101?1	11101	11110	111?1	1
C. sp. *Halcon 2*	101?1	11101	11110	111?1	1
C. baileyi	?0001	10011	10111	10001	0
C. monticola	10001	10011	10111	10001	0
C. umbellifera	1001?	11?01	11110	11011	1
C. tohiveaensis	10010	11101	1111?	11011	1
C. stenoptera a	10001	11111	10111	11011	1
C. stenoptera b	10001	11111	10111	11011	1
C. trichodon	10001	11111	10111	11011	1
C. rhyncanthera a	10001	11111	10111	11011	1
C. rosea	10001	11111	10111	11011	1
C. impressivenia	10001	11111	10111	11011	1
C. sandei	10001	11111	10111	11011	1
C. sandei55	10001	11111	10111	11011	1
C. picta	10001	11111	10111	11011	1
C. aureotincta	10001	01111	10101	11011	1
C. sp. *LMRF1*	10001	11111	10111	11011	1
C. sp. *LMRF2*	10001	11111	10111	11011	1
C. peltata	10001	11111	10111	11011	1
C. pendula	10001	11111	10111	11011	1
C. rhyncanthera b	10001	11111	10111	11011	1
C. anisophylla	00001	11111	10111	11011	1
C. longepetiolata	10001	11111	10111	11011	1
C. trisepala	10001	11111	00111	01011	1
C. pendula(GB37)	10001	11111	10111	11011	1
C. wallichii (GB25)	10001	11110	10111	11101	1
C. cupulata	10001	11111	10111	11011	1
C. aff. *wallichii(GB32)*	10001	11111	10111	11011	1
C. wallichii(GB33)	10001	11110	10111	11011	1
C. aff. *wallichii(FRI44491)*	10001	11111	11011	11011	1

	1 6 11 16 21
C. stonei	00001 11111 10111 11011 1
C. wallichii(GB35)	10001 11110 10111 11011 1
C. patula	10001 01111 10111 11010 1
C. wallichii(FRI47032)	10001 11110 10111 11011 1
C. inconspicua(Church292)	10001 11111 10011 11011 1
C. inconspicua (Church171)	10001 11111 10011 11011 1
C. aff. *cuprea*	10001 11111 10111 11011 1
C. sp. *(GB49)*	10001 11111 10111 11011 1
C. mesilauensis	10001 11111 00111 11011 1
C. corniculata	10001 11111 10111 11011 1
C. fulvisericea	10001 11111 00111 01011 1
C. burbidgei	10001 11111 10111 11011 1
C. smithiana	10000 11111 10111 10011 1
C. aurantiaca	10001 11111 10111 11011 1
C. gibbsiae	10001 11111 10011 11011 1
C. clarkei	10001 11111 10111 11011 1
C. chrysea	00001 11111 10111 11011 1
C. kermesina	10001 11111 10111 11011 1
C. dispar	10001 11111 10111 11010 1
Aeschynanthus pulcher	10001 11111 10101 11011 1

1= gap present; 0= gap absent
Positions of gaps in matrix:

1= 34-35
2= 45-51
3= 69-74
4= 70
5= 75
6= 79-80
7= 86-89
8= 129-131
9= 135
10= 169
11= 229
12= 263
13= 274-276
14= 325
15= 351
16= 446-447
17= 474-476
18= 490-499
19= 500
20= 545
21= 571-57

APPENDIX 11: *trn*L-F MATRIX

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[                                  10        20        30        40        50        60        70        80        90        100]
[                                  .         .         .         .         .         .         .         .         .         .]

Aeschynanthuslongiflorus     GTATGGAAACCTACTAAGTGAAAACTTTCAA-TTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [98]
Aeschynanthussp              GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAATACAAG   [99]
Aeschynanthusbracteatus      GTATGGAAAC-TACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [98]
T5Cyrtandraafftrisepala      GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T28Cyrtandrasmithiana        GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T4Cyrtandraanisophylla       GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T12Cyrtandrastonei           GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T24Cyrtandrafulvisericea     GTATGGAAACCTACTAAGTGGAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T1Cyrtandratrichodon         GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T2Cyrtandrarhyncanthera      GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T3CyrtandrawallichiiGB25     GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T6Cyrtandrapeltata           GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T8CyrtandraaffwallichiiGB32  GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T9CyrtandrapendulaSum        GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T15Cyrtandraaureotincta      GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T10Cyrtandralongepetiolata   GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T11Cyrtandracupulata         GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T21Cyrtandrachrysea          GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCTTGTTTTCTCAAAACGAG   [100]
T22Cyrtandramesilauensis     GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T7BCyrtandrapendulaMPGB37    GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T23Cyrtandragibbsiae         GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAACGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T19Cyrtandraburbidgei        GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T25Cyrtandrapatula           GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T26Cyrtandraclarkei          GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T27Cyrtandrakermesina        GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
T29Cyrtandraimpressivenia    GTATGGAAACCTACTAAGTGAAGACTTTCAAATTCAGAGAAACCCTGGAATTAATAAAAATGGGCAATCCTGAGCCAAATCCT-GTTTTCTCAAAACAAG   [99]
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[                                     110       120       130       140       150       160       170       180       190       200]
[                                       .         .         .         .         .         .         .         .         .         .]

