SOME ASPECTS OF ABUNDANCE AND DISTRIBUTION OF ZINGIBERACEAE AND COSTACEAE IN TABIN WILDLIFE RESERVE, SABAH

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DECLARATION

I hereby certify that this thesis is the result of my own investigations except for quotations and summaries, each of which have been fully acknowledged in the text.

June 2002
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ABSTRACT

A quantitative inventory of Zingiberaceae and Costaceae was carried out in transect plots at Tabin Wildlife Reserve (TWR) to study the ecology of species in these plant families. Systematic keys were also constructed for identification of the gingers in the reserve. Cytotoxicity tests of extracts from three species of *Amomum* (Zingiberaceae) against brine shrimp were also carried out. Forty transects of 100 m by 5 m were studied in two general areas within 2 km of the Lipad Mud Volcano and within 5 km of the Tabin Mud Volcano (the 'Core Area'). Each study area included both primary and logged forests. Twenty transects were laid out in each forest type; eight transects at Lipad and 12 transects at Core Area. Nineteen environmental parameters were measured in every transect for ecological study, i.e., abundance and diameter at breast height (DBH) of trees, leaf litter ground cover, frequency of lianas, canopy gaps (CIE index), slope and soil chemistry (pH, loss-on-ignition (L.O.I.), texture and cation concentration). Forty-six species from 13 genera of gingers were found in the reserve. However, inside the plots only 36 and 35 species were recorded in primary and logged forests, respectively. These species represented mainly the genera *Etlingera*, *Zingiber* and *Amomum*, with very few from the genera *Geocharis*, *Homstedtia* and *Elettaria*. Only a slight differences in total abundance of gingers was found between primary and logged forests with 1058 and 828 individuals, respectively. *Boesenbergia* sp. A (31.6%) and *Costus speciosus* (10.5%) were the dominant species in primary and logged forests, respectively. Study of patterns in the gingers' spacial distribution showed a clumped (contagious) distribution, fitted to log series and log normal distribution models in primary forest and fitted to all abundancy models in logged forest. Diversity of gingers was found to be higher in logged forest and significantly different compared to primary forest. Based on abundance and faithfulness of occurrence, *Costus speciosus*, *Etlingera brevilabrum*, and *Plagiostachys strobilifera* showed a high and significant indicator value for logged and primary forest habitats, respectively. In general, species preferred to primary forest habitat (in TWINSPLAN) had negative correlations (Correlation Analysis) with the species that preferred logged forest and with the environmental variables that characterised it. Multivariate analyses (DCA and CCA) showed that abundance of gingers had a strong correlation to the presence of trees of 2-15 cm DBH, soil pH, proportion of silt and sand and concentration of sodium and magnesium in soil. Multiple Regression Analysis showed magnesium to be the most important predictor to the ginger abundance. In the cytotoxicity test, the three species of *Amomum* were found to be non-toxic to brine shrimp compared to potassium dichromate (control).
ABSTRAK

# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Title</td>
<td>1</td>
</tr>
<tr>
<td>Tajuk</td>
<td>ii</td>
</tr>
<tr>
<td>Declaration</td>
<td>iii</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>iv</td>
</tr>
<tr>
<td>Abstract</td>
<td>v</td>
</tr>
<tr>
<td>Abstrak</td>
<td>vi</td>
</tr>
<tr>
<td>Contents</td>
<td>vii</td>
</tr>
<tr>
<td>List of abbreviations</td>
<td>x</td>
</tr>
<tr>
<td>List of tables</td>
<td>xi</td>
</tr>
<tr>
<td>List of figures</td>
<td>xiii</td>
</tr>
<tr>
<td>List of appendices</td>
<td>xv</td>
</tr>
<tr>
<td>List of plates</td>
<td>xvii</td>
</tr>
</tbody>
</table>

## CHAPTER 1: INTRODUCTION

## CHAPTER 2: LITERATURE REVIEW

2.1 The gingers
   2.1.1 The family Zingiberaceae
   2.1.2 The family Costaceae

2.2 Studies of gingers in Borneo

2.3 Previous studies of gingers at the Tabin Wildlife Reserve

2.4 Ecology of gingers
   2.4.1 Distribution relative to elevation
   2.4.2 Distribution in relation to forest type
   2.4.3 Distribution in relation to soil type and landforms

