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

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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

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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*, *Hornstedtia* 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 prefered to primary forest habitat (in TWINSPAN) had negative correlations (Correlation Analysis) with the species that prefered logged forest and with the evironmental 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

Inventori kuantitatif Zingiberaceae dan Costaceae telah dijalankan dalam plot-plot transek di Rizab Hidupan Liar Tabin untuk mengkaji ekologi spesies-spesies dalam setiap famili tersebut. Kekunci-kekunci sistematik juga disediakan untuk pencaman halia-halia hutan di hutan simpan tersebut. Ujian ketoksikan ekstrak-ekstrak dari tiga spesies *Amomum* (Zingiberaceae) juga telah dijalankan ke atas anak udang. Empat puluh transek sebesar 100 m kali 5 m telah dikaji dalam dua kawasan umum sekitar 2 km dari Mata Air Garam Lipad dan sekitar 5 km dari Mata Air Garam Tabin ('Core Area'). Setiap kawasan kajian merangkumi kawasan hutan primer dan hutan dibalak. Dua puluh transek telah ditebarkan masing-masing dalam setiap jenis hutan dengan lapan transek di Lipad dan 12 transek di Core Area. Bagi kajian ekologi, 19 paramater persekitaran telah diukur dalam setiap transek iaitu jumlah dan diameter batang pokok pada aras dada (DBH), litupan sarap-daun pada permukaan tanah, frekuensi liana, bukaan kanopi (index CIE), kecerunan permukaan tanah dan sifat kimia tanah (pH, kehilangan-tenaga-dalam tindakbalas kimia (L.O.I), tekstur dan kepekatan kation-kation). Terdapat 46 spesies dari 13 genera halia-halia hutan yang wujud di hutan simpan tersebut, tetapi masing-masing hanya 36 dan 35 spesies telah direkodkan dalam plot-plot kajian di hutan primer dan hutan dibalak. Spesies kebanyakkannya dari genera *Etlingera*, *Zingiber* dan *Amomum* dan paling sedikit dari genera *Geocharis*, *Hornstedtia* dan *Elettaria*. Jumlah kelimpahan halia-halia hutan berbeza sedikit sahaja antara hutan primer dan hutan dibalak dengan masing-masing 1053 dan 828 individu. *Boesenbergia* sp. A (31.6%) dan *Costus speciosus* (10.5%) masing-masing menjadi spesies dominan di hutan primer dan hutan dibalak. Kajian rupabentuk taburan kelimpahan menunjukkan halia-halia hutan tumbuh berumpun-rumpun, mengikut model kelimpahan *log series* dan *log normal* di hutan primer dan mengikut kesemua jenis model kelimpahan di hutan dibalak. Kepelbagaian halia hutan adalah lebih tinggi di hutan dibalak dan berbeza secara bererti berbanding di hutan primer. *Costus speciosus*, *Etlingera brevilabrum*, dan *Plagiostachys strobilifera* masing-masing menunjukkan nilai penunjuk kualiti habitat yang tinggi dan bererti kepada habitat hutan dibalak dan hutan primer. Umumnya, spesies yang memilih habitat hutan primer (dalam TWINSPAN) mempunyai korelasi negatif (Analisis Korelasi) dengan spesies yang memilih habitat hutan dibalak dan parameter persekitaran yang mencirikannya. Analisis pelbagai pembolehubah (DCA dan CCA) menunjukkan kelimpahan halia-halia hutan berkorelasi kuat kepada pokok-pokok dengan DBH 2-15 cm, pH tanah, kandungan pasir dan lanar serta kepekatan magnesium dan garam dalam tanah. Analisis *Multiple Regression* telah memilih magnesium sebagai penjangka kelimpahan halia-halia hutan yang paling penting. Dalam ujian ketoksikan, tiga spesies *Amomum* tersebut didapati kurang toksik berbanding dengan kalium dikromat (kawalan).