Aeschynanthuslongiflorus     GGTTCA-GAGAGCGAAAAAGGGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [193]
Aeschynanthussp              GGTTCA-GAGATCGAAAAAGGGGATAGGTGCAGAGACTCAATGGGAGCTGTTCTGACAAATGGAGTTGTCCGCGTTGG----TAGAACAATTGCAACTTC  [194]
Aeschynanthusbracteatus      GGTTCAAGAGAGCGAAAAAGGGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T5Cyrtandraafftrisepala      GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T28Cyrtandrasmithiana        GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T4Cyrtandraanisophylla       GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T12Cyrtandrastonei           GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T24Cyrtandrafulvisericea     GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T1Cyrtandratrichodon         GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T2Cyrtandrarhyncanthera      GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTCGTTGGTAGAAGAATTGAAACTTC  [198]
T3CyrtandrawallichiiGB25     GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T6Cyrtandrapeltata           GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T8CyrtandraaffwallichiiGB32  GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T9CyrtandrapendulaSum        GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T15Cyrtandraaureotincta      GGTTCA-TAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T10Cyrtandralongepetiolata   GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T11Cyrtandracupulata         GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [195]
T21Cyrtandrachrysea          GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACTAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T22Cyrtandramesilauensis     GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T7BCyrtandrapendulaMPGB37    GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T23Cyrtandragibbsiae         GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T19Cyrtandraburbidgei        GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T25Cyrtandrapatula           GGTTCA-TAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T26Cyrtandraclarkei          GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T27Cyrtandrakermesina        GGTTCA-GAGAGCGAAAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [194]
T29Cyrtandraimpressivenia    GG-------------AAAAGAGGATAGGTGCAGAGACTCAATGGAAGCTGTTCTAACAAATGGAGTTGACCGCGTTGG----TAGAAGAATTGAAACTTC  [182]
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[                                    210       220       230       240       250       260       270       280       290       300]
[                                      .         .         .         .         .         .         .         .         .         .]

Aeschynanthuslongiflorus      AGAAAGTATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCCGTATCTGGGTTTTTGTA   [273]
Aeschynanthussp               CGCAAGTATGRAGGATAAGCGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCCGTATCTGGGTTTTTGTA   [274]
Aeschynanthusbracteatus       AGAAAGTATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AATGTGATGATTAATAATGGCCCGAATCCGTATCTGGGTTTTTGTA   [289]
T5Cyrtandraafftrisepala       AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [274]
T28Cyrtandrasmithiana         AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [274]
T4Cyrtandraanisophylla        AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [274]
T12Cyrtandrastonei            AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [274]
T24Cyrtandrafulvisericea      AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [274]
T1Cyrtandratrichodon          AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [274]
T2Cyrtandrarhyncanthera       AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [278]
T3CyrtandrawallichiiGB25      AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [274]
T6Cyrtandrapeltata            AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [274]
T8CyrtandraaffwallichiiGB32   AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [274]
T9CyrtandrapendulaSum         AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [274]
T15Cyrtandraaureotincta       AGAAAGGAGGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [274]
T10Cyrtandralongepetiolata    AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [274]
T11Cyrtandracupulata          AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [275]
T21Cyrtandrachrysea           AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCCGTATCTGGGTTTTTGTA   [274]
T22Cyrtandramesilauensis      AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAATTAATAAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [279]
T7BCyrtandrapendulaMPGB37     AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [274]
T23Cyrtandragibbsiae          AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAATTCATAAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [279]
T19Cyrtandraburbidgei         AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [274]
T25Cyrtandrapatula            AGAAAGGAGGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [274]
T26Cyrtandraclarkei           AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTATTGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [274]
T27Cyrtandrakermesina         AGAAAGGATGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [274]
T29Cyrtandraimpressivenia     AGAAAGGAGGAAGGATAAACGTATCTATTGAATACTATTGATGATTAAT-----AAT---------------GGCCCGAATCTGTATCTGGGTTTTTGTA   [262]
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[                                    310       320       330       340       350       360       370       380       390       400]
[                                      .         .         .         .         .         .         .         .         .         .]