2.5 Medicinal uses and toxicity in gingers
   2.5.1 Medicinal uses of species in the genus *Amomum*

## CHAPTER 3: METHODOLOGY

3.1 The Study Sites
   3.1.1 Climate
   3.1.2 Geology and soil
   3.1.3 Vegetation

3.2 Sampling design
   3.2.1 Selection of an area to sample
   3.2.2 Sampling procedure

3.3 Counting individual gingers

3.4 Collection of specimens
   3.4.1 Field collection
   3.4.2 Pressing and drying

3.5 Collection of environmental data
   3.5.1 Light-Index
   3.5.2 Topography
   3.5.3 Soil sampling
3.5.4 DBH and abundance of trees 36
3.5.5 Leaf litter 37
3.5.6 Frequency of lianas 38

3.6 Laboratory Methods 38
3.6.1 Identification of species 38
3.6.2 Soil analysis 39

3.7 Data analyses 40
3.7.1 Environmental parameter statistical analyses 41
3.7.2 Gingers community structure analyses 43
  3.7.2.1 Species count, species richness estimation and species area curve 43
  3.7.2.2 Species diversity and evenness 44
  3.7.2.3 Abundance and importance value 45
  3.7.2.4 Classification 46
3.7.3 Relationship between ginger abundance and measured environmental parameters 48
  3.7.3.1 Ordination 48
  3.7.3.2 Multiple regression 50
  3.7.3.3 Correlation analysis 51

3.8 Construction of keys to the species 51

3.9 Brine shrimp lethality test 52
  3.9.1 Preparation of plant extracts 52
  3.9.2 Preparation of test solution and control 52
  3.9.3 Preparation of brine shrimps for bioassay 53
  3.9.4 Bioassay procedure for determination of lethal concentration (LC_{50}) of the plant extracts 53
  3.9.5 General control 55

CHAPTER 4: RESULT

4.1 Number of species 56
4.2 Species richness estimation 58
4.3 Species accumulation curve and heterogeneity 58
4.4 Species diversity and evenness 59
4.5 Species abundance distribution 61
  4.5.1 Rank abundance curve 65
  4.5.2 Goodness-of-fit to the abundance model 66
  4.5.3 Classification 67
    4.5.3.1 Cluster analysis 67
    4.5.3.2 Two Way Indicator (TWINSPAN) and indicator species analyses 68
  4.5.4 Relation to the measured environmental parameters 71
    4.5.4.1 Environmental conditions in the transect plots 71
    4.5.4.2 DCA on species composition and rammets 78
    4.5.4.3 CCA on species composition and rammets 83
    4.5.4.4 Multiple regression 85
    4.5.4.5 Correlation between species and to the environmental variables 85
4.6 Keys to the species 86
4.7 Lethal concentration (LC_{50}) of the Amomum extracts 86
CHAPTER 5: DISCUSSION

5.1 Species composition
   5.1.1 Estimation of species richness
   5.1.2 Species diversity
   5.1.3 Why are gingers in logged forest more diverse?

5.2 Species abundance
   5.2.1 Gingers as an indicator of habitat quality
   5.2.2 Relation between classification of plots using ginger abundance and the measured environmental parameters
   5.2.3 Effect of forest structure modification
   5.2.4 Effect of soil characteristics
   5.2.5 Other factors affecting ginger abundance/ occurrence