CONTENTS

CHAPTER 5: DISCUSSION

LIST OF ABBREVIATIONS

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

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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 migh 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 cytoxicity 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 *rbc*L, 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

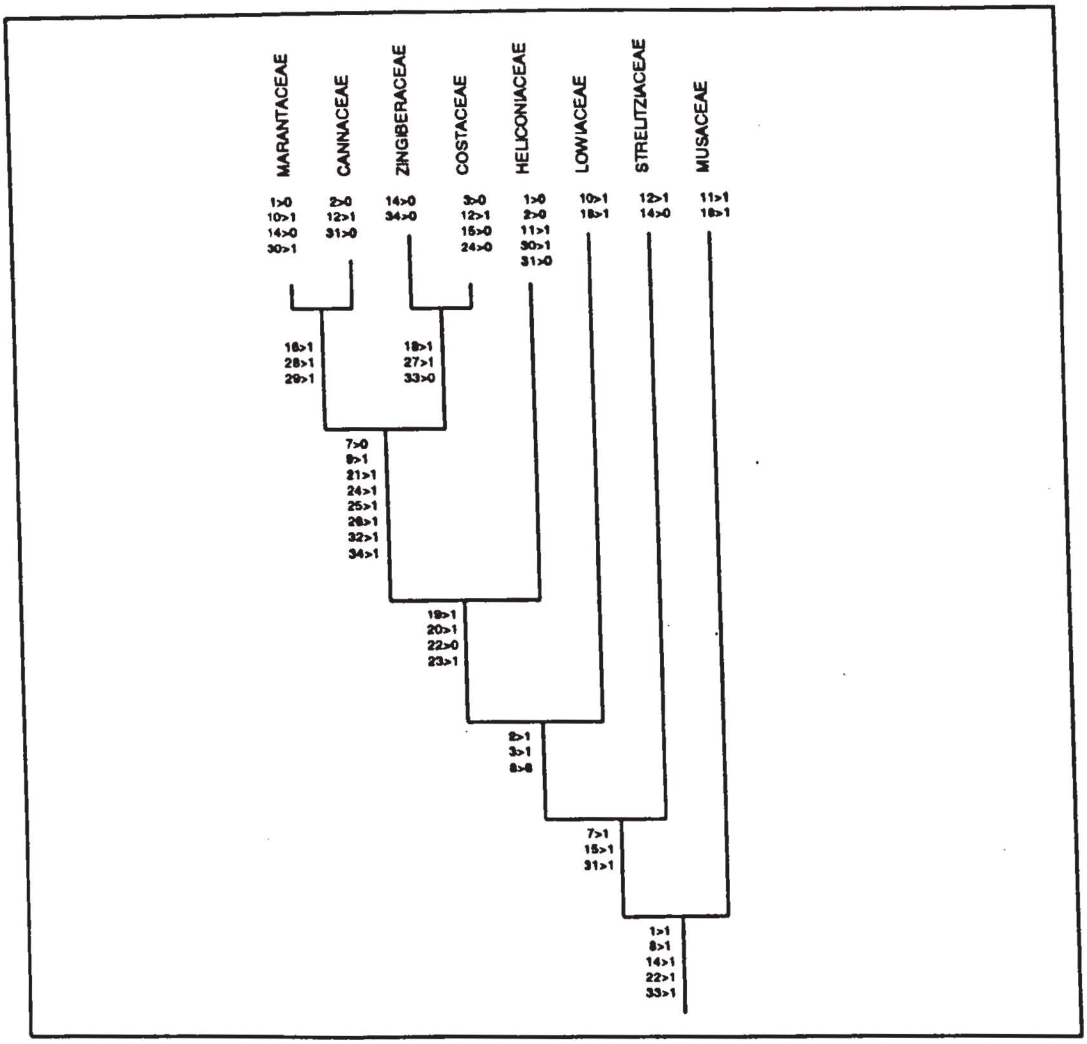


Figure 2.1 Cladogram of the Zingiberales. Numbers to the left of the arrows (>) refer to the characters that distinguish each family, e.g., 14: vessels present at root only; 34: chalazosperm present, 3: leaf adaxial hypodermis more than one cell layer; 12: internal silica cell bodies (druse-shaped) absent; 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).