Aeschynanthuslongiflorus      TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAATAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGGTAGATCTC   [371]
Aeschynanthussp               TATGATTGATATAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAATAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [374]
Aeschynanthusbracteatus       TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAATAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [387]
T5Cyrtandraafftrisepala       TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [372]
T28Cyrtandrasmithiana         TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [372]
T4Cyrtandraanisophylla        TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAAGCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [372]
T12Cyrtandrastonei            TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAAGCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [372]
T24Cyrtandrafulvisericea      TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCATAGTCCGATAGATCTC   [372]
T1Cyrtandratrichodon          TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [372]
T2Cyrtandrarhyncanthera       TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [376]
T3CyrtandrawallichiiGB25      TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [372]
T6Cyrtandrapeltata            TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [372]
T8CyrtandraaffwallichiiGB32   TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [372]
T9CyrtandrapendulaSum         TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [372]
T15Cyrtandraaureotincta       TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [372]
T10Cyrtandralongepetiolata    TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [372]
T11Cyrtandracupulata          TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [373]
T21Cyrtandrachrysea           TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [372]
T22Cyrtandramesilauensis      TATGAAAAA--TATAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [377]
T7BCyrtandrapendulaMPGB37     TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [372]
T23Cyrtandragibbsiae          TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [377]
T19Cyrtandraburbidgei         TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [372]
T25Cyrtandrapatula            TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [372]
T26Cyrtandraclarkei           TATGAGAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [372]
T27Cyrtandrakermesina         TATGAGAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [372]
T29Cyrtandraimpressivenia     TATGAAAAA--TAGAAGAATTGGTGTGAATTGATTTCACATTGATAAAAGAATCGAATATTCATTAATCAAATCATTCACTCCACAGTCCGATAGATCTC   [360]
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[                                    410       420       430       440       450       460       470       480       490       500]
[                                      .         .         .         .         .         .         .         .         .        .]

Aeschynanthuslongiflorus      TTAAAGAA--TTTATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATAACGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [464]
Aeschynanthussp               TTAAAGAA--TTTATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATAACGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [467]
Aeschynanthusbracteatus       TTAAAGAA--TTTATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATAACGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [480]
T5Cyrtandraafftrisepala       TTAACGAACT--TTTAATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [465]
T28Cyrtandrasmithiana         TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [465]
T4Cyrtandraanisophylla        TTAACGAACT--TATAATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [465]
T12Cyrtandrastonei            TTAACGAACT--TATAATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCCATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [465]
T24Cyrtandrafulvisericea      TTAACGAACT--TTTAATT-----TGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [465]
T1Cyrtandratrichodon          TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [465]
T2Cyrtandrarhyncanthera       TTAAAGAACT--TATTATTTTATTCGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [474]
T3CyrtandrawallichiiGB25      TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [465]
T6Cyrtandrapeltata            TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [465]
T8CyrtandraaffwallichiiGB32   TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [465]
T9CyrtandrapendulaSum         TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [465]
T15Cyrtandraaureotincta       TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [465]
T10Cyrtandralongepetiolata    TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [465]
T11Cyrtandracupulata          TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [466]
T21Cyrtandrachrysea           TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [465]
T22Cyrtandramesilauensis      TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [470]
T7BCyrtandrapendulaMPGB37     TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAAC-TATAGTAAGAGGAAAATC   [464]
T23Cyrtandragibbsiae          TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATATCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [470]
T19Cyrtandraburbidgei         TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [465]
T25Cyrtandrapatula            TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [465]
T26Cyrtandraclarkei           TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [465]
T27Cyrtandrakermesina         TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [465]
T29Cyrtandraimpressivenia     TTAAAGAACT--TATTATT-----CGGACGAGAATAAAGATAGAGTCCCGTTCTACATGTCAATACCGGCAACAATGAAACTTATAGTAAGAGGAAAATC   [453]
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[                                      510       520       530       540       550       560       570       580       590       600]
[                                      .         .         .         .         .         .         .         .         .         .]