5.3 Toxicity of *Amomum* extracts

CHAPTER 6: CONCLUSION

References
Appendices
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.s.l</td>
<td>Above sea level (for altitude).</td>
</tr>
<tr>
<td>ACE</td>
<td>An abundance-based coverage estimator of species richness.</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of variance.</td>
</tr>
<tr>
<td>c. or ca.</td>
<td>Circa or approximately</td>
</tr>
<tr>
<td>CCA</td>
<td>Canonical correspondence analysis.</td>
</tr>
<tr>
<td>Chao1</td>
<td>An abundance-based estimator of species richness</td>
</tr>
<tr>
<td>Chao2</td>
<td>An incidence-based estimator of species richness.</td>
</tr>
<tr>
<td>CIE</td>
<td>Crown Illumination Ellipses</td>
</tr>
<tr>
<td>DBH</td>
<td>Diameter at breast height.</td>
</tr>
<tr>
<td>DCA</td>
<td>Detrended correspondence analysis.</td>
</tr>
<tr>
<td>DVCA</td>
<td>Danum Valley Conservation Area.</td>
</tr>
<tr>
<td>ICE</td>
<td>An incidence-based coverage estimator of species richness.</td>
</tr>
<tr>
<td>ISA</td>
<td>Indicator species analysis.</td>
</tr>
<tr>
<td>L.O.I</td>
<td>Loss-on-ignition.</td>
</tr>
<tr>
<td>MV</td>
<td>Mud Volcano (LMV: Lipad MV; TMV: Tabin MV)</td>
</tr>
<tr>
<td>PCA</td>
<td>Principal component analysis.</td>
</tr>
<tr>
<td>ppm</td>
<td>Parts per million.</td>
</tr>
<tr>
<td>TWINSPAN</td>
<td>Two-way Indicator species analysis.</td>
</tr>
<tr>
<td>TWR</td>
<td>Tabin Wildlife Reserve.</td>
</tr>
</tbody>
</table>
### LIST OF TABLES

<table>
<thead>
<tr>
<th>TABLE NO.</th>
<th>Description</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 2.1</td>
<td>The number of ginger species recorded in several areas in Borneo.</td>
<td>10</td>
</tr>
<tr>
<td>Table 2.2</td>
<td>The number of ginger species collected from TWR in previous studies.</td>
<td>12</td>
</tr>
<tr>
<td>Table 3.1</td>
<td>Summary of method for assigning scores for gaps.</td>
<td>33</td>
</tr>
<tr>
<td>Table 3.2</td>
<td>The size of the ellipses applied in the C.I.E. method.</td>
<td>33</td>
</tr>
<tr>
<td>Table 3.3</td>
<td>Tree DBH groups.</td>
<td>36</td>
</tr>
<tr>
<td>Table 3.4</td>
<td>The Domin cover scale to assign an index of leaf litter ground cover.</td>
<td>37</td>
</tr>
<tr>
<td>Table 4.1</td>
<td>Ginger species collected in TWR.</td>
<td>57</td>
</tr>
<tr>
<td>Table 4.2</td>
<td>The estimation of gingers richness in primary and logged forests.</td>
<td>58</td>
</tr>
<tr>
<td>Table 4.3</td>
<td>The diversity of gingers in the primary and logged forests.</td>
<td>60</td>
</tr>
<tr>
<td>Table 4.4</td>
<td>The mean and the range of abundance and ramnets of gingers in primary and logged forests per transect and per species.</td>
<td>63</td>
</tr>
<tr>
<td>Table 4.5</td>
<td>Ginger species that differed significantly in abundance between primary and logged forests.</td>
<td>63</td>
</tr>
<tr>
<td>Table 4.6</td>
<td>Species abundance overlap in primary and logged forests.</td>
<td>65</td>
</tr>
<tr>
<td>Table 4.7</td>
<td>Ginger species abundance goodness-of-fit-test to abundancy models.</td>
<td>66</td>
</tr>
<tr>
<td>Table 4.8</td>
<td>The preferential pseudospecies from TWINSPLAN at level 1 of the dendrogram.</td>
<td>70</td>
</tr>
<tr>
<td>Table 4.9</td>
<td>Monte Carlo test of significance of the indicator values of ginger species.</td>
<td>70</td>
</tr>
<tr>
<td>Table 4.10</td>
<td>A one-way ANOVA on environmental parameters in the transects in primary and logged forests.</td>
<td>72</td>
</tr>
<tr>
<td>Table 4.11</td>
<td>Relationship between groupings of transects based on environmental conditions and based on ginger composition.</td>
<td>77</td>
</tr>
</tbody>
</table>
Table 4.12 The PCA component matrix of environmental parameters in the transects.

Table 4.13 Statistics on axes from DCA and CCA composition and rammets of ginger species in primary and logged forests.