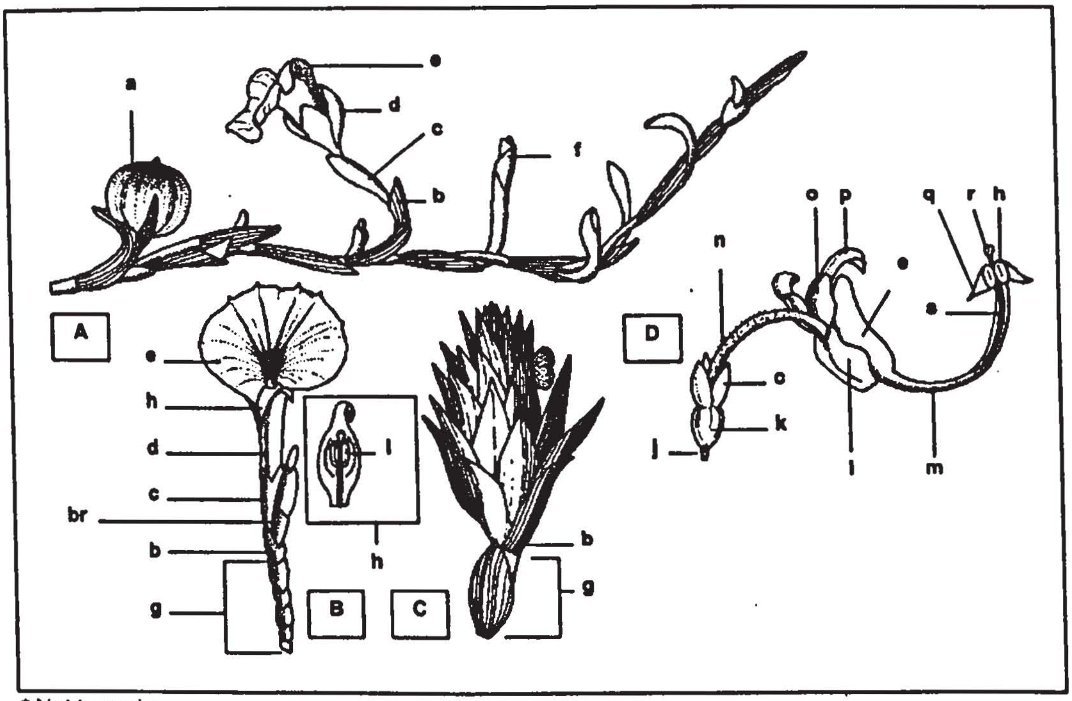
in Tomlinson, 1969), Zingiberaceae and Costaceae were treated as a single family, Zingiberaceae. This family was then subdivided into two subfamilies, Zingiberoideae and Costoideae (Halijah, 1989; Smith, 1986). In recent years many taxonomists have begun to accept Costaceae as an independent family, 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 several publications, *e.g.*, Poulsen and Lock (1999), Sakai *et al.* (1999), Larsen (1996), Sakai (1996), Kress *et al.* (1995), Kirchoff (1991), Kress (1990) and Tomlinson (1969).

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 brevilabris* (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).



* Not to scale

Figure 2.2 Floral morphology of gingers. Drawn by the author based on herbarium specimens; label follow Smith (1988a, 1985) and Holttum (1950). A: Inflorescence of *Elettaria longituba*; B: inflorescence and anther (insert) of *Costus paradoxus*; C: Inflorescence of *Amomum testaceum* showing the imbricated bracts; D: flower of *Globba pendula*. a: fruit, b: bract, br: bracteole, c: calyx, d: petal, e: lip or labellum, f: young flower, g: peduncle, h: anther, i: anther thecae, j: pedicel, k: ovary, l: dorsal petal, m: filament, n: corolla tube, o: lateral petal, p: lateral staminode, q: anther crest or anther appendage, r: stigma and s: style. Detailed descriptions are also available in Smith (1988, 1987a, 1986, 1985, 1982), Tomlinson (1969) and Holttum (1950).

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

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