Aeschynanthuslongiflorus     CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [561]
Aeschynanthussp              CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [564]
Aeschynanthusbracteatus      CGTCGACTTTTAAAA-TCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [577]
T5Cyrtandraafftrisepala      CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [562]
T28Cyrtandrasmithiana        CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [562]
T4Cyrtandraanisophylla       CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [562]
T12Cyrtandrastonei           CGTCGACTTT-AAAAATCGTG-AGGGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [563]
T24Cyrtandrafulvisericea     CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [562]
T1Cyrtandratrichodon         CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [562]
T2Cyrtandrarhyncanthera      CGTCGACTTT-AAAAATCGTGGA-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [572]
T3CyrtandrawallichiiGB25     CGTCCGACTTTAAAAATCGTG-A-GG-TTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [562]
T6Cyrtandrapeltata           CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [562]
T8CyrtandraaffwallichiiGB32  CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [562]
T9CyrtandrapendulaSum        CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [562]
T15Cyrtandraaureotincta      CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [562]
T10Cyrtandralongepetiolata   CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [562]
T11Cyrtandracupulata         CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [563]
T21Cyrtandrachrysea          CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCTCAAAATATTTATCCTATCCGCTTTGTTCGTT   [562]
T22Cyrtandramesilauensis     CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [567]
T7BCyrtandrapendulaMPGB37    CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [561]
T23Cyrtandragibbsiae         CGTCGACTTT-CAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [567]
T19Cyrtandraburbidgei        CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [562]
T25Cyrtandrapatula           CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAGTTGATTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [562]
T26Cyrtandraclarkei          CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [562]
T27Cyrtandrakermesina        CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [562]
T29Cyrtandraimpressivenia    CGTCGACTTT-AAAAATCGTG-A-GGGTTCAAGTCCCTCTATCCCCAAAAAAATCCTATAATTGACTCCCAAAATATTTATCCTATCCGCTTTGTTCGTT   [550]
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[                                      610       620       630       640       650       660       670       680       690       700]
[                                        .         .         .         .         .         .         .         .         .         .]

Aeschynanthuslongiflorus      AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGKCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [653]
Aeschynanthussp               AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGGCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [656]
Aeschynanthusbracteatus       AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGGCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [669]
T5Cyrtandraafftrisepala       AACGGTTCAAAATCCCTTTATCTTTCTAATTCTTTTACAAACGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [654]
T28Cyrtandrasmithiana         AACGGTTCAAAATCCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [654]
T4Cyrtandraanisophylla        AACGCTTCAAAATCCCTTTATATTTCTAATTCTTTTACAAAAGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [654]
T12Cyrtandrastonei            AACGCTTCAAAATCCCTTTATATTTCTAATTCTTTTACAAAAGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [655]
T24Cyrtandrafulvisericea      AACGGTTCAAAATCCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATAACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [654]
T1Cyrtandratrichodon          AACGGTTCAAAATT-CTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATTGAATATA--------C   [653]
T2Cyrtandrarhyncanthera       AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATCGAATATA--------C   [664]
T3CyrtandrawallichiiGB25      AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [654]
T6Cyrtandrapeltata            AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATCGAATATA--------C   [654]
T8CyrtandraaffwallichiiGB32   AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATCGAATATA--------C   [654]
T9CyrtandrapendulaSum         AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATCGAATATA--------C   [654]
T15Cyrtandraaureotincta       AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [654]
T10Cyrtandralongepetiolata    AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCCCATGTGATATCGAATATA--------C   [654]
T11Cyrtandracupulata          AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [655]
T21Cyrtandrachrysea           AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATTACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [654]
T22Cyrtandramesilauensis      AACGGTTCAAAATCCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [659]
T7BCyrtandrapendulaMPGB37     AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATCGAATATA--------C   [653]
T23Cyrtandragibbsiae          AACGGTTCAAAATTCC------TTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [653]
T19Cyrtandraburbidgei         AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [654]
T25Cyrtandrapatula            AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [654]
T26Cyrtandraclarkei           AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [654]
T27Cyrtandrakermesina         AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGAT-TGTGATATA-GAATATAC   [660]
T29Cyrtandraimpressivenia     AACGGTTCAAAATTCCTTTATCTTTCTAATTCTTTTACAAATGTCTTTGGTCGTAAATGACTTTCTCTTCTCACATGTGATATAGAATATA--------C   [642]
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[                                     710       720       730       740       750       760       770       780       790       800]
[                                      .         .         .         .         .         .         .         .         .         .]