Table 4.14 The acute LC50 (6 hr exposure) and chronic LC50 (24 hr exposure) of potassium dichromate and of extracts from Etlingera sp. B and Amomum spp. A, C and D.
**LIST OF FIGURES**

<table>
<thead>
<tr>
<th>FIGURE NO.</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 2.1</td>
<td>Cladogram of the Zingiberales.</td>
</tr>
<tr>
<td>Figure 2.2</td>
<td>Floral morphology of gingers.</td>
</tr>
<tr>
<td>Figure 2.3</td>
<td>The number of ginger species recorded in relation to elevation, forest type, soil type and landforms.</td>
</tr>
<tr>
<td>Figure 3.1</td>
<td>The location of Tabin Wildlife Reserve in Sabah, Borneo, and of the study areas in the reserve.</td>
</tr>
<tr>
<td>Figure 3.2</td>
<td>Monthly precipitation and temperature at TWR.</td>
</tr>
<tr>
<td>Figure 3.3</td>
<td>Illustration showing the criteria for counting gingers as individuals.</td>
</tr>
<tr>
<td>Figure 3.4</td>
<td>Shape of ellipses used in the C.I.E. method.</td>
</tr>
<tr>
<td>Figure 3.5</td>
<td>Measurement of topography.</td>
</tr>
<tr>
<td>Figure 3.6</td>
<td>Soil sampling points.</td>
</tr>
<tr>
<td>Figure 3.7</td>
<td>The nine measured floral characters of gingers.</td>
</tr>
<tr>
<td>Figure 4.1</td>
<td>Species accumulation curves of gingers in primary and logged forests.</td>
</tr>
<tr>
<td>Figure 4.2</td>
<td>Performance of various diversity indices to estimate diversity of gingers in primary and logged forests.</td>
</tr>
<tr>
<td>Figure 4.3</td>
<td>K-dominance plot of ginger composition in primary and logged forests.</td>
</tr>
<tr>
<td>Figure 4.4</td>
<td>Relative abundance of gingers in primary and logged forests.</td>
</tr>
<tr>
<td>Figure 4.5</td>
<td>Rank-abundance distribution of ginger species in primary and logged forests.</td>
</tr>
<tr>
<td>Figure 4.6</td>
<td>Ward's dendrogram of Euclidean distance coefficients of transects from primary and logged forests based on ginger composition.</td>
</tr>
<tr>
<td>Figure 4.7</td>
<td>TWINSPLAN dendrogram of sites based on ginger composition.</td>
</tr>
<tr>
<td>Figure 4.8</td>
<td>Ward's dendrogram of Euclidean distance coefficients of transects in primary and logged forests based on forest structure.</td>
</tr>
</tbody>
</table>
Figure 4.9  Ward's dendrogram of Euclidean distance coefficients of transects in primary and logged forests based on soil chemistry.

Figure 4.10  Ward's dendrogram of Euclidean distance coefficients of transects in primary and logged forests based on forest structure and soil chemistry.

Figure 4.11  An ordination of transects in the primary and logged forests based on PCA of forest structure and soil chemistry.

Figure 4.12  A DCA ordination of transects from primary and logged forests based on ginger composition.

Figure 4.13  A DCA ordination of ginger species based on their composition in primary and logged forest transects.

Figure 4.14  A DCA ordination of transects from primary and logged forests based on species rammets.

Figure 4.15  A DCA ordination of ginger species based on rammets in primary and logged forest transects.

Figure 4.16  A CCA ordination of transects in primary and logged forests based on ginger composition.

Figure 4.17  Ginger abundance and species richness as function of magnesium concentration in primary and logged forests.
**APPENDIX NO.** | **PAGE** |
---|---|
Appendix I List of gingers in Sarawak, Sabah, Brunei and in several areas therein. | 138 |
Appendix II Summary of the habitat of gingers. | 142 |
Appendix III Medicinal ginger species in Malaysia. | 146 |
Appendix IV Description of species of gingers in TWR. | 147 |
Appendix V Synonyms of ginger species collected in TWR. | 164 |
Appendix VI Keys to the families, tribes, genera and species. | 167 |
Appendix VII Character and character state guidelines for description of ginger species. | 169 |
Appendix VIII Abundance of species of gingers in forest transects in primary and logged forest. | 173 |
Appendix IX Abundance, frequency, relative abundance, relative frequency and importance value of 39 ginger species in 40 sampling plots in primary and logged forest. | 174 |
Appendix X Number of rammets of the gingers in forest transects in primary and logged forest. | 175 |
Appendix XI Two-way ordered table of the TWINSPLAN. | 176 |
Appendix XII Monte Carlo Test of significance based on 19 permutations of observed maximum indicator values for species. | 177 |
Appendix XIII Kendall’s Rank Test on significance of association among ginger species at TWR. | 177 |
Appendix XIV Kendall’s Rank Test on significance of associations between ginger species and the environmental variables. | 178 |
Appendix XV Location of the transects at the study site. | 179 |
Appendix XVI Environmental statistics from transects in primary and logged forests. | 180 |
Appendix XVII The Monte Carlo Test and the intraset correlation of axes from CCA of ginger composition in primary and logged forest samples. | 181 |
Appendix XVIII  The Monte Carlo Test and the intraset correlation of axes from CCA of gingers rammets in primary and logged forest samples.