Aeschynanthuslongiflorus      ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACTGATACTTACAAAGTCGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [751]
Aeschynanthussp               ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACTGATACTTACAAAGTCGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [754]
Aeschynanthusbracteatus       ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACTGATACTTACAAAGTCGTCTTTTTAAAGATCCAAGAGATTAGAGAAC    [767]
T5Cyrtandraafftrisepala       ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [752]
T28Cyrtandrasmithiana         ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [752]
T4Cyrtandraanisophylla        ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [752]
T12Cyrtandrastonei            ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [753]
T24Cyrtandrafulvisericea      ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [752]
T1Cyrtandratrichodon          ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [751]
T2Cyrtandrarhyncanthera       ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [762]
T3CyrtandrawallichiiGB25      ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [752]
T6Cyrtandrapeltata            ATTCAARGAATCCTT--ATTGGAATAATTCACAATCAATAGCTTTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [752]
T8CyrtandraaffwallichiiGB32   ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [752]
T9CyrtandrapendulaSum         ATTCAAAGAATCCTT-AATTGGAATAATTCACAATCAATAGCATTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [753]
T15Cyrtandraaureotincta       ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGTTTTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [752]
T10Cyrtandralongepetiolata    ATTCAAAGAATCCTT-AATTGGAATAATTCACAATCAATAGCATTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [753]
T11Cyrtandracupulata          ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [753]
T21Cyrtandrachrysea           ATTCAAAGAATCCTT--ATTGCAATAATTCACAATCAATAGCATTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [752]
T22Cyrtandramesilauensis      ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACTGATACTTACAAAGTCGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [757]
T7BCyrtandrapendulaMPGB37     ATTCAAAGAATCCTT-AATTGGAATAATTCACAATCAATAGCATTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [752]
T23Cyrtandragibbsiae          ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACTGATACTTACAAAGTCGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [751]
T19Cyrtandraburbidgei         ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [752]
T25Cyrtandrapatula            ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGTTTTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [752]
T26Cyrtandraclarkei           ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [752]
T27Cyrtandrakermesina         ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGCATTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [758]
T29Cyrtandraimpressivenia     ATTCAAAGAATCCTT--ATTGGAATAATTCACAATCAATAGTTTTACGCATACCGATACTTACAAAGTTGTCTTTTTAAAGATCCAAGAGATTAGAGGAC    [740]
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[                                      810       820       830       840       850       860       870       880       890   ]
[                                      .         .         .         .         .         .         .         .         .     ]

Aeschynanthuslongiflorus      TTGGAGAAAACTTTGTAATTTTCTCTTGTCCCTTTAATTGACAGAGAACCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGGAATGG   [850]
Aeschynanthussp               TTGGAGAAAACTTTGTAATTTTCTCTTGTCCCTTTAATTGACAGAGAACCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGGAATGG   [853]
Aeschynanthusbracteatus       TTGGAGAAAACTTTGTAATTTTCTCTTGTCCCTTTAATTGACAGAGAACCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGGAATGG   [866]
T5Cyrtandraafftrisepala       TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGGAATGG   [851]
T28Cyrtandrasmithiana         TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGGAATGG   [851]
T4Cyrtandraanisophylla        TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGGAATGG   [851]
T12Cyrtandrastonei            TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATYGGGAATGG   [852]
T24Cyrtandrafulvisericea      TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGGAATGG   [851]
T1Cyrtandratrichodon          TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGGAATGG   [850]
T2Cyrtandrarhyncanthera       TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACWTTGGGAAYGG   [861]
T3CyrtandrawallichiiGB25      TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACGTKGGGAAKGG   [851]
T6Cyrtandrapeltata            TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCKTTAATTGACATAGCCCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGGAATGG   [851]
T8CyrtandraaffwallichiiGB32   TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGGAATGG   [851]
T9CyrtandrapendulaSum         TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGG-TGCTACATTGGG??TGG   [851]
T15Cyrtandraaureotincta       TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATYGGGAATGG   [851]
T10Cyrtandralongepetiolata    TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGGAATGG   [852]
T11Cyrtandracupulata          TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACAAAGACCCCAGTCCTCTAATAAAATGAGGMTGGGATGCTACAYYGGGAATGG   [852]
T21Cyrtandrachrysea           TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGGAATGG   [851]
T22Cyrtandramesilauensis      TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAAACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGAAATGG   [856]
T7BCyrtandrapendulaMPGB37     TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGGAATGG   [851]
T23Cyrtandragibbsiae          TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGGAATGG   [850]
T19Cyrtandraburbidgei         TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAACCAGGATGGGATGATACATTGGGAATGG   [851]
T25Cyrtandrapatula            TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGGAATGG   [851]
T26Cyrtandraclarkei           TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGGAATGG   [851]
T27Cyrtandrakermesina         TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACATTGGGAATGG   [857]
T29Cyrtandraimpressivenia     TTGGAGAAAACTTTGTAATTTTCCCTTGTCCCTTTAATTGACATAGACCCCAGTCCTCTAATAAAATGAGGATGGGATGCTACWTAGGGAC?CG   [839]
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APPENDIX 12: *trn*L-F Gap Matrix

	1	2	3	4	5
Aeschynanthus longiflorus	1	1	0	1	1
A. sp.	1	1	0	1	1
A. bracteatus	1	1	0	0	1
Cyrtandra trisepala	1	0	1	1	1
C. smithiana	1	0	1	1	1
C. anisophylla	1	0	1	1	1
C. stonei	1	0	1	1	1
C. fulvisericea	1	0	1	1	1
C. trichodon	1	0	1	1	1
C. rhyncanthera	1	0	1	1	1
C. wallichii	1	0	1	0	1
C. peltata	1	0	1	1	1
C. aff. *wallichii*	1	0	1	1	1
C. pendula	1	0	1	1	0
C. aureotincta	1	0	1	1	1
C. longepetiolata	1	0	1	1	0
C. cupulata	1	0	1	1	1
C. chrysea	1	0	1	1	1
C. mesilauensis	0	0	1	1	1
C. pendulaMP	1	0	1	1	1
C. gibbsiae	0	0	1	1	1
C. burbidgei	1	0	1	1	1
C. patula	1	0	1	1	1
C. clarkei	1	0	1	1	1
C. kermesina	1	0	1	1	1
C. impressivenia	1	0	1	1	1

Gap positions
1= 250-254
2= 409-410
3= 411-412
4= 511
5= 717

APPENDIX 13: Leaf anatomy of Sumatran and Malaysian *Cyrtandra* species

Leaf anatomy of selected Sumatran *Cyrtandra* species

This investigation examined the Radhiah & Cronk (R&C) collections of Sumatran *Cyrtandra* that were included in the molecular phylogenetic analyses in chapter three. The methods used to examine leaves for foliar sclereids are described in chapter three.

C. anisophylla (R&C 109). Epidermal cells with conical outer wall, 1-layered hypodermis, mesophyll at least four times as thick as the hypodermis, no sclereids. (Figure 7).

C. aureotincta (R&C 122). 1-layered hypodermis, no sclereids.

C. impressivenia (R&C 116). 1-layered hypodermis, lower leaf surface with many hairs, no sclereids. (Figure 6).

C. longepetiolata (R&C 108). 1-layered hypodermis, mesophyll with highly branched astrosclereids. (Figure 1).

C. peltata (R&C 71). 1-layered hypodermis, mesophyll at least three times as thick as the hypodermis with astrosclereids that tend to branch horizontally.

C. pendula (R&C 74). 1-layered hypodermis, mesophyll at least three times as thick as the hypodermis, with astrosclereids similar to those in *C. peltata.* (Figure 2).

C. picta (R&C 54). 2-layered hypodermis, mesophyll packed with astrosclereids.

C. rhyncanthera (R&C 111, 112). 1-layered hypodermis, thin mesophyll layer, only slightly thicker than the hypodermis, with occasional shortly branching astrosclereids.

C. rosea (R&C 115). 2-(3) layered hypodermis, mesophyll 3-4 times as thick as the hypodermis, no sclereids (Figure 5).

C. sandei (R&C 53). 1-layered hypodermis with occasional osteosclereids. (figure 4).

C. stenoptera (R&C 110). 1-layered hypodermis, mesophyll with shortly branching astrosclereids.

C. trichodon (R&C 124). 1-layered hypodermis, mesophyll with highly branched astrosclereids. (Figures 3a, 3b).

C. sp. LMRF 1 (R&C 57). 1-(2) layered hypodermis, astrosclereids in the mesophyll.

C. sp. LMRF 2 (R&C 58). 1-layered hypodermis, no sclereids.

Leaf anatomy of the Malayan species of *Cyrtandra*, by M.H.Bokhari

Professor Bokhari examined the leaf anatomy of all the Peninsular Malaysian Cyrtandra species except *C. lanceolata*. His investigation was based mainly on the collections of Professor Toni Weber (WU).