Appendix XIX  Brine Shrimp Lethality Test.

Appendix XX  Terminology.

Appendix XXI  List of formulae used in the data analyses
# LIST OF PLATES

<table>
<thead>
<tr>
<th>PLATE NO.</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLATE 1</td>
<td>195</td>
</tr>
<tr>
<td>A</td>
<td>Amomum laxisquamosum K. Schumann</td>
</tr>
<tr>
<td>B</td>
<td>Amomum sp. B (cf. A. uliginosum Koenig)</td>
</tr>
<tr>
<td>C</td>
<td>Amomum sp. E (cf. A. borealiborneense I.M. Turner)</td>
</tr>
<tr>
<td>D</td>
<td>Costus globosus Blume (flower red)</td>
</tr>
<tr>
<td>E</td>
<td>Costus globosus Blume (flower yellow)</td>
</tr>
<tr>
<td>F</td>
<td>Costus globosus Blume (flower orange)</td>
</tr>
<tr>
<td>PLATE 2</td>
<td>196</td>
</tr>
<tr>
<td>A</td>
<td>Etlingera aff. fimbriobracteata (K. Schum.) R.M. Smith</td>
</tr>
<tr>
<td>B</td>
<td>Etlingera fimbriobracteata (K. Schum.) R.M. Smith</td>
</tr>
<tr>
<td>C</td>
<td>Etlingera littoralis (Koenig) Giseke (flower yellow)</td>
</tr>
<tr>
<td>D</td>
<td>Etlingera littoralis (Koenig) Giseke (flower orange-red)</td>
</tr>
<tr>
<td>E</td>
<td>Etlingera brevilabrum (Val.) R.M. Smith</td>
</tr>
<tr>
<td>F</td>
<td>Etlingera punicea (Roxb.) R.M. Smith</td>
</tr>
<tr>
<td>PLATE 3</td>
<td>197</td>
</tr>
<tr>
<td>A</td>
<td>Etlingera sessilianthera R.M. Smith</td>
</tr>
<tr>
<td>B</td>
<td>Etlingera pyramidosphaera (K. Schum.) R.M. Smith</td>
</tr>
<tr>
<td>C</td>
<td>Costus speciosus (Koenig) J.E. Smith</td>
</tr>
</tbody>
</table>
CHAPTER 1
INTRODUCTION

Studies on gingers (Zingiberaceae and Costaceae) have been progressing in several aspects of their biology and chemistry. However, to date there is still much work left to be done as knowledge of ginger ecology (Sakai, 1996), pollination and dispersion (Larsen et al., 1999; Sakai et al., 1999), and chemical content (Larsen et al., 1998) is known only for certain species within these families. Overall, chemical aspects of gingers are somewhat less studied than their biological aspects. In many instances taxonomic study is quite advanced, as many botanists, taxonomists and phylogeneticists have worked to explore the diversity of species in this group. As might be expected, more taxonomic effort has been devoted to Zingiberaceae since it holds many more genera and species than its sister family, Costaceae. Though publications on gingers are numerous, quantitative ecology of gingers in tropical rain forests, including those in Borneo, has been less studied. Thus, abundance and distribution of gingers are rarely mentioned in the literature (Poulsen, 1994).

Quantitative information on spatial patterns of gingers in Borneo is limited, but the subject has not been completely neglected. There are at least three studies (Magintan, 2000; Poulsen, 1996; Sakai, 1996) quantifying gingers in a particular area in Bornean lowland mixed dipterocarp forest. However, none of these studies was carried out on ginger ecology exclusively. Studies on the ecology of other Bornean ground herbs are also few. The distribution of ground herbs in tropical rain forest has attracted little attention and therefore only a few detailed studies can be found in
which individual ground herbs were counted in transected plots (Poulsen, 1996; Poulsen & Balslev, 1991).

Even though descriptions of habitats have been included in taxonomic studies of gingers (Sakai & Nagamasu, 2000a, 2000b; Poulsen et al., 1999; Theilade & Mood, 1999, 1997a, 1997b; Sakai, 1997; Smith, 1988, 1987a, 1986, 1985, 1982) quantitative studies on their ecology are still needed to support the qualitative knowledge of ginger ecology for *ex-situ* or *in-situ* conservation in the future. Cultivating gingers as ornamental or medicinal plants or for *ex-situ* conservation, as at Tenom Orchid Centre, Sabah Agricultural Park, requires a good understanding of ginger ecology. In general, light, temperature, humidity, water and drainage system, soil nutrients and aeration, and tolerance to disturbance are important determinants of plant distributions in a particular area (Huston, 1995). In gingers, soil chemistry, forest type, forest disturbance, light and humidity have all been reported to affect spatial distributions (Poulsen & Lock, 1999; Mood, 1996; Halijah, 1995).

The ginger flora of the Tabin Wildlife Reserve (TWR) has been studied (Magintan et al., 1999; Halijah, 1989). However, spatial patterns of gingers at a local scale across habitats in the reserve are less well-known. Species richness and diversity of gingers in the reserve also have not been intensively studied. As TWR is an *in-situ* conservation area for the flora and fauna of Sabah, the correlation between the composition of gingers and variation of environmental conditions in TWR merits study. The presence of mud volcanoes in the reserve may affect the distribution of ground herbs such as the gingers, as understory plants are much more sensitive to environmental changes than any other plants (Newbery et al., 1996; Richards, 1996). Certain tree species in the reserve have already been found to have the unusual habit of the formation of growth rings (Takahashi & Maryati, 1999), which normally occurs only in trees in seasonal climates. Besides ecology, toxicity and chemistry of
gingers have never been reported for TWR gingers. A toxicity study of wild gingers, especially species in the genus *Amomum*, would be interesting as many *Amomum* species have been used medicinally (de Padua et al., 1999).

In accordance with these points and considering that gingers in Sabah have been little-studied quantitatively, this study aimed to elucidate the importance of environmental parameters in determining the distribution and abundance of ginger species in TWR. Thus, the study was carried out on Zingiberaceae and Costaceae in TWR with the main objectives:

(i) to study species composition and diversity,
(ii) to study the association between abundance of species in Zingiberaceae and Costaceae to several selected environmental parameters in transect plots,
and
(iii) to assess (i) and (ii) with several mathematical data analysis approaches.

Two additional objectives were also included with the aim to contribute to the taxonomic study of gingers in Sabah and to study the general medicinal potential of wild gingers. These additional objectives were (i) to construct systematic keys for identification of TWR gingers, and (ii) to carry out cytotoxicity tests of three species in *Amomum* against brine shrimp. It is hoped that the information reported in this study, especially the list of gingers in the reserve, forest stand information, soil chemistry, and toxicity of the *Amomum* species will help to highlight the importance of TWR as one of the centres of biodiversity in Sabah.
CHAPTER 2

LITERATURE REVIEW

2.1 THE GINGERS

Zingiberaceae and Costaceae belong to the order Zingiberales (Kress, 1990). Zingiberales consists of eight families, which are grouped into two groups of families: 1) families with one fertile stamen (Zingiberaceae, Costaceae, Marantaceae and Cannaceae) and, 2) families with five fertile stamens (Musaceae, Strelitziaceae, Lowiaceae and Heliconiaceae) (Figure 2.1). These eight families in Zingiberales are highly distinctive (Kirchoff, 1991), but the subordinal classification of Zingiberales is subject to change since morphological features, sequence data of plastid gene rbcL, and sequence data of the nuclear 18S rDNA do not agree with each other (Kress et al., 1995; Kress, 1990). This disagreement is still unresolved as molecular analysis has had limited success to date in determining interfamilial evolutionary relationships in Zingiberales (Kress et al., 1995).

In this study, “gingers” or “ginger” has been used as a short term to refer the species in the families Zingiberaceae and Costaceae. Thus, should not be mistaken to Zingiber officinale Roscoe, the spice ginger, a species in the genus Zingiber within the family Zingiberaceae. The vernacular term “gingers” has been used in the past to refer to species in these two families, relying on the fact that members of the families are monophyletic (sister taxa) and share similar floral characteristics and habitat (Sakai, 1996). Prior to the designation of Costaceae as a family by Nakai (1941; cited
Figure 2.1 Cladogram of the Zingiberales. Numbers to the left of the arrows (>) refer to the characters that distinguish each family, e.g., 14: vessels present at root only; 34: chalazosperm present, 3: leaf adaxial hypodermis more than one cell layer; 12: internal silica cell bodies (druse-shaped) absent; 15: spiral phyllotaxy; 24: outer whorl median stamen present; the numbers to the right of the arrows are apomorphic character states at that node (from Kress, 1990).

In Tomlinson, 1969), Zingiberaceae and Costaceae were treated as a single family, Zingiberaceae. This family was then subdivided into two subfamilies, Zingiberoideae and Costoideae (Halijah, 1989; Smith, 1986). In recent years many taxonomists have begun to accept Costaceae as an independent family, but some taxonomists still prefer to use the subfamilies (Larsen et al., 1999; Smith, 1996; Kress, 1990). Treating Costaceae as a family and separate from the Zingiberaceae can be found in

2.1.1 THE FAMILY ZINGIBERACEAE

The family Zingiberaceae consists of aromatic plants with a distichous arrangement of leaves, with the leaf sheaths open at one side opposite the lamina. The assemblage of leaf sheaths forms a pseudo-stem. Most species produce a much-shortened, real and non-woody stem but some species, especially in *Amomum* and *Zingiber*, may occasionally produce a real stem up to one meter long wrapped by a few layers of leaf sheaths. Some species are hairy with almost invariably unicellular, but rarely branched, hairs. The leaf epidermis has a thin cuticle and occasionally the epidermis is minutely papillose. Many floral and vegetative characters of the species in Zingiberaceae are significant taxonomically, such as slit of the anther thecae in *Elettaria* (Sakai & Nagamasu, 2000a) or relation between the arrangement of insertion of the leaves and the direction of the rhizome division system in different genera (Smith, 1985; Tomlinson, 1969). However, some structures are basically the same across genera, for instance, calyx and corolla are connate to form a beak on the ovary in *Elettaria* and the corolla and staminodes are connate in *Globba* (Larsen et al., 1998; see Figure 2.2 for basic botanical terms). In the Globbeae, the presence/absence and number of anther crests are also good characters for generic identification (Smith, 1988). While, swollen and pulvinus-like petioles are specific for identification of *Zingiber* spp. Some colours on the leaves are also taxonomically useful: the reddish margin on the lower leaf surface in most *Etlingera* species (Mood, 1999) or red patches on the leaves of *Etlingera brevilabrum* (Valeton) R.M. Smith, which are unique and useful to identify sterile individuals and even juveniles of this species or variegation in certain *Boesenbergia* species. Taxonomic notes on species

* The correct latin name for *Etlingera brevilabrum* (Valeton) R.M. Smith (Mark Newman, personal communication). Authorised for the scientific names of the Bornean gingers presented in Appendix I.
of Bornean Zingiberaceae have been treated in numerous publications by Smith (1988, 1987a, 1986, 1985, 1982).


Zingiberaceae is distributed mainly in tropical areas with its centre of diversity in the Malesian region (Sakai & Nagamasu, 1998; Theilade, 1998b), but with a range extending through tropical Africa to Central and South America (Larsen, 1996; Tomlinson, 1969). The worldwide total numbers of species and genera in this family have been quoted variously as 1,000 to 1,500 species with 45 to 51 genera (Larsen et al., 1998; Sakai, 1996; Kress et al., 1995). However, it may be reasonable to state that the family comprises 1,200 species and at least 50 genera. About 1,000 species
REFERENCES