Cyrtandra cupulata [Weber 870720, WU]. 1-layered hypodermis of large cells about 3x larger than the upper epidermal cells; spongy mesophyll of only 2-layers.

C. dispar [Weber 86018-2/2, WU]. 1-layered hypodermis of large cells about 2 x than upper epidermal cells, spongy mesophyll 5-6-layered.

C. gimlettei [Ridley 2199, K]. 3-4-layered hypodermis. Osteosclereids all lying in the Hypodermis. Short armed astrosclereids in spongy mesophyll.

C. patula [Weber 840806-2/3, WU]. 1-layered hypodermis; spongy mesophyll 6-8-layers, no sclereids.

C. pendula [Weber 840762-2/4, WU]. 1-2-layered hypodermis, upper epidermis papillose. Long-armed astrosclereids throughout spongy mesophyll.

C. stonei [Weber 790805, WU]. 2-layered hypodermis, spongy mesophyll 9-10 cells thick, no sclereids.

C. suffruticosa [Weber 260892-1/4, WU]. 2-layered hypodermis. Epidermis shortly papillose, no sclereids.

C. wallichii [Weber 80615-1/4. WU]. Hypodermis 1-2-layered with long and short osteosclereids. Long-armed astrosclereids scattered throughout spongy mesophyll.

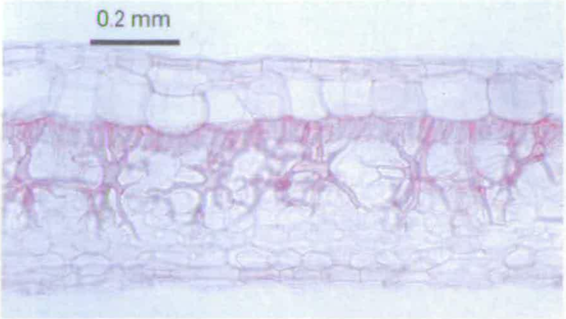

Figure 1: *Cyrtandra longepetiolata* de Vriese (R&C 108). Transverse section of the lamina showing astrosclereids in the mesophyll.

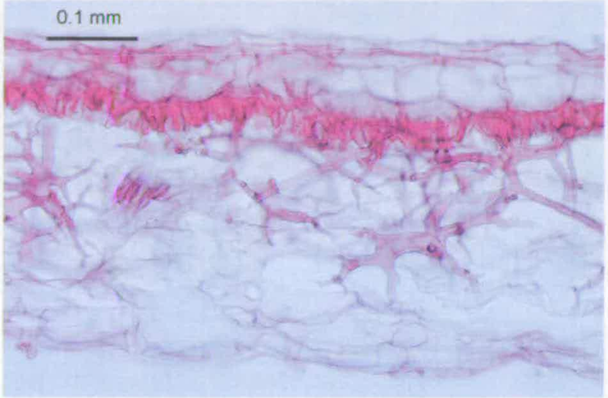

Figure 2: *Cyrtandra pendula* Blume (R&C 74). Transverse section of the lamina showing astrosclereids in the mesophyll.

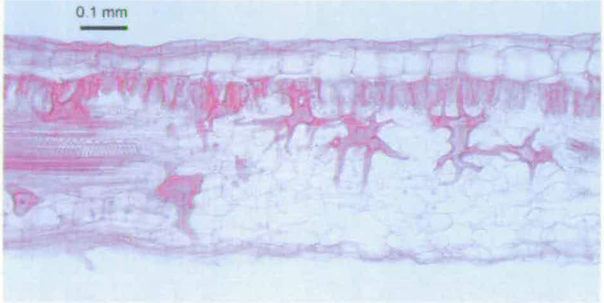

Figure 3a: *Cyrtandra trichodon* Ridl. (R&C 124). Transverse section of the lamina showing astrosclereids in the mesophyll.

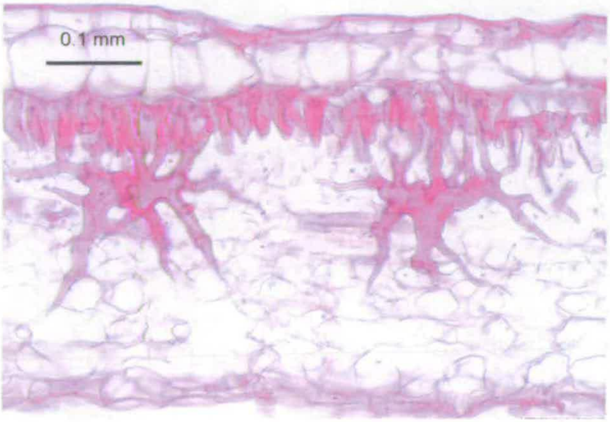

Figure 3b: *Cyrtandra trichodon* (R&C 124). Astrosclereids at a greater magnification (x20).

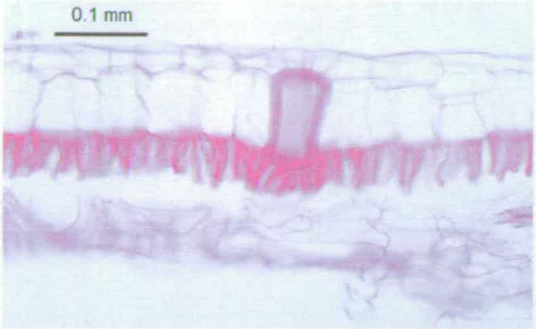

Figure 4: *Cyrtandra sandei* de Vriese (R&C 53). Transverse section of the lamina showing an osteosclereid in the hypodermis.

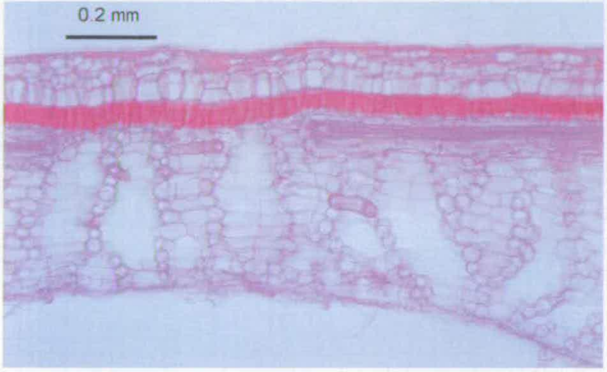

Figure 5: *Cyrtandra rosea* Ridl. (R&C 115). Transverse section of the lamina showing an absence of sclereids, note however the thick mesophyll layer.

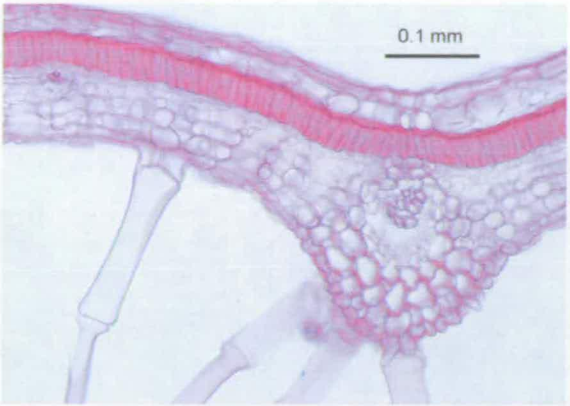

Figure 6: *Cyrtandra impressivenia* C.B.Clarke (R&C 116). Transverse section of the lamina showing the absence of sclereids. The section includes hairs and a vascular bundle on the lower surface of the leaf.

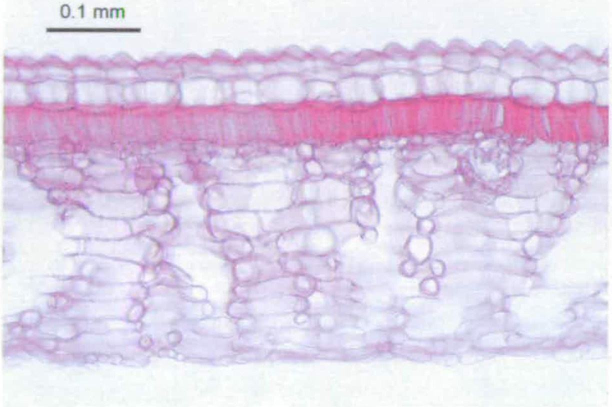

Figure 7: *Cyrtandra anisophylla* C.B.Clarke (R&C 109). Transverse section of the lamina showing the absence of sclereids. Note the conical epidermal cells